# THE WESTERN GREENLAND SEA

## A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS East area

NERI Technical Report no. 719 2009

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
AARHUS UNIVERSITY

*[Blank page]*

# THE WESTERN GREENLAND SEA

## A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS East area

NERI Technical Report no. 719 2009

**Editors**:
David Boertmann
Anders Mosbech
Doris Schiedek
Kasper Johansen

**Authors**:
David Boertmann
Kasper Johansen
Lars Maltha Rasmussen
Doris Schiedek
Fernando Ugarte
Anders Mosbech
Morten Frederiksen
Morten Bjerrum

**Sections with specific authors**:
Erik W. Born (GINR), Rune Dietz (NERI), Øystein Wiig (Natural History Museum, Oslo), Jon Aars (Norwegian Polar Institute) & Magnus Andersen (Norwegian Polar Institute): Polar bear

Erik W. Born (GINR): Walrus
Aqqalu Rosing-Asvid (GINR): Seals
Frank Riget (NERI): Arctic char
Helle Siegstad (GINR) & Ole Jørgensen (DTUAqua): Fish, fisheries, Greenland Halibut.
Michael Sejr (NERI), Martin Blicher (GINR) & Søren Rysgaard (GINR): Benthos

Bureau of Minerals and Petroleum

Grønlands Naturinstitut
Pinngortitaleriffik · Greenland Institute of Natural Resources

NATIONAL ENVIRONMENTAL RESEARCH INSTITUTE
AARHUS UNIVERSITY

## Data sheet


| | |
|---|---|
| Series title and no.: | NERI Technical Report No. 719 |
| Title: | The western Greenland Sea |
| Subtitle: | A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS East area |
| Editors: | David Boertmann, Anders Mosbech, Doris Schiedek & Kasper Johansen |
| Department: | Department of Arctic Environment |
| Authors: | David Boertmann, Kasper Johansen, Lars Maltha Rasmussen, Doris Schiedek, Fernando Ugarte, Anders Mosbech, Morten Frederiksen & Morten Bjerrum |
| Departments: | Department of Arctic Environment and Greenland Institute of Natural Resources |
| Sections with specific authors: | Erik W. Born (GINR), Rune Dietz (NERI), Øystein Wiig (Natural History Museum, Oslo), Jon Aars (Norwegian Polar Institute) and Magnus Andersen (Norwegian Polar Institute): Polar bear<br>Erik W. Born (GINR): Walrus<br>Aqqalu Rosing-Asvid (GINR): Seals<br>Frank Riget (NERI): Arctic char<br>Helle Siegstad (GINR) & Ole Jørgensen (DTUAqua): Fish, fisheries, Greenland Halibut.<br>Michael Sejr (NERI), Martin Blicher (NERI) & Søren Rysgaard (GINR): Benthos |
| Publisher: | National Environmental Research Institute©<br>Aarhus University – Denmark |
| URL: | http://www.neri.dk |
| Year of publication: | May 2009 |
| Editing completed: | April 2009 |
| Please cite as: | Boertmann, D., Mosbech, A., Schiedek, D. & Johansen, K. (eds) 2009. The western Greenland Sea. A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS East area. National Environmental Research Institute, Aarhus University, Denmark. 246 pp. – NERI Technical report no. 719. http://www.dmu.dk/Pub/FR719.pdf<br><br>Reproduction permitted provided the source is explicitly acknowledged |
| Abstract: | This report is a preliminary strategic environmental impact assessment of activities related to exploration, development and exploitation of oil in the Greenland Sea off Northeast Greenland. |
| Keywords: | Strategic environmental impact assessment, SEIA, oil exploration, oil exploitation, oil spill, Greenland Sea, northeast Greenland, fauna. |
| Layout: | Tinna Christensen |
| Greenland summary: | Bjørn Rosing |
| English proof reading: | Carey Smith |
| Drawings: | NERI Graphics Group, Silkeborg |
| ISBN: | 978-87-7073-099-0 |
| ISSN: | 1600-0048 |
| Number of pages: | 246 |
| Internet version: | The report is available in electronic format (pdf) at NERI's website<br>http://www.dmu.dk/Pub/FR719.pdf |

## Content

# Preface

In 2006 the Bureau of Minerals and Petroleum decided to initiate a decision process for the so-called KANUMAS areas in order to prepare the areas for hydrocarbon licensing rounds. The KANUMAS areas comprise the waters off Northeast and Northwest Greenland. This preliminary strategic environmental impact assessment (SEIA) forms part of this process and deals with the KANUMAS area in Northeast Greenland: the KANUMAS East area (Figure 1).

A regional seismic exploration programme, the KANUMAS project, was initiated at the end of 1989, when a group of companies, the KANUMAS group, was granted a prospecting licence for the KANUMAS areas. The prospecting licence did not include any exclusive rights to the licensee and implied considerable obligations with regard to exploration. This was balanced by the KANUMAS group companies being granted a preferential position in relation to potential petroleum exploration licencing in Northeast and Northwest Greenland.

Interest in the KANUMAS areas increased substantially after the opening of the Disko West licensing round in the waters immediately to the south of KANUMAS West. The geology of the KANUMAS East area (Greenland Sea) is comparable to the offshore areas off West Norway, whereas the KANUMAS West area (Baffin Bay) constitutes a northern geological extension of the Disko West licensing area. Preparation of the KANUMAS areas for possible future exploration and exploitation requires that new knowledge in a number of areas is acquired in advance.

This preliminary SEIA was prepared as a co-operation bewteen National Environmental Research Institute (NERI), Greenland Instutute of Natural Resources (GINR) and Bureau of Minerals and Petroleum (BMP).

Before the final SEIA is issued in 2010 this preliminary version will be subject to a public hearing process in Greenland.

# Acknowledgements

Malene H. Petersen and Marie Frandsen compiled the reference list. Flemming Getreuer Christiansen (GEUS) supplied the potential drill sites for oil spill modelling.

# Summary and conclusions

This document is a preliminary Strategic Environmental Impact Assessment (SEIA) of activities related to exploration, development and exploitation of hydrocarbons in the sea off Northeast Greenland between 68° and 81° N. The KANUMAS East area (Figure 1).

The KANUMAS project was a regional seismic exploration programme that was initiated at the end of 1989. A group of companies, the KANUMAS group, was then granted a prospecting licence to the KANUMAS areas. The Kanumas areas also encompass the Greenland part of the Baffin Bay – the KANUMAS West area.

The prospecting licence did not include any exclusive rights to the licensee, and the licence implied a considerable obligation of exploration. This was balanced by granting the KANUMAS_companies a special preferential position. This preferential position will be activated if the right to petroleum exploration in Northeast and Northwest Greenland is put up for licensing.

The SEIA was prepared by the National Environmental Research Institute, Denmark and the Greenland Institute of Natural Resources in cooperation with the Greenland Bureau of Minerals and Petroleum.

The assessment area is shown in Figure 1. This is the region which potentially could be impacted by oil exploration and exploitation activities within the expected licence areas, although drift modelling indicates that an oil spill may drift further than the extent of this area.

The expected activities in the 'full life cycle' of a petroleum field are briefly described. Exploration activities are likely to take place during summer and autumn, because harsh weather and particularly sea ice hamper activities in winter and spring. However, if oil production is initiated activities will take place throughout the year.

## The environment

The physical environment of the study area is briefly described with focus on oceanography and ice conditions. Sea ice and icebergs are present throughout the year, with the lowest concentrations in August and September. One of the most important physical features of the biological environment is the polynyas (ice-free or almost ice-free areas surrounded by sea ice). The most important polynyas are found at the entrance to Scoresby Sund, at Wollaston Forland and at the northeast corner of Greenland (the Northeast Water), see Figure 5. These polynyas become free of ice very early in spring (April) and also have ice-free parts throughout the winter.

An updated account of some of the physical conditions was issued in late 2008 by the Danish Meteorological Institute (DMI) (Hvidegaard *et al.* 2008).

The study area is situated within the Arctic region, with all the typical biological properties of this climatic region: low biodiversity, but often numerous and dense animal populations; a relatively simple food web, from primary producers to top predators, with a few species playing a key role in the ecology of the region (Figure 6). In the marine environment the most significant event is the spring bloom of planktonic algae, the primary producers in the food web (Figure 6). These are grazed upon by zooplankton, including the important copepods of the genus *Calanus*, which is one of the key species groups in the ecosystem. Copepods again form the most important prey for small fish, large crustaceans as well as some seabirds and marine mammals.

Benthos is the fauna living on and in the seabed. Benthic macrofauna species are an important component of coastal ecosystems. They consume a significant fraction of the available production and are in turn an important food source for fish, seabirds and mammals. Very little is known on the benthos communities in the assessment area.

In and on the underside of the sea ice a specialised community exists: the sympagic flora and fauna. Algae live in and on the ice and are grazed upon by crustaceans, which in turn sustain populations of polar cod and Arctic cod.

Fish, seabirds and marine mammals represent some of the higher trophic levels in the marine environment, where polar bear and man are the top predators.

Fish fauna is low in diversity, but some species are important: the polar cod is very numerous, both pelagic and associated with the ice, and constitutes a major food resource for seals, whales and seabirds. It is one of the key species. Other important species are Greenland halibut and Arctic char. Capelin occurs in the southeastern offshore waters.

Seabirds are locally abundant with several species present in the study area in summer and spring. Many species breed in colonies mainly close to the polynyas, where dense aggregations of birds can be found as early as May. In spring and autumn millions of seabirds migrate through the area on their passage between Svalbard and Russian breeding sites and Canadian wintering sites. The most important species are common eider, thick-billed murre, little auk and ivory gull (Table 1). Almost all the seabirds leave the area for the winter to return in May and June. Thick-billed murre, common eider and black-legged kittiwake are all red-listed in Greenland due to declining populations, although mainly in West Greenland. Other red-listed bird species which occur in the marine part of the assessment area include Sabines gull, Arctic tern and light-bellied brent goose. Also ivory gull is red-listed, mainly because of the expected reductions in its primary habitat, sea ice. The coasts of the Northeast Water are a stronghold for this species.

Furthermore, some species are designated as species of national responsibility, which means that the population in Greenland is so large that the local management of the species is vital to the entire population. The most important of these species is the little auk. Other national responsibility species occurring in the marine part of the assessment area are black guillemot and light-bellied brent goose.

Marine mammals are significant components of the ecosystem. Four species of seals as well as walrus, many species of whales and polar bear occur in the assessment area. The most important species are narwhal, bowhead whale, walrus, harp seal, hooded seal and polar bear (Table 2). They are often associated with ice edges, polynyas or shear zones, where open water is present, and harp and hooded seals assemble in large numbers on the drift ice in March to whelp and later to moult.

Polar bear, walrus and bowhead whale are red-listed because their populations are small, declining or expected to decline because of climate change (polar bear).

The open waters to the east of the drift ice are very little known with respect to marine mammals. But whales occurring frequently in Icelandic waters (blue, fin, sei, humpback, sperm whale etc) may be similarly frequent in eastern parts of the assessment area.

Human use of natural resources only occurs in the southern part of the assessment area. Subsistence hunting (marine mammals and seabirds) and a little fishing is carried out near the town of Scoresbysund and hunters from Tasiilaq occasionally venture as far north as the southernmost part of the assessment area.

Commercial fishery is limited to Greenland halibut and this takes place in offshore areas in the southern part of the assessment area. The catches are small compared to other parts of Greenland.

Tourism is a growing industry in Greenland, and this is also the case in Scoresbysund, where activities take place from early spring (April) and throughout the summer. There is a local operator and also a few Icelandic operators which have activities in the Scoresbysund area.

Knowledge on background levels of contaminants such as hydrocarbons and heavy metals is important in assessing environmental impacts from petroleum activities. The available knowledge on background levels of hydrocarbons in the assessment area is limited, but the general picture is that levels are low.

## Assessment

### Exploration

The environmental impacts of exploration activities will mainly be disturbance from activities creating noise such as seismic surveys and drilling. The impacts are expected to be relatively small, local and temporary, because of the intermittent nature of the exploration activities. Furthermore, the season for exploration activities is very short and limited to the few months with light ice conditions (July–September). No severe impacts are expected if adequate mitigative measures are applied, activities in sensitive areas are avoided in the most sensitive periods and no accidents such as oil spills occur.

Temporary impacts of intensive seismic activity could be displacement of Greenland halibut, which again could cause reduced catches in fisheries near affected areas.

Marine mammals, particularly whales, may also be displaced from critical areas as feeding grounds. However, as seismic surveys are temporary such effects are expected to be of short duration (e.g. weeks or a maximum of a few months). In case of displacement, availability to hunters may also change.

Unless a zero-discharge policy is applied, drilling mud and cuttings will be released on the seabed, with local impacts on the benthos as a consequence. During exploration, when it is expected that wells are few and dispersed, this impact can be minimal and local with proper mitigation, but impacts may be more severe if development and production is initiated (see below).

There is always a risk of oil spills from blowouts during exploration drilling (see below).

#### Development and production

The activities during development, production and transport are on the other hand long-lasting and there are several activities which have the potential to cause severe environmental impacts. Careful Health, Safety and Environment (HSE) procedures, application of Best Available Technique (BAT) and Best Environmental Practice (BEP), zero-discharge policy and planning in combination with thorough background studies and application of the Precautionary Principle can mitigate most of these. Even though discharges and emissions can be limited, there will be a risk of cumulative and long-term impacts from many of the released substances, but knowledge is generally limited in this field.

The largest contribution to the pollution from an oil field is the discharge of produced water (if not re-injected). This contains, besides oil residues, small amounts of substances which are acutely toxic or radioactive, contain heavy metals, have hormone-disruptive effects or a nutrient effect. Some of the substances may bio-accumulate, although long-term effects of release of produced water are unknown. There is, however, an increasing concern about the environmental impacts of this activity. Particularly if produced water is released under ice, where there is reduced turbulence in the surface layer, increased impacts could occur. The most obvious way to mitigate effects of produced water is to re-inject it into the wells.

Discharge of ballast water is of concern, as there is a risk for introducing non-native and invasive species. This is currently not a severe problem in the Arctic, but the risk will increase with climate change and the intensive tanker traffic related to a producing oil field.

Development and production are energy-consuming activities which will contribute significantly to the Greenland emission of greenhouse gases. A single large Norwegian production field emits more than twice the total Greenland emission of today.

Commercial fishery will be affected by development and production if installations are placed in the fishing grounds. A safety zone (of typically

500 m) will be applied around the offshore facilities. Commercial fishery is currently limited and takes place only in the southern part of the assessment area.

Placement of structures and the disturbance related to these have the potential to displace in particular marine mammals. Noise from drilling platforms has displaced migration routes of bowhead whales in Alaska. Depending on the location of installations, displacement of migrating and staging whales (mainly narwhal and bowhead whale) and walrus must be expected. This can in certain areas limit their access to critical habitats which could be important for survival, and walrus is the most sensitive species in this respect, because the population is dependent on relatively few and localised benthic feeding areas. Furthermore, displacement can result in reduced availability of quarry species for local hunters.

Placement of offshore structures and infrastructure may locally impact seabed communities and there is a risk, in some shallow areas, of spoiling important feeding grounds, particularly for walrus. If onshore structures are established there will be a risk of river obstruction impacting anadromous Arctic char and damage to unique coastal flora and fauna.

Intensive helicopter activity also has the potential to displace seabirds and marine mammals from critical habitats (e.g. feeding grounds important for winter survival) and from traditional hunting grounds used by local people.

Finally, placement of structures and installation onshore will also have an aesthetic impact on the landscapes, an issue especially important to consider when evaluating impacts on tourism.

Development and production activities are difficult to evaluate when their location and the level of activity are unknown. Overall, impacts will depend on the number of activities, how far they are scattered in the areas in question, and also on their durability. In this context cumulative impacts will be important to consider.

Careful planning in combination with thorough environmental background studies, BEP, BAT and application of the Precautionary Principle can do much to limit and mitigate impacts from development and production, e.g. by avoiding the most sensitive areas and avoiding activities in the most sensitive periods.

### Oil spills

The environmentally most severe accident would be a large oil spill. This has the potential to impact the marine ecosystem on all levels from primary production to the top predators. The recent oil and gas assessment by the Arctic Council working groups (AMAP 2007) concluded that the main issue of environmental concern for the marine Arctic environment is a large oil spill, which particularly in ice-covered waters represents a threat at the population and even species level. Furthermore, will the lack of adequate response methods in ice-covered waters and the remoteness and lack of infrastructure in most of the assessment area add to the severity of an oil spill.

Accidental oil spills may occur either during drilling (blowouts) or from accidents when storing or transporting oil. Large oil spills are rare events today due to ever-improving technical solutions and HSE policies. However, the risk cannot be eliminated and in a frontier area like the KANUMAS East with the presence of sea ice and icebergs, the possibility of an accident will be elevated.

Oil spill trajectory modelling was carried out by DMI as a part of this SEIA. In most of the modelled oil spill drift scenarios oil does not reach the coasts, but stays offshore. However, two of the 18 scenarios indicate that under certain conditions, oil may reach shores up to several hundred kilometres from the spill site.

In general, oil spills occurring in the coastal zone are regarded as much more deleterious than oils spills in the open sea. This may, however, not apply in an area such as KANUMAS East, which is dominated by sea ice for the major part of the year. Ice may trap and transport oil over long distances, but may also limit the spread of oil slicks compared with the situation in ice-free waters and even protect shores from being polluted. Furthermore, the ice edges, leads and polynyas are very important in a biological sense and therefore potentially very sensitive to oil spills. Knowledge on the behaviour of oil spill in ice-covered waters is however limited.

The coastal zone is sensitive because of the high biodiversity present, including concentrations of breeding and moulting seabirds and Arctic char. The high sensitivity is also related to the fact that oil may be trapped in bays and fjords where high and toxic concentrations can build up in the water. Furthermore, local fishermen and hunters use the coastal zone in the southern part of the assessment area intensively.

Long-term impacts may occur if oil is buried in sediments, among boulders, in mussel beds or is embedded in crevices in rocks. From such sites oil may seep and cause chronic pollution which may persist for decades. In Prince William Sound in Alaska such preserved oil has caused long-term effects on birds utilising the polluted coasts.

Effects of an oil spill in the open sea (without ice) are expected to be less severe than in coastal areas. Attention should be given to potential oil spills in areas with hydrodynamic discontinuities, such as hydrographic fronts or upwelling zones, particularly during the spring bloom. However, knowledge on these events in the KANUMAS East assessment area is very limited.

Bird populations particularly at risk of being impacted by an oil spill in the KANUMAS East area include the large breeding colonies of little auk and the two thick-billed murre colonies, all at the coasts of the Scoresby Sund polynya. Furthermore, the large assemblages of pre-breeding eiders in the polynyas will be very exposed. Some red-listed seabird species (e.g. thick-billed murre, ivory gull) occur in the assessment area and the populations of these will be exposed to increased mortality in case of a large oil spill.

Marine mammals can also be impacted by oil spills, although individuals (except polar bears) are not dependent on an intact fur layer for insulation. Polar bears are an exception to this, because they are very sensitive to oiling of their fur. Walrus and bearded seal feeding on benthos may also be exposed to oil through their food if oil sinks and accumulates on the seafloor. Bowhead whales, which occur in low numbers (and are red-listed), belong to a stock which was almost exterminated by heavy exploitation. The recovery of this population may be halted by even a slight increase in mortality.

There are special problems related to oil spills in ice. Oil will, at least in the beginning, tend to be contained and the spread limited, unlike the situation in ice free waters. Oil will be contained between the ice floes and on the rough underside of the ice. However, oil caught in or under the ice may be transported in an almost un-weathered state over long ranges and may impact the environment, e.g. seabirds and marine mammals, far from the spill site when the ice melts. Oil may also be caught along ice edges, where primary production is high. Particular concerns have been expressed about polar cod stocks, because this fish spawns in late winter, and the eggs accumulate just below the ice where spilled oil will also accumulate. This could also be the case if produced water (with dispersed oil) is released from a platform in ice-covered waters.

In this context it is worth noticing that recent studies indicate that at least killer whales are very sensitive to inhaling oil vapours. This could apply to narwhals and bowhead whales, which often occur in densely ice-covered waters. During a large oil spill such areas with limited open water will be covered by oil and whales will be forced to surface here. Walruses and other seals living in the ice may also be vulnerable to this scenario.

The seals whelping on the drift ice will be very exposed to an oil spill in the area and many adults and pups may be fouled. Adult seals are rather robust to oiling, but pups are more likely to succumb. Walruses are also sensitive because the population is concentrated at relatively few sites and also because they are gregarious.

Even though seals may tolerate some oil on their fur, such oiling may impact local hunters, as fouled skins are of no use and are impossible to sell.

Oil spill effects on commercial fisheries are mainly linked to the closure of fishing grounds (Greenland halibut) for longer periods (weeks to months) due to the risks associated with marketing polluted or tainted fish. Effects on subsistence hunting and fishing will include closure of polluted coasts and probably also temporary changes in the distribution and habits of quarry species.

The tourist industry in the assessment area is also expected to be negatively impacted by a large oil spill.

This assessment is based on current conditions. However, climate change may alter these conditions considerably and the present assumptions may not apply to the future. Therefore reservations should be attached to some of the conclusions when looking a number of decades ahead.

## Further studies

There is a general lack of knowledge on many of the ecological components and processes in the KANUMAS East area. To fill some of these data gaps, BMP, GINR and NERI have initiated a number of studies which will proceed in 2009 and 2010. The results from these studies will be incorporated in the revised and updated SEIA, planned to be issued in 2010. See section 13 for a review of the projects.

Many more knowledge gaps remain to be filled and there will be a need for further regional strategic studies as well as project-specific studies in order to have adequate data to perform site-specific EIAs. A full analysis of data gaps will be included in the 2010 SEIA. A preliminary list of the most important studies identified so far is given in section 14. Some of these knowledge gaps are generic to the Arctic and have also been identified in the Arctic Council Oil and Gas Assessment (AMAP 2007, Skjoldal *et al*. 2007), and relevant studies will hopefully be initiated by cooperative international research. But there are also knowledge gaps specific to the assessment area.

# Dansk resumé

## Foreløbig, strategisk miljøvurdering af olieaktiviteter i KANUMAS East-området

Denne rapport er en foreløbig, strategisk miljøvurdering af aktiviteter forbundet med olieefterforskning og -udvinding i den grønlandske del af Grønlandshavet. Nærmere bestemt farvandet mellem 68° og 70° 30′ N (Figur 1). Dette område kaldes her KANUMAS East.

KANUMAS projektet var et regionalt seismisk efterforskningsprogram, som blev igangsat i slutningen af 1989. En gruppe selskaber – KANUAMS gruppen – blev dengang tildelt en forundersøgelsestilladelse til KANUMAS områderne, som også omfatter den grønlandske del af Baffin Bugt – KANUMAS West.

KANUMAS gruppen består af de nuværende olieselskaber ExxonMobil, StatoilHydro, BP, JOGMEC, Chevron og Shell.

Forundersøgelsestilladelsen indebar ikke nogen eneret for licenshaverne. Men tilladelsen medførte en betydelig efterforskningsforpligtelse. Dette blev afbalanceret ved, at selskaberne i KANUMAS gruppen blev tildelt en speciel privilegeret rettighed. Den privilegerede position vil blive aktiveret i tilfælde af, at rettighederne til olieefterforskning i Nordøst- og Nordvestgrønland bliver udbudt i en licensrunde.

Rapporten her er udført af Danmarks Miljøundersøgelser (DMU) og Grønlands Naturinstitut (GN) i samarbejde med Råstofdirektoratet.

Rapporten behandler et område som er større end selve KANUMAS East-området (se Figur 1). Det skyldes, at der skal tages højde for, at oliespild kan drive meget langt og dermed også ud af det område som vil blive udbudt. Det vurderede område kaldes i rapporten ”the assessment area” = det vurderede område.

Området er beliggende i den højarktiske zone og viser de for denne zone karakteristiske biologiske træk: Forholdsvis lav biodiversitet, korte fødekæder, og områder med meget høje koncentrationer af organismer. Den lave biodiversitet modsvares af at visse arter er uhyre talrige, og nogle af disse er nøglearter i fødekæderne. Dvs. at de højere trofiske niveauer er afhængige af nøglearternes forekomst i tid og rum.

Det vurderede område er i lokale områder meget rigt i biologisk/økologisk forstand. Primærproduktionen om foråret er visse steder høj, der er rige dyresamfund på havbunden ligesom der er store og meget vigtige forekomster af både fugle og havpattedyr. Blandt fuglene er der vigtige (både nationalt og internationalt) og rødlistede arter som polarlomvie og ismåge. Blandt havpattedyrene er der vigtige (både nationalt og internationalt) arter som isbjørn, hvalros, narhval og grønlandshval.

Væsentlige biologiske områder i det marine miljø er polynierne, som er isfrie områder på ellers isdækket hav. De tre store er Nordøstvandet ud for Nordostrundingen, farvandet ud for Wollaston Forland og mundingen af Scoresby Sund. Der er tillige flere mindre fordelt langs kysten. Polynierne er mere eller mindre isfrie om vinteren og der opstår store områder med åbent vand tidligt om foråret (april/maj). Det betyder at primær-produktionen kan indledes meget tidligere end i de omkringliggende isdækkede områder. Den tidlige produktion tiltrækker koncentrationer af havpattedyr og fugle, og det er ikke tilfældigt at byen Scoresbysund blev etableret ved et af de store polynier. Vurderingsområdets store ynglekolonier af havfugle ligger alle ved polynierne og det er her mange af indlandets vandfugle samles inden isen forsvinder fra søer og kær. Områdets hvalrosser overvintrer i polynierne og i denne sammenhæng er Nordøstvandet meget vigtigt.

Hellefisk udnyttes kommercielt i den sydlige del af vurderingsområdet og fangst og fiskeri til lokalt brug er vigtige aktiviteter for beboerne i Scoresbysund og for de fangere fra Tasiilaq der tager på fangst mod nord til vurderingsområdet.

Aktiviteterne fra en komplet livscyklus for et oliefelt er så vidt muligt vurderet med vægt på de aktiviteter og hændelser som erfaringsmæssigt giver de væsentligste miljøpåvirkninger. Men da der ikke er erfaringer med udvinding af olie i Grønland, er vurderinger af aktiviteter i denne forbindelse ikke konkrete, men bygger på erfaringer fra andre områder med så vidt muligt sammenlignelige forhold. Der er især trukket på den meget omfangsrige litteratur om det store oliespild i Prince William Sound i Alaska i 1989, den norske miljøvurdering af olieaktiviteter i Barentshavet (2003) og på Arktisk Råds netop færdiggjorte "Arctic Oil and Gas Assessment", som endnu kun er delvist tilgængeligt på internettet (Link).

## Vurdering af aktiviteter

Vurderingerne bygger på de eksisterende klimatiske forhold. Men klimaændringerne forventes at ændre meget på miljøet i vurderingsområdet i de kommende årtier. Især isens forekomst forventes at ændre sig. Det betyder ændrede leveforhold, som vil medføre at nogle arter reduceres i forekomst og udbredelse mens andre vil indvandre og etablere sig.

## Efterforskning

Efterforskningsaktiviteter er midlertidige, de varer typisk nogle år og vil for det meste være spredt ud over de tildelte licensområder. De udføres desuden kun i den isfrie periode, dvs. om sommeren og efteråret, formentlig i perioden juli til oktober. Hvis der ikke lokaliseres olie, der kan udnyttes, ophører aktiviteterne helt. Findes der olie, vil aktiviteterne overgå til udvikling og udnyttelse af oliefeltet (se nedenfor).

De væsentligste påvirkninger fra efterforskningsaktiviteter vil blive forstyrrelser fra støjende aktiviteter (f.eks. seismiske undersøgelser, boring i havbunden og helikopterflyvning). Der forventes kun relativt svage, midlertidige og lokalt forekommende påvirkninger, idet mere alvorlige påvirkninger kan undgås med forebyggende tiltag, som f.eks. ved at undgå aktiviteter i særligt følsomme områder eller perioder.

Intensive seismiske undersøgelser kan formentlig få hellefisk til at søge væk fra området i en periode, og sker det i vigtige fiskeområder vil undersøgelserne også kunne påvirke fiskeriet negativt. Undersøgelser af andre fiskearter tyder på at denne påvirkning er midlertidig. Koncentrerede gydeområder betragtes som særligt følsomme overfor seismiske undersøgelser, fordi der er risiko for at skræmme de gydemodne fisk væk. Men denne risiko er ikke aktuel for hellefisk i undersøgelsesområdet da de ikke gyder her.

Der er en risiko for at havpattedyr vil søge bort fra vigtige fødesøgningsområder og trækruter pga. forstyrrelserne fra seismiske undersøgelser. Det forventes dog at påvirkningen vil være midlertidig (varighed uger til måneder), fordi aktiviteten ophører.

Efterforskningsboring giver også anledning til støjende aktiviteter. Både selve boringen, men også maskineri og skruer, der holder en flydende platform på plads (vandet er næsten overalt for dybt til at man kan bruge borerigge, der står på bunden) frembringer kraftig støj. Støjen kan påvirke havpattedyr så de søger væk fra lydkilden, og særligt hvaler angives at være følsomme. Der er derfor risiko for at narhvaler, grønlandshvaler og hvalros kan blive fortrængt fra vigtige opholdsområder. Der er også risiko for midlertidig fortrængning af fin-, våge og pukkelhval i sommermånederne. Fangst på disse havpattedyr kan tænkes at blive påvirket, hvis byttedyr bortjages fra traditionelle fangstpladser.

Den væsentligste risiko for miljøpåvirkninger under en efterforskningsboring opstår i forbindelse med uheld (”blowout”), som medfører et stort oliespild. De mulige følger af oliespild er omtalt nedenfor.

Ved en boring dannes der typisk ca. 450 $m^3$ borespåner og der bruges ca. 2000 $m^3$ boremudder. Begge dele udledes som regel, efter rensning af spånerne, til havbunden. Dette påvirker bundfaunen i nærområdet. Påvirkningerne var særligt tydelige da man brugte oliebaseret boremudder, som i dag er afløst af mere miljøvenlige vandbaserede typer.

Det er vanskeligt at vurdere virkninger af udledning af boremudder og -spåner i KANUMAS East-området, fordi den foreliggende viden om bunddyrsamfundene er meget begrænset. Men det forventes at udledningerne fra en enkelt efterforskningsboring kun vil give minimale, lokale påvirkninger, hvis de mest miljøvenlige typer af boremudder benyttes. Påvirkninger kan undgås ved at undlade at udlede boremudder og -spåner, men i stedet bringe det i land eller pumpe det tilbage i borehullet ved endt boring.

## Udvikling og produktion

I modsætning til efterforskningsfasen er aktiviteterne under udvikling af et oliefelt og produktion af olie af lang varighed (årtier), og flere af aktiviteterne har potentiale til at forårsage alvorlige miljøpåvirkninger. Disse påvirkninger kan i høj grad forebygges gennem nøje planlægning, anvendelse af anerkendte ”Health, Safety and Environment” (HSE) procedurer, brug af ”Best Available Technique” (BAT) og ”Best Environmental Practice” (BEP). Der er dog mangel på viden om kumulative virkninger og langtidsvirkninger af de udledninger (f.eks. fra produktionsvand), der forekommer selv ved anvendelse af førnævnte tiltag.

Produktionsvand udgør langt den største udledning til havmiljøet. Et oliefelt kan udlede op til 30.000 $m^3$ om dagen, og på årsbasis udledes der på den norske sokkel 174 millioner $m^3$. Der er i de senere år udtrykt en vis bekymring for udledning af produktionsvand, på trods af at det er behandlet og de internationale miljøstandarder er blevet strammet. Der knytter sig desuden specielle problemer til udledning af produktionsvand i et isdækket hav der har reduceret opblanding i overfladelaget. Miljøproblemerne ved produktionsvand kan undgås ved at pumpe vandet tilbage i oliebrønden, sådan som den norske ”zero-discharge” politik foreskriver for Barentshavet.

Den anden store potentielle udledning omfatter boremudder og -spåner, da der skal bores intensivt under udvikling og produktion. Miljøpåvirkningerne for en enkelt efterforskningsboring er beskrevet ovenfor. Under udvikling og produktion vil de udledte mængder blive væsentlig større, med risiko for at større områder af havbunden påvirkes. Der vil tillige opstå en risiko for at fisk, der lever i de påvirkede områder får afsmag (”tainting”) af olie fra de rester der findes i borespånerne. Miljøpåvirkningerne fra boremudder og -spåner forebygges bedst ved at deponere begge dele i land eller i gamle borehuller (”zero-discharge”).

Energiforbruget ved udvikling og produktion er meget stort, og anlægget af et stort oliefelt i KANUMAS East-området vil bidrage meget væsentligt til Grønlands samlede udledning af drivhusgasser. F.eks. udleder et af de store norske oliefelter mere end dobbelt så meget $CO_2$ som Grønlands samlede bidrag.

Selve placeringen af installationer og de forstyrrelser, der kommer fra disse, kan påvirke havpattedyr, sådan at de fortrænges permanent fra vigtige fourageringsområder eller således at de ændrer trækruter. I KANUMAS East-området er det især narhval, grønlandhval og hvalros, der er på tale i denne sammenhæng. Dette kan desuden vanskeliggøre fangst på de jagtbare af disse arter.

Ved placering af installationer i land, skal deres landskabelige påvirkninger vurderes og minimeres, idet de medvirker til at reducere et områdes værdi som turistmål.

Intensiv helikopterflyvning har også potentialet til at bortskræmme både havfugle og havpattedyr fra vigtige områder.

Fiskeriet i de områder, hvor der vil forekomme udvikling og produktion vil blive begrænset omkring installationer på havbunden (brønde og rørledninger) og ved de forskellige typer af platforme. Normalt anlægges en sikkerheds/afspærringszone i en afstand ud til 500 m fra sådanne installationer.

Produceret olie skal transporteres bort med skib, som tømmer deres tanke for ballastvand inden de laster olie. Dette vil medføre en risiko for at indføre invasive (dvs. at de breder sig på bekostning af lokale arter), fremmede arter til det lokale havmiljø. Problemet har hidtil ikke været særligt stort i Arktis, men formodes at blive større som følge af klimaændringerne. Risikoen kan formindskes ved behandling af ballastvandet.

Det skal påpeges, at det er meget vanskeligt at vurdere de påvirkninger eventuel udvikling og produktion kan medføre, fordi lokaliseringen, omfanget, varigheden og typen af aktiviteter ligesom de tekniske løsninger ikke er kendt.

## Oliespild

De mest alvorlige miljøpåvirkninger, der kan forekomme i forbindelse med olieaktiviteter, er store oliespild. De forekommer enten fra udblæsninger, hvor kontrollen med borehullet mistes under boring, eller fra uheld i forbindelse med opbevaring og transport af olie, f.eks. i forbindelse med forlis af tankskibe.

Store oliespild er meget sjældne nu om dage, fordi teknikken og sikkerhedsforanstaltningerne hele tiden forbedres. Men risikoen er til stede, og særligt i "frontier"-områder, som de grønlandske farvande med tilstedeværelsen af en særlig risikofaktor i form af isbjerge, er muligheden for uheld og ulykker forhøjet. AMAP (2007) vurderer at risikoen for oliespild i Arktis er størst i forbindelse med transport af olie.

DMI har modelleret drivbanerne for oliespild i KANUMAS East-området med udgangspunkt i tre spildsteder forholdsvis langt fra kysten (Figure 48). I to ud af 18 simuleringer når olien kysten inden 30 dage og kysten rammes op til flere 100 km fra spildstedet. Modellerne er kørt for 30 dage, men under særlige forhold, som f.eks. hvis et spild opfanges i havis, kan olien transporteres meget længere og påvirke kyster længe efter de 30 dage.

Oliespild i kystnære farvande regnes generelt som meget mere ødelæggende end oliespild på åbent hav. Men i et område som KANUMAS East må denne generalisering modificeres. Det hænger sammen med forekomsten af is, som kan holde på olien og transportere den over lange afstande uden at den nedbrydes væsentligt. Men som også kan begrænse et spilds udbredelse sammenlignet med et spild i isfrie farvande. Den foreliggende viden om oliespilds adfærd og skæbne i isdækkede farvande er begrænset.

Grunden til at kystnære fravande er mest sårbare over for oliespild er, at olien her kan påvirke områder med høj biodiversitet og med tætte dyrebestande, som f.eks. banker med bunddyr som hvalrosser lever af og områder med store fugleforekomster. Olien kan fanges i bugter og fjorde, hvor høje og giftige koncentrationer af oliekomponenter kan bygges op i vandsøjlen og nå bunden. Der er også risiko for at olie kan fanges i bundsedimenter eller i strande med rullesten, hvorfra olie langsomt kan frigives til det omgivende miljø med risiko for langtidsvirkninger f.eks. på fuglebestande som udnytter kysterne. Endelig udnyttes de kystnære fravande af lokale indbyggere til fangst og fiskeri.

På åbent hav er fortyndingseffekten og spredningen på vandoverfladen med til at mindske miljøeffekterne af et oliespild. I og nær KANUMAS East-området kan det ikke udelukkes at der er områder langt fra kysten, som alligevel er særligt sårbare over for oliespild. Men den foreliggende viden er ikke tilstrækkelig til at udpege sådanne områder. Det kan f.eks. være frontzoner, "up-welling"-områder og de ydre dele af drivisen ("marginal ice zone"), hvor primærproduktionen er særligt høj om foråret, og hvor høje koncentrationer af planktoniske alger og dyrisk plankton forekommer i den øvre del af vandsøjlen.

Et oliespild vil dog næppe påvirke bestanden af hellefisk, den eneste fiskeart der udnyttes kommercielt i vurderingsområdet.

Fugle er særligt sårbare overfor oliespild på havoverfladen, og i KANUMAS East-området er der lokalt mange udsatte fugleforekomster. Ynglefuglene omfatter store kolonier af polarlomvie, søkonge, ederfugl, havterne og ismåge, ligesom der er fældende ederfugle og mindst en fjord med fældende kongeederfugle.

Havpattedyr kan også påvirkes af oliespild på havoverfladen. Indenfor KANUMAS East-området vil hvalros være særligt udsat, fordi hvalrosserne forekommer meget koncentreret omkring nogle få vigtige fødesøgnings områder. Der er tillige helt nye undersøgelser der tyder på, at spækhuggere (og dermed formentlig også andre hvaler) er sårbare overfor indånding af oliedampe over et spild; et forhold som kan blive aktuelt ved oliespild i is (se nedenfor).

Isbjørne er specielt sårbare, fordi de har en tendens til at rense olie af pelsen ved at slikke den ren og derved blive forgiftet af den indtagne olie. Grønlandshvalerne, der forekommer i området, tilhører en meget lille bestand, som blev næsten udryddet i begyndelsen af 1900-tallet. Bestanden er så reduceret, at selv en lille ekstra dødelighed kan tænkes at påvirke bestandens bedring.

Et oliespild i havområder med is vil formentlig samles i åbne revner og under isflager, hvor den kan påvirke de fugle og havpattedyr, der er afhængige af åbent vand, men også yngel af polartorsk, der netop samles lige under isen. Havpattedyr kan blive tvunget til at dykke ud i oliespild i de meget begrænsede åbenvandsområder og derved blive udsat for at indånde oliedampe.

Fiskeri og fangst kan blive påvirket ved at oliepåvirkede områder lukkes for den slags aktiviteter. Dette gøres for at hindre at der fanges og markedsføres fisk, der har været i kontakt med olie (for eksempel med afsmag) eller som blot er mistænkt for at have været det. Der er eksempler på at oliespild har lukket for fiskeri i månedsvis. Der er også en risiko for at fangstdyr bliver sværere tilgængelige i en periode efter et oliespild, ligesom sælskind bliver umulige at afsætte hvis der er olie på dem.

## Yderligere studier

Der mangler generelt viden om mange af de økologiske komponenter, sammenhænge og processer i KANUMAS East-området. Råstofdirektoratet, Grønlands Naturinstitut og Danmarks Miljøundersøgelser har indledt en række undersøgelser for at tilvejebringe noget af denne manglende viden. Disse studier vil fortsætte indtil 2010, og resultaterne skal indarbejdes i den reviderede og opdaterede udgave af denne Strategiske Miljøvurdering, der skal udgives i 2010. I Sektion 13 findes en oversigt over disse studier, og Box 1 og 2 viser nogle foreløbige resultater.

Der vil desuden blive behov for yderligere undersøgelser til at supplere de projekt-specifikke miljøvurderinger, der skal udføres når og hvis konkrete aktiviteter indledes. I Sektion 14 gives en foreløbig udpegning af vigtig manglende viden. En mere gennemgribende analyse vil blive inkluderet i den opdaterede udgave af denne rapport. En del af de listede emner er fælles for det arktiske område og fremgår også af Arktisk Råds' "Oil and Gas Assessment" (AMAP 2007, Skjoldal *et al*. 2007). Relevante studier er derfor indlysende internationale samarbejdsopgaver.

# Imaqarniliaq kalaallisooq

## Utaaqqiisaagallartumik KANUMAS East-imi uuliasiornikkut ingerlatanut tunngatillugu siumut isigaluni avatangiisinik naliliineq

Nalunaarusiaq una utaqqiisaagallartumik Grønlandshavet-p kalaallinut atasortaani uuliamik ujarlernermut piiaanermullu tunngatillugu ingerlatanut siumut isigaluni avatangiisinik naliliineruvoq. Erseqqissumik oqaatigalugu imartami allorniusap 68° aamma 70° 30’ N-ip akornanniittumi (Titartagaq 1). Tamanna KANUMAS East-imik taaneqarpoq.

KANUMAS tassaavoq tamaani sajuppillatitsisarluni ujarlernissamik pilersaarut 1989-ip naalernerani aallartinneqartoq. Ingerlatseqatigiiffiit ataatsimoorussisut – KANUMAS gruppen – taamanikkut tamaani, Baffin Bugtenip kalaallinut atasortaanittumik - Kanumas West-imi –- misissueqqaarnissamut akuersissummik tunineqarput.

KANUMAS gruppen-imut ilaapput massakkut uuliasioqatigiiffiusut ExxonMobil, StatoilHydro, BP, JOGMEC, Chevron aamma Shell.

Misissueqqaarnissamut akuersissut akuersissutaatillit kisermaassisussaatinneqarnerannik ilaqartinneqanngilaq. Akuersissummili annertuumik ujarlernissamut pisussaatitsinertaqarpoq. Taannartaa ingerlatsiviit KANUMAS gruppen-imiittut immikkut ittumik pisinnaatinneqarnerannik illuatungilerneqarpoq. Immikkut taamatut pisinnaatinneqarnerat atuutilersussaavoq Tunup avannaani Kitaatalu avannaani uuliamik ujarlernissamut pisinnaatitaaffiit akuersissutitaasa neqeroorutigineqarnerisigut.

Nalunaarusiaq una Danmarks Miljøundersøgelser (DMU)-mit aamma Pinngortitaleriffimmit (GN) Råstofdirektoratet suleqatigalugu suliarineqarpoq.

Nalunaarusiami sammineqarpoq imartaq KANUMAS East-ip ingerlatsivissaanit annertunerusoq (takuuk titartagaq 1). Tamatumunnga pissutaavoq uuliaarluernerup neqeroorutigineqartussamiit sumorujussuaq siaruaassinnaanerata ilanngunneqartussaanera. Nalunaarusiami nalilersuiffigineqartoq tamanna ”the assessment area”-mik (nalilersuiffigineqartumik), taagorneqarpoq.

Tamanna issittorsuarmiippoq, højarktisk zone-miippoq, zone-llu taassuma biologiikkut ilisarnaataanik takuffiulluni: Uumasut assiginngisitaat amerlavallaanngillat, nerisareqatigiit ikittuinnaapput aammalu uumasuaqat annertoorsuarmik eqiteruffiinik peqarluni. Uumasut assigiinngisitaartut ikinnerat uummasut ilaasa amerlasoorujussuakkuutaarnerannik illuatungilerneqarpoq, aammalu tamakkua ilaasa nerisareqatigiinnermi pingaaruteqartuuneratigut. Imaappoq nerisareqatigiinniittut qaqugukkut amerlanerusarnerannut uumasut nerisarinnittut pingaaruteqarnerit qaqugukkut takkusimasarnerat qanorlu amerlatigisarnerat tassani apeqqutaasarluni.

Nalilersuiffigineqartoq biologiimut/uumasoqatigiinnermut tunngatillugu pisoorujussuuvoq. Minnerpaanik pilersitsiortorneq upernaakkut ilaanni annertoorujussuusarpoq, immap naqqani uumasoqatigeeqarluarpoq aammalu uumasunik angisuunik, timmissanik miluumasunillu imarmiunik pilerujussuulluni. Timmissanut ilaapput pingaarutillit (nunamut namminermut nunanullu allanut) uumasut aarlerinartorsiortut nalunaarsorsimaffianiittunik, soorlu appat naajavaarsuillu. Miluumasut imarmiut pingaarnerit (nunamut namminermut nunanullu allanut) tassaapput nannut, aarrit, qilalukkat qernertat arfiviillu.

Immami avatangiisinut tunngatillugu biologiimut pingartuteqartorujussuit tassaapput immami sikusimagaluartumi aakkarnersuaqartarfiit (polynier). Taama ittut angisoorsuit pingasuupput tassaallutik Nordøstvandet, Tunup avannaani Nordostrundingen-ip avataaniittoq, immami Wollaston Forland-ip avataaniittoq aamma Kangerlussuup Scoresby Sund-ip paavaniittoq. Taakkua saniatigut allanik annikinnerusunik sineriak sinerlugu aakkarneqarfeqartiterpoq. Polyniat ukiuugaluartoq ammaannangajattuusarput upernaleqqaarneratigullu (aprilimi / majimi) imartarujussuannguuttarlutik. Taamaammat tamaani uumassusilinnik mikisuaqqanik pinngorartitsineq avatangiisiinit suli sikuusunit piaarnerujussuarmik aallartittarpoq. Taamatut aallartijaartarnerata miluumasut imarmiut timmissallu tamakkununnga assut katersuuttitittarpai, taamaattumik Ittoqqortoormiit polyniap taamaattup killinganut inissinneqarsimanera nalaatsornerinnakkut pinngilaq. Nalilersuiffiup timmissanik imarmiunik timmiaqarferujussui tamarmik polyniaqarfiit eqqaaniittiterput, aammami nunami tiffasinnerusumi naloraarusilii katersuutilersarput tatsit masarsuillu suli sikuertitilinngitsut. Aarrit tamaaniittut polyniaqarfinni ukiisarput, tassungalu atatillugu Nordøstvandet pingaarutilerujusuuvoq.

Nalilersuiffiup kujasinnerusuani qalerallit iluanaarniutigalugu aalisarneqartarput aammalu najukkami atugassanik piniarneq aalisarnerlu Ittoqqortoormiijormiunut Tasiilallu piniartuinut avannarparterlutik nalilersuiffimmut piniariartartunut ingerlataapput pingaaruteqartut.

Uuliasiorfimmi ukioq kaajallallugu ingerlataasartut misilittakkallu sapinngisamik tunngavigalugit pisartut avatangiisinut sunniuteqarnerusartut pingaarnerutillugit nalilersorniarneqarsimapput. Kalaallit Nunaannili uuliamik piiaanermik misilittagaqartoqanngimmat tassunga tunngatillugu ingerlatanik nalilersuinerit aalajangersumut tunngatinneqanngillat, allamili sapinngisamik maani pissutsinut assersuunneqarsinnaasumi misilittakkanik tunngavilersorniarneqarsimallutik. Pingaartumik Alaskamiittumi Prince William Sound-imi 1989-imi uuliaalluerujussuarnermut tunngatillugu naqitigarpassuit, norskit Barentshavetmi (2003) uuliasiornikkut ingerlatanut tunngatillugu avatangiisinik naliliinerat, aamma Arktisk Råd-ip nalunaarusiaa saqqummerlaavik ”Arctic Oil and Gas Assessment”, internet-ikkut suli ilaanakortuinnarmik takuneqarsinnaasoq, isumassarsiorfigineqarsimapput (Link).

## Ingerlatanik naliliinerit

Nalilliinerni klimap pissusii massakkut atuuttut toqqammavigineqarsimapput. Klimalli allanngorneri ukiuni qulikkuutaani aggersuni annertuumik nalilersuiffimmi avatangiisinik allanngortitsiumaartut ilimagineqarpoq. Pingaartumik sikuusarnerata allannguuteqarnissaa ilimagineqarpoq. Tamatumalu inooriaatsimi pissutsit allanngornerat, aamma uumasoqatigiit ilaasa takkusimaartarnerata siammartarneratalu annikillisinneqara, allalli takkuttalerumaarnerat tamaaniilerumaarnerallu kinguneriumaarpaa.

## Ingerlatanik naliliinerit

Nalilliinerni klimap pissusii massakkut atuutut toqqammavigineqarsimapput. Klimalli allanngorneri ukiuni qulikkuutaani aggersuni annertuumik nalilersuiffimmi avatangiisinik allanngortitsiumaartut ilimagineqarpoq. Pingaartumik sikuusarnerata allannguuteqarnissaa ilimagineqarpoq. Tamatumalu kinguneriumaarpaa inooriaatsimi pissutsit allanngornerat, aamma uumasoqatigiit ilaasa takkusimaartarnerat siammartarnerallu annikillisinneqarumaarpoq, allallit takkuttalerumaarput tamaaniilerlutillu.

## Ujarlerneq

Uulliamik ujarlernikkut ingerlatat utqqiisaannaagallarput, tammanna ukiualunnik sivisussuseqarajuppoq amerlanertigut akuersissuteqarfimmi sumut tamaanga assigiinngitsunut simmarsimallutik ingerlanneqartarlutik. Aammalu tamakkua imarorsimaerinnaani, tassa aasaanerani ukiakkut oktoverip ingerlalerneranut ingerlanneqartarlutik. Uuliamik atorneqarsinnaasumik nassaartoqanngikkaangat ingerlatat unitsivinneqartarput. Uuliamilli nassaartoqarpat ingerlatat piiaaninngorlutik uuliaqarfimmik iluaquteqarninngortarput, (ataaniittoq takuuk).

Ujarlernikkut ingerlatat sunniineri pingaarnerit tassaasarput nipiliornikkut akornusersuinerit (soorlu sajuppillatitsisarluni misissuinertigut, immap naqqani qillerinikkut helikopterimillu ingerlasoqartarnratigut). Ilimagineqarpoq najugarpiami annertoorsuunngitsumik qaangiukkumaartumillu tammakua sunniuteqarumaartut, tassami sunniutit pikkunarnerusut pinngitsoorneqarsinnaammata mianersornikkut iliuuseqarnikkut, soorlu ingerlatat piffissani najukkanili sunniuteqarnerluffiusinnaasuniitsinnaveersaarnerisigut.

Annertuumik sajuppillatitsisarnikkut misissuinerit qalerallit tamaaniittut qimagukkallartissinnaassagunarpaat, tamannalu aalisarfinni pingaarnerni pissappat taava misissuinerit aamma aalisarnermut ajoqutaalersinnaapput. Aalisakkanulli allanut tunngatillugu misissuinerit takutippaat taamatut sunnerneqarneq qaangiukkumaartoq. Suffiffiusartut immikkut sajuppillatitsisarluni misissuinernut misikkarinnerusartutut isigineqartarput, qalerallilli nalilersuiffiusumi suffineq ajormata taamatut akornusiisinnaaneq tamaani pinavianngilaq.

Miluumasut imarmiut neriniartarfimminni ingerlaartarfimminnillu misissuinikkut akornusersuinerit pissutigalugit qimagussinnaanerat aarleqqutigineqarsinnaavoq. Kisiannili taamatut sunniuteqarnera sivikitsuinnaajumaartoq naatsorsuutigineqarpoq (immaqa sapaatip akunnialuinik qaammatinilluunniit) tamatumunnga tunngavigineqarpoq ingerlatat unittussaanerat.

Uppernarsarneqarpoq qamutillit silaannarmik imaqartut sajuppillatitsisarnikkut misissuinermi atorneqartartut aalisakkat suaannik tukerlaanillu toqutsisinnaammata ungasinnerpaamik 5 m ungasissuseqarsimappata. Noorgime aalisakkat piaqqiverujussuini annertuumik sajuppillatitsisarluni misissuinerit aalisagaaqqanik tukerlaanik amerlasuunik toqoraasinnaanerat aalisakkat inersimasut amerlassusiannut sunniuteqarsinnaanera aarleqqutigineqarpoq. Tamatut aalisagaaqqat amerlasoorsuuffiinik kalaallit imartaanni ilisimasaqartoqanngilaq, amerlasuullu taamatut ataatsimoortarnerat upernaakkut pisarpoq sajuppillatitsisarluni misissuinerit nalinginnaasumik aallartittarnerat sioqqullugu. Sajuppillatitsisarluni KANUMAS East-imi misissuinerit annertunerusumik aalisagaqatigiinnut sunniuteqarnissaat aarleqqutigineqanngilaq.

Ujarlerluni qillerisarnerit nipiliortumik ingerlatanut ilaapput. Qillerineq nammineq, aammali maskinat sarpiillu qilleriviusumik illikarnaveersaartitsisut (qilleriviusussani tamani imaq itivallaarpoq qilleriviit naqqanut tunngatillugit qajannaakkat atornissaannut) sakkortuumik nipiliortuupput. Taamatut nipiliornermut miluumasut imarmiut, minnerunngitsumik arferit, misikkarissuunerarneqartarput. Taamaattumik qilalukkat qernertat, arfiviit aarfillu najortakkaminnit pingaaruteqartunit qimaatinneqarnissaat aarleqqutigineqarsinnaavoq. Aarleqqutigineqarsinnaavortaaq tikaagulliusaat, tikaagulliit qipoqqaallu aasaanerani tamaanngaannit illikarsimatinneqarsinnaanerat. Miluumasunik tamakkuninnga piniarneq akornuserneqartoq takorloorneqarsinnaavoq piniagarineqartartut tamakkua piniarfigineqartumiit qimaatinneqassappata.

Ujarlernerup nalaani qillerinermi avataangiisinik sunninissaq aarlerinarnerpaaq uaniippoq ajutoorluni (”blow-out”) uuliamik annertoorsuarmik aniatitsisoorsinnaaneq. Taamatut uuliamik aniasoornerup kingunerisinnaasai matuma ataani eqqartorneqarput.

Qillerinikkut qillernerlukut 450 m$^3$ missiliortut pilersinneqartaput aammalu qilleriffiup sulluanut maralluk 2000 m$^3$ missaanik annertussusilik atorneqartarluni. Taakkua qillernerlukut salinneqareeraangata immap naqqanut igiinnarneqarajupput. Taakkua immap naqqata uumasui qanituminniittut sunnertarpaat. Sunniutit sule erseqqinnerusarput qillerinermut maralluk atorneqartoq uuliamik tunngaveqartoq, ullumikkut avatangiisinut naleqqunnerusunik imermik tunngaveqartunik taarserneqarsimasoq, atugaagallarmat.

Maralluup qillerinermut atorneqartup qillernerlukullu KANUMAS East-imi sunniutaat nalileruminaatsuupput, tassami immap naqqani uumasuusunut tunngatillugu ilisimasat amerlanngeqimmata. Ilimagineqarporli ataasiarluni ujarlernermut atatillugu qillerinerup sunniutigiumaagai annikitsuinnaajumaartut qillerinermut maralluit atorneqartut avatangiisinut sallaannerusuusimappata. Sunniutissat pinngitsoorneqarsinnaapput maralluk qillerinermut atugaq qillernerlukullu nunamut qallorneqartuuppata imaluunniit pumpi atorlugu qillerinerup naammassineratigut qilleriffikumut immiuteqqinneqartuuppata.

## Ineriartortitsineq tunisassiornerlu

Ujarlernermi ingerlatanut naleqqiullugu uuliaqarfiup ineriartortinneranut uuliamillu tunisassiornissamut atatillugu ingerlatat sivisoorujussuarmik (ukiuni qulikkuutaanni arlalinnik) ingerlanneqarsinnaapput, ingerlatallu tamakkua ilarpassui annertuumik avatangiisinut ajoqusiissutaasinnaasuupput. Tamakkunatigut sunniutaasinaasut sillimaffigineqarluarsinnaapput sukumiisumik pilersaarusiornikkut, periaatsinillu ”Health, Safety and Environment” (HSE)-imi ”Best Available Technique” (BAT)-imi aamma ”Best Environmental Practice” (BEP)-imi akuerisaasunik atuinikkut. Kisiannili tamakkua annikitsuararpassurnik aniatitsinertaqartarmata tamakkua ataatsimut katillutik ajoqusiisinnaanerannut sivisuumillu sunniusimasarnerannut tunngatillugu ilisimasat tamakkiisuunngillat (assersuutigalugu imermut tunissassiornermi atorneqartumut tunngatillugu), taannami siornani periaatsit taaneqartut atoraluaraangataluunnit atorneqartarmat.

Imeq tunisassiornermut atorneqartoq tassaavoq immami avatangiisimut aniatinneqartut annerpaartaat. Uuliasiorfik ullormut 30.000 $m^3$ tikillugu aniatitsisinnaavoq, ukiorlu tamaat norskit uuliasiorfigisaanni aniatinneqartartoq 174 millioner $m^3$ annertussuseqartarpoq. Ukiuni kingullerni erngup tunisassiornermi atorneqartup aniatitaanera isumakuluutigineqaleriartorpoq, naak taanna nunarsuarmi avaatangiisinut tunngatillugu killissatut atugassaritinneqartut malillugit salinneqartaraluartoq. Immami sikusimasumi immap qaavani akuleruttarneq annikillisinneqartarmat erngup tunisassiornermi atukkap aniatinneqarneranut atatillugu aamma allanik ajornartorsiuteqarpoq. Avatangiisinut tunngatillugu erngup tunisassiornermut atorneqartup aniatinneqarneratigut avatangiisitigut ajornartorsiuteqalernissaq pinngitsoorneqarsinnaavoq imeq taanna norskit Barentshavet-mut tunngatillugu ”zero-discharge” –imik politikkianni nassuiarneqartutuut erngup uuliap aniavianut pumperlugu uterartinneqarneratigut.

Aniatitserujussuartitsisinnaasunut ilaapput qillerinermi maralluk atorneqartoq qillernerlukullu, tassami ineriartortitsinerup tunisassiornerullu nalaanni qillerineqartorujussuusarmat. Avatangiisinut sunniutit ataasiaannarluni ujarlernermi qillerinerumut tunngasut qulaani eqqartorneqareerput. Ineriatortitsinermi tunisassiornermilu aniatitat annertunerulluartussaapput taamaattumillu immap naqqata annertunerusup sunnerneqarsinnaanissaa aarlerinarnerulluni. Aarlerissutaasinnaavortaaq aalisakkat taamatut sunnerneqartup eqqaaniittut uuliamit qillernerlukuniittumit uuliasunnitsunngortinneqarnissaat (”tainting”). Maralluup qillerinermi atorneqartup qillernerlukullu avatangiisinik sunniinerat pinngitsoortinniarneqarsinnaavoq taaneqartut taakkua nunamut iginneqartarneratigut imaluunnit qilleriffiusimasunut immiuteqqinneqartarnerisigut, (”zero-discharge”).

Ineriartortitsinermi tunisassiornermilu nukimmik atuineq annertoorujussuusarpoq, uuliaqarfissuarmillu KANUMAS East-imi sananerup Kalaallit Nunaata naatsitsiviit gassiinik tamakkisumik aniatitsinera malunnaatilimmik annertusisittussaavaa. Assersuutigalugu norskit uuliasiorfiini $CO_2$ -mik aniatitsineq Kalaallit Nunaata tamakkiisumik aniatitaata marloriaatigaa.

Sanaartukkat sumiinnerat akornusersuutillu taakkunannga pisut miluumasut imarmiut sunniuteqarnerluffigisinnaavai neriniarfinnaaminnit qimagutitivinneqarsinnaammata ingerlaartarfimminnillu allanngortitsisinneqarsinnaallutik. KANUMAS East-imi pingaartumik qilalukkat qernertat, arfiviit aarrillu aarleqqunnarneruppput. Taamaalineratalu aamma uumasunik taakkuninnga piniagaasartunik piniarniarneq ajornarnerulersissinnaavaa.

Sanaartugassat nunamut inissinneqarneratigut nunap ilusaanut sunniutissat nalilersorneqarlutillu annikillilerniarneqartariaqarput, tassami nunap tamatuma takornarianit soqutiginarneranik annikillisitseqataasinnaammata.

Annertuumik helikopterinik angallanneq aamma timmissat miluumasullu imarmiut najugannaaviniit pingaarutilinniit tatamisillugit qimaatinneqarsinnaanerannik kinguneqarsinnaasuuvoq.

Ineriartotitsiviusumi tunisassiorfiusumilu aalisarneq immap naqqatigut atortulersuutinit (piiaaviup milluaaviinit ruujorinillu) aallalu qilleriviit assigiinngitsut ivertissorneqarnerisigut periarfissamigut annikillileriffigineqassaaq. Nalinginnaasumik sanaartukkat taammaattut isumannaallisaaneq pissutigalugu 500 m-init qaninneruleqqusaaneq ajorput.

Uulia tunisassiarineqartoq umiarsuarnit, uuliamik usilersulersinnatik imermik ballasterisimasaminnik igitseqqaartartussanit, assartorllugu aallarussorneqartussaavoq. Taamatut igitsisarnerup uumasut kissaatigineqanngitsut (imaappoq tamaani uumasooreersut tatillugit siaruariartortartut) kalaallit imartaanni takornartaagaluartut eqquneqartalernissaannut aqqutaasinnaavoq. Ajornartorsiut taanna Issittumi imatorsuaq ajornartorsiortitsisimanngikkaluarpoq, kisiannili klimap allanngoriartornerata kinguneranik annertusiartorsinnaasorineqarpoq. Aarlerinartua erngup ballasterineqarsimasup saleqqaarneqartarneratigut annikillisinneqarsinnaavoq.

Erseqqissarneqassaaq ineriartortitsinerup tunisassiornerullu sunniutigisinnaasaasa nalilersorniarnerat ajornakusoortorujussuummat, tassami sumut inissinneqarnissaat, annertussusissaat, sivisussusissaat ingerlatallu sorpiaanissaat aammalu teknikikkut suut aaqqissutigineqarnersut ilisimaneqanngimmata.

## Uuliaarluerneq

Uuliasiornermut atatillugu avatangiisinut sunniisinnaasut ajornerpaartaat pisinnaasoq tassaavoq uuliakoornerujussuaq. Tamanna pisinnaavoq samannga aniasooriataarujussuarnikkut qileriviup putuanik nakkutilliineq aserorneqaraangat, imaluunniit ajutoornikkut uulia katersugaq assartugarluunnit, soorlu umiarsuup uuliamik assartuutip umiuneratigut, maangaannartoortinneqaraangat.

Ullutsinni uuliamik aniasoorujussuarnerit qaqutigoortorujussuanngornikuupput isumannaallisaanikkut iliuusiusartut pitsanngorsarneqartuarmata. Aarlerinartuali tassaajuarpoq, pingaartumik ”frontier”-områdini, kalaalit imaartaasut ittuni, iluliaqarnermigut immikkut arlerinartorsiorfiusuni ajutoornissaq ajunaarnissarluunniit annertunerusarmat. AMAP (2007)-imi naliliivoq Issittumi uuliaarluertoqarnissaanut aarlerinartup annersaa uuliamik assartuinermiittoq.

DMI-p KANUMAS East-imi uuliaarluernikkut uuliap siammariartorfissaa assersuusiorsimavaa uuliaarluerfinnut assigiinngitsunut pingasunut avasissumiit aallartittunut tunngatillugu (Titartagaq 48). Pisuusaartitsinernit 18-iusunit marluinnaat sinerissamut annguppput mingutitsiviusumiit 100 km ungasissusilimmut.

Sinerissap qanittuani uuliaarluernerit avasissumi uuliaarluernernit ajorqutaanerujussuusartutut isigineqarput. KANUMAS East-itulli ittumut tunngatillugu taamatut oqarneq allanngortittariaqarpoq. Tamatumunnga pissutaavoq sikoqartarnera sikullu uuliamik tigusisarnera uuliamillu ungasissorujussuaq tikillugu allanngortitsinngingajavilluni assartuisarnera. Aammali siku sikuuneq ajortumi imaannarmi uuliaarluernerup siaruartarneranut naleqqiullugu killiliinerusinnaasarpoq. Uuliaarluernerup immami sikumik qallersimasumi qanoq pisarneranut tunngatillugu ilisimasat killeqarput.

Nunamut qanittumi uuliaarluernerup ajoqutaanerusarneranut pissutaavoq uulia assigiinngitsorpassuarnik eqimasunillu uumasoqarfiusunik sunniisinnaammat, assersuutigalugu ammassannik suffisunik, ikkannersuarnik natermiunik aarrit nerisartagaannik uumasulinnik aammalu timmiarpassuit najortagaannik ajoqusiisumik. Uulia iterlanni kangerlunnilu katersuussinnaavoq taamalu uuliap akui toqunartut immap qaavaniit naqqa tikillugu akornutaalersinnaallutik. Uulia immap naqqani kinnernut, sissamut tuapannullu aammalu uiloqarfinnut unissinnaavoq arriitsuinnarmillu katagarluni avatangiisinut, soorlu timmiaqatigiinnut sinerissamik atuisunut siammarterluni sunniinerlussinnaalluni. Aammami imaq sinerissamut qanittoq tamaanimiunit piniarnermut aalisarnermullu atorneqartarpoq.

Avasissumili uuliaarluernerup immap qaavani siaruarnermigut kimikillisarnera avatangiisit ajoquserneqarnerannik annikillisitseqataasarpoq. KANUMAS East-imi eqqaanilu isiginngitsuusaarneqarsinnaanngilaq avasissumi uuliaarluernerugaluartoq ulorianartorsiortitsilluinnarsinnaammat. Taamaattulli sorpiamiinnersut tikkuarnissaannut ilisimasat naammanngillat. Taamaattut tassaasinnaapput frontzonit, ”up-welling”-ngeqarfiit (sarfap samannga pikialaarfii) sikullu tissukartut sinaaqarfii (”marginal ice Zone”) upernaakkut uumasuaqqat pinngorarfigilluartagaat aammalu quajaatitut naasuusut uumasuaqqallu tappiorarnartut imartani taamaattuni immap qaavata tungaa eqiterusimaffigilluinnartarpaat.

Uuliamilli aniasoornerup qaleralinnut, tamaani iluanaarniutigalugu aalisagatuaasumut, sunniuteqarnissaa ilimananngilaq.

Immap qaavata uulliakoorfigineqarneratigut timmissat eqqornerlunneqarnerpaasarput, KANUMAS East-imilu timmiaqatigiippassuaqarpoq navianartorsiortinneqarsinnaasunik. Tamaani erniortartunut ilaapput apparpassuit, appaliarsuppassuit, miterpassuit, imeqqutaallat naajavarsuillu, aammalu minnerpaamik kangerluk ataaseq mitit siorakitsut isaffigisarpaat.

Miluumasut imarmiut immap qaavanut uuliaarluernermit aamma sunnerneqarsinnaapput. KANUMAS East-ip iluani aaveq aarlerinartorsiorneruvoq, aarrimmi neriniarfimmik amerlanngeqisut eqqaannut katersuussimasarmata. Misissuinerittaaq nutaat takutippaat aarluit (aammalu qularnanngitsumik arferit allat) sikumi uuliaarluernermi uuliap aalarnerinik najuussuissagunik ajoqutigisinnaassagunaraat (ataaniittoq takuuk).

Nannut aamma ajoquseruminartorujussuupput meqquminnimi uuliaarluernernik aluttuillutik saliisarneq ileqqorigamikku taamaalillutillu uuliamik iijorakkamikkut toqunartortorsinnaallutik. Arfiviit tamaaniittartut arfeqatigiinnut 1900-ikkut aallartinneranni nungutaangajaluinnariarlutik aatsaat qanittukkut amerliartornerannik malunnarsisinut ilaapput. Sulili ikittunnguugamik annertunngikkaluamik toqorarnerulernerat amerliartuleraluarnerannut ajoqutaasinnaassasoq takorloorneqarsinnaavoq.

Immami sikulimmi uuliaarluerneq qularnanngitsumik sikup ataanut quppanullu ammasunut pularartussaavoq taamaalillunilu timmissat miluumasullu imarmiut immamik sikoqanngitsumik pisariaqartitsisuusut aammalu eqalukkat piaraat sikup ataani katersuussimasartut sunnernerlussinnaavai. Miluumasut imamiut imartatuannguatigut amerlanngeqisutigut uuliaarluerneq pikiarsaarfigisinnaavaat taamalu uuliap aalarnera najuussorsinnaallugu.

Uuliarluerfiusimasut aalisarfigalugillu piniarfigeqqusaajunnaarnerisigut aalisarneq piniarnerlu eqqornerlugaasinnaapput. Taamaaliortoqarsinnaavoq tamatumuuna aalisakkat uuliaternikumiissimasut (immaqa uuliasunnilesimasut) pisarineqarnissaat tuniniaanikkullu nittarsaanneqarnissat pinngitsoorniarlugu. Uuliaarluerfiusimasut qaammaterpassuarni aalisarfioqqusaajunnaarsinneqartarnerannut assersuutissaqareerpoq. Aamma aarleqqutigineqarsinnaavoq piniagassat uuliaarluersimanerup nalaani akuttornissaat, aammami puisit amiisa uuliaarluersimasut tuninissaat ajornarsisarpoq.

## Misissueqqinnerit

Avatangiisinik nalilersuilluni suliaq aallartimmat erseqqissivoq KANUMAS East-imi uuliasiorlluni ingerlatanut tunngatillugu ilisimasat pingaarutillit pisariaqartinneqartut amigaatigineqartut. Misissuinerit arlallit aallartiterneqarput, maannamulli angusat ikittuinnaat nalunaarusiamut uunga ilanngunneqarsinnaasunngorsimapput. Tamakkua ilaat Box 1-imi aamma 2-mi takuneqarsinnaapput. Pilersaarutaavoq utaqqiisaagallartumik avatangiinik naliliineq 2010-p naalernerani nutarterneqarumaartoq, tassungalu misissuinerni kingullerpaani angusaat ilanngunneqarumaarput.

Naatsorsuutigineqarportaaq nunap ilaani siumut sammisitanik aalajangersunik ilassutaasussanik misissuinissaq pisariaqartinneqassasoq, tamakkualu ingerlanneqassallutik ingerlatat aalajangersut aallartinneqarpata avatangiisinullu tunngatillugu naliliiffigineqartussanngorpata.

# 1 Introduction

This document comprises a preliminary strategic environmental impact assessment (SEIA) of expected activities in the KANUMAS East area. It was prepared by the National Environmental Research Institute (NERI) and the Greenland Institute of Natural Resources (GINR) in co-operation with the Bureau of Minerals and Petroleum (BMP).

We have used many sources of information, including impact assessments of oil activities from more or less similar areas. Especially the recent assessment from the Lofoten-Barents Sea area in Norway (Anonymous 2003) has been drawn upon for comparison of potential impacts, because the environment there in a number of respects is comparable to West Greenland waters. Another important source of information is the Arctic Council's working group's (AMAP) Oil and Gas Assessment from 2007/8, which is under publication and is available in part on the AMAP homepage (Link). Also the extensive literature form the Exxon Valdez oil spill in 1989 has been a valuable source of information.

Several studies were initiated to supplement the background knowledge and fill data gaps relevant to this assessment. Some of these are still in progress and only preliminary results have been available for this assessment.

It is important to stress that an SEIA does not replace the need for site-specific Environmental Impact Assessments (EIAs). The SEIA provides an overview of the environment in the licence area and adjacent areas which may potentially be impacted by the activities. It identifies major potential environmental impact associated with expected offshore oil and gas activities. The SEIA will also identify knowledge and data gaps, highlight issues of concern, and make recommendations for mitigation and planning. An SEIA forms part of the basis for relevant authorities' decisions, and may identify general restrictive or mitigative measures and monitoring requirements that must be dealt with by the companies applying for oil licences.

Finally, an important issue in this Arctic context is climate change. This affects both the physical and the biological environment; for example, the ice cover is expected to be reduced, which again will impact the ecology and particularly wildlife dependent on the ice, such as polar bears. Most of the data used for this SEIA has been sampled over a number of decades and as oil activities, particularly development and exploitation, may be initiated more than 10 years from now, environmental conditions may then be very different from the present conditions described in this report.

## 1.1 Coverage of the SEIA

The offshore waters and coastal areas between 68° N to 81° N (from Kangerlussuaq Fjord northwards to Amdrup Land) are the object of focus, as this is the region which potentially can be most affected by hydrocarbon activities, particularly by means of accidental oil spills originating from oil activities in the KANUMAS East area (Figure 1). This area will be referred to as 'the assessment area'. However, the oil spill trajectory models devel-

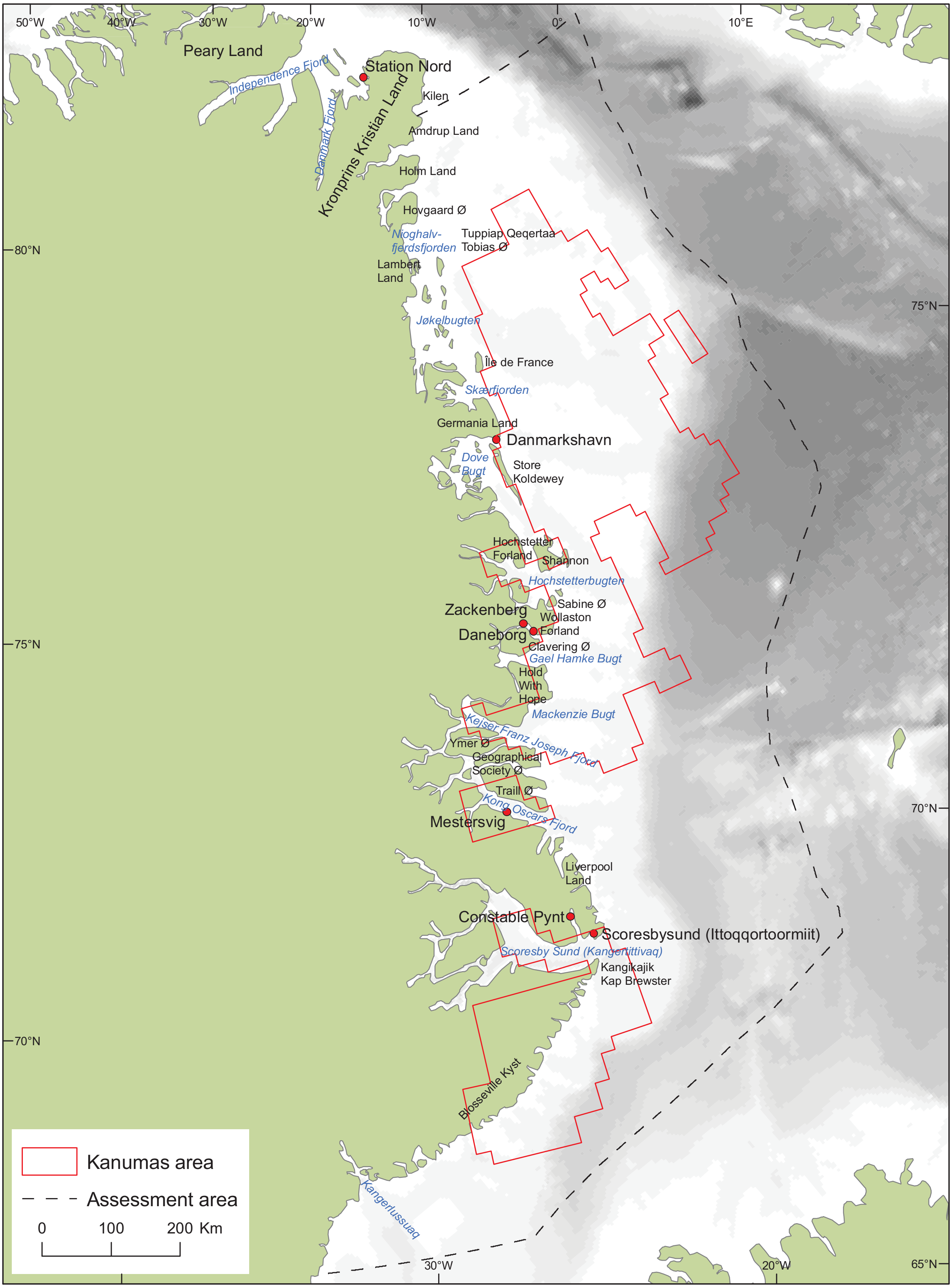



**Figure 1.** The assessment area with the most important place names shown. Red dots indicate inhabited sites: Towns (only one: Scoresbysund), military outposts, weather and research stations etc. See also text.

oped by DMI and SINTEF indicate that oil may drift further, outside the boundaries of this area and into Norwegian and Icelandic EEZs (Nielsen *et al.* 2008, Johansen 2008).

The assessment area extends over waters of the former municipality of Scoresbysund and the National Park of North and Northeast Greenland. There is only one town in the area outside the National Park: Scoresbysund (Ittoqqortormiit) with an airport (Constable Pynt) and few villages / settlements nearby (these are more or less abandoned today), with approx. 500 inhabitants. The National Park is a pristine high arctic environment, almost without anthropogenic impacts. There are a few permanently manned sites: the weather station Danmarkshavn and the military outposts Daneborg and Station Nord. Moreover, there is the old airport at Mestersvig guarded by military personnel and there is a research station at Zackenberg which currently is manned from May to September.

To the south, the assessment area borders the former municipality of Tasiilaq. The inhabited sites here are far from the assessment area, but hunters may occasionally travel as far as the southern part of the Blosseville Kyst. The two East Greenland municipalities are now part of a large municipality covering both the east and the west coast of Greenland: Kommuneqarfik Sermersoq.

## 1.2 Abbreviations and acronyms

BAT = Best Available Technique
bbl = barrel of oil
BEP = Best Environmental Practice
BMP = Bureau of Mineral and Petroleum, Greenland Home Rule Government
BTX = Benzene, Toluene and Xylene components in oil
CI = confidence interval
CRI = Cuttings Re-Injecting
CV = Coefficient of Variance
DMI = Danish Meteorological Institute
DPC = Danish Polar Centre
EEZ = Exclusive Economical Zone
EIA = Environmental Impact Assessment
FPSO = Floating Production, Storage and Offloading unit
GBS = Gravity Based Structure
GEUS = Geological Survey of Denmark and Greenland
GINR = Greenland Institute of Natural Resources
gww = grammes, wet weight
HSE = Health, Safety and Environment
ICES = International Council for the Exploration of the Sea
IWC = International Whaling Commission
LRTAP = Convention on Long-Range Transboundary Air Pollution
MARPOL = International Convention for the Prevention of Pollution from Ships
MIZ = Marginal Ice Zone
NAO = North Atlantic Oscillation
NERI = National Environmental Research Institute, Denmark.
NEW = Northeast Water polynya
OBM = Oil based drilling mud

OSPAR = Oslo-Paris Convention for the protection of the marine environment of the Northeast Atlantic
PAH = Polycyclic Aromatic Hydrocarbons
PLONOR = OSPARs list over substances which Pose Little Or No Risk to the Environment
PNEC = Predicted No Effect Concentration
ppm = parts per million
ppb = parts per billion
PTS = permanent elevation in hearing threshold shift
rms = root mean squared
SBM = Synthetic based drilling mud
SEIA = Strategic Environmental Impact Assessment
TAC = Total Allowable Catch
TPH = Total Petroleum Hydrocarbons
TTS = temporary elevation in hearing threshold
USCG = United States Coast Guard
VEC = Valued Ecosystem Components
VOC = Volatile Organic Compounds
WBM = Water based drilling mud
WSF = Water Soluble Fraction
ww = wet weight

# 2 Summary of petroleum activities

Utilisation of an oil / gas field develops through several phases which to some degree overlap. These include exploration, field development and production, and finally decommissioning. The main activities during exploration are seismic surveys, exploration drilling and well testing. During field development, drilling continues (production wells, injection wells, delineation wells) and production facilities, pipelines and shipment facilities, etc are constructed. Production requires maintenance of equipment and, during decommissioning, structures and facilities are dismantled and removed. These phases occur over long periods of time, usually several decades. For example, in the North Sea, oil exploration started in the 1960s and petroleum activities still continue today.

## 2.1 Seismic surveys

The purpose of seismic surveys is to locate and delimit oil / gas fields, to identify drill sites and later during production to monitor developments in the reservoir. Marine seismic surveys are usually carried out by a ship that tows a sound source and a cable with hydrophones that receive the echoed sound waves from the seabed. The sound source is an array of airguns that generates a powerful pulse at 10-second intervals. Sound absorption generally is much lower in water than in air, causing the strong noise created by seismic surveys to travel very long distances, potentially disturbing marine animals. Regional seismic surveys (2D seismics) are characterised by widely spaced (over many kilometres) survey lines, while the more localised surveys (3D seismics) usually cover small areas with densely spaced lines. Vertical seismic profiles (VSPs) are essentially small-scale seismic surveys carried out during exploration drilling. They are highly localised and of short duration (a few days), and their effects will be covered by the discussion of seismic surveys in general.

## 2.2 Exploration drilling

Exploration drilling follows the seismic surveys. Offshore drilling takes place from drill ships or semi-submersible platforms, both of which have been used in Greenland waters. Most of the potential oil exploration areas in West Greenland waters are too deep for using a third type of drilling platform, the jack-up rigs, which are built to stand on the seabed. It is assumed that the drilling season in the waters of Baffin Bay is limited to summer and autumn by the presence of ice and harsh weather conditions during winter and spring. Drilling requires the disposal of cuttings and drill mud. In the strategic EIA of the Lofoten-Barents Sea area it is assumed that approx. 450 $m^3$ cuttings are produced and approx. 2,000 $m^3$ mud is used per well (Akvaplan-Niva & Acona 2003). Energy consumption is very high during drilling, resulting in emissions of combustion gases such as $CO_2$, $SO_2$ and NOx.

A significant amount of underwater noise can be produced during drilling. This noise has the potential to disturb marine mammals and acoustically sensitive fish (Schick & Urban 2000, Popper *et al.* 2004).

## 2.3 Drilling mud and cuttings

Drilling muds are used to optimise drilling operations. Muds were previously oil-based (OBM), but due to the toxicity, they have now mainly been replaced by water-based muds (WBM) or for drilling under certain difficult conditions by synthetic-based muds (SBM). The drilling results in a mixture of drilling mud fluids and solids, rock fragments (cuttings) and certain chemicals. Cuttings and mud have usually been deposited on the sea floor surrounding drill sites, resulting impacts on the benthic communities.

## 2.4 Other exploration activities

One activity that may have environmental impact during the exploration phase is helicopter transport, which is noisy and can scare birds and marine mammals over a range of many kilometres.

Well testing takes place when a well has been drilled and the presence of hydrocarbons and the potential for production is to be evaluated. The testing activities normally imply the use and release to the sea of different chemicals, occasionally including radioactive compounds.

## 2.5 Development and production

Field development also includes seismic surveys and extensive drilling activities (delineation wells, injection wells, etc) and drilling will take place until the field is fully developed. An oil development feasibility study in the sea west of Disko Island (south of the assessment area) assessed the most likely scenario to be a subsea well and gathering system tied back to a production facility either in shallower water established on a gravity-based structure (GBS) or onshore (APA 2003). From the production facility crude oil subsequently has to be transported by shuttle tankers to a transshipment terminal, most likely in eastern Canada.

Environmental concerns during the development will mainly be related to seismic surveys, to drilling, to the construction of the facilities on the seabed (wells and pipelines) and to discharges to sea and emissions to air. The major discharge to the sea is produced water.

## 2.6 Produced water

Produced water is by far the largest ‘by-product’ of oil production process. On a daily basis some Canadian offshore fields produced between 11,000 and 30,000 $m^3$/day (Fraser *et al.* 2006), and the total amount produced on the Norwegian shelf was 174 millions $m^3$ in 2004 (OLF 2005). Produced water contains small amounts of oil, salts from the reservoir and chemicals added during the production process. Some of these chemicals are acutely toxic or are radioactive, contain heavy metals, have hormone disruptive effects or act as nutrients which influence primary production (Lee *et al.* 2005). Some are persistent and have the potential to bioaccumulate. The produced water moreover contributes to the majority of the oil pollution discharge during normal operation, e.g. in Norway up to 88 %.

Produced water has usually been discharged to the sea after a cleaning process which reduces the amount of oil to levels accepted by the authorities (in the North Sea sector of Norway, for example, 40 mg / l or 30 mg / l as recommended by OSPAR). Discharges of produced water and chemicals to the water column appear to have acute effects on marine life only in the immediate vicinity of the installations due to the dilution effect. But long-term effects of the releases of produced water have not been studied, and several uncertainties have been expressed concerming, for example, the hormone-disrupting alkylphenols and radioactive components with respect to toxic concentration, bioaccumulation, etc (Meier *et al.* 2002, Rye *et al.* 2003, Armsworthy *et al.* 2005).

Due to environmental concerns in the arctic environment, discharges will be further reduced, e.g. by the zero-discharge policy in the Lofoten-Barents Sea area (Anonymous 2003), where produced water will be re-injected except during a 5 % 'off-normal' operation time (Anonymous 2003).

## 2.7 Air emissions

Emissions to the air occur during all phases of petroleum development, including seismic survey and exploration drilling, although the major releases occur during development and production. Emissions to air are mainly combustion gases from the energy producing machinery (for drilling, production, pumping, transport, etc). For example, the drilling of a well may produce 5 million $m^3$ exhaust per day (LGL 2005). But also flaring of gas and trans-shipment of produced oil contribute to emissions. The emissions consist mainly of greenhouse gases ($CO_2$, $CH_4$), NOx, VOC and $SO_2$. The production activities produce large amounts of $CO_2$ in particular and, for example, the emission of $CO_2$ from a large Norwegian field (Statfjord) was more than 1.5 million tonnes in 1999 (STF 2000). Another very active greenhouse gas is methane ($CH_4$), which is released in small amounts together with other VOCs from produced oil during trans-shipment.

## 2.8 Other activities

Ship transport of produced oil will be an integrated part of the production phase. The APA (2003) assessment presents a scenario where ships containing 1 million bbl will depart, within a 5-day cycle, from a highly productive field west of Disko in southern Baffin Bay. Something similar could be expected for the KANUMAS East area.

Decommissioning is initiated when production wells are terminated and will generate large amounts of waste material which have to be disposed of or regenerated.

## 2.9 Accidents

There are serious, acute and long-term environmental concerns in relation to accidents and off-normal operations. As expressed by the recent Oil and Gas Assessment by AMAP (2007). The main issue of environmental concern for the marine arctic environment is a large oil spill, which particularly in ice-covered waters represents a threat to ecological populations and even to species (AMAP 2007).

# 3 Physical environment

This section only gives a short account of some of the most important physical components of the assessment area. Other components will be dealt with in a report by the Danish Meteorological Institute (DMI).

The assessment area lies mainly within the High Arctic climate zone, which means that the average July temperature does not exceed 5° C. It is also far north of the Polar Circle, so continuous daylight is present during summer and there is a period of continuous darkness in the winter.

The most significant feature in the physical marine environment is the presence of icebergs and sea ice throughout the year (section 3.4.4), and permafrost is widespread in the inland areas.

The offshore part of the assessment area is the western part of the Greenland Sea. The bathymetry is generally poorly known, illustrated by the fact that as late as in 1993 a new island was discovered 80 km off the Greenland coast (Bennike *et al.* 2006). The shelf (waters below 200 m depth) has a width of more than 300 km in the northern and central part of the assessment area, and in the southern part it becomes much narrower – down to approx. 80 km. Off the shelf, waters are very deep reaching more than 3,000 m.

## 3.1 Oceanography

### 3.1.1 Currents

The Greenland Sea is important in the global thermohaline circulation as a region where the ocean loses heat to the atmosphere causing a change in the buoyancy of the surface water. As a result, the surface water sinks. The less dense portion of these water masses can flow south and across the Greenland-Scotland Ridge into the North Atlantic, where it contributes considerably to the North Atlantic Deep Water. The importance of this process for the global thermohaline circulation ('the cold heart of the oceans') has drawn a great deal of attention to the Greenland Sea and to the water masses and mechanisms that create the overflow water (Olsen *et al.* 2005 and references therein).

The East Greenland Current (EGC) is the main source of the waters of the Arctic Ocean to the North Atlantic (Figure 2). In the surface layers it transports cold and low salinity Polar Surface Water and sea ice during spring and summer (Rudels *et al.* 2002). A branch of the North Atlantic Current, known as the Irminger Current (IC), turns westward along the west coast of Iceland (Figure 2). Part of the Irminger Current turns southward towards Greenland, flowing parallel to the East Greenland Current down to Cape Farewell, where it joins the East Greenland Current (Figure 2), and flows up the west coast. The East Greenland Current continues southward along the coast of East Greenland and rounds Cape Farewell. In the central part of the Greenland Sea the currents move counter-clockwise in the large Greenland Sea Gyre.

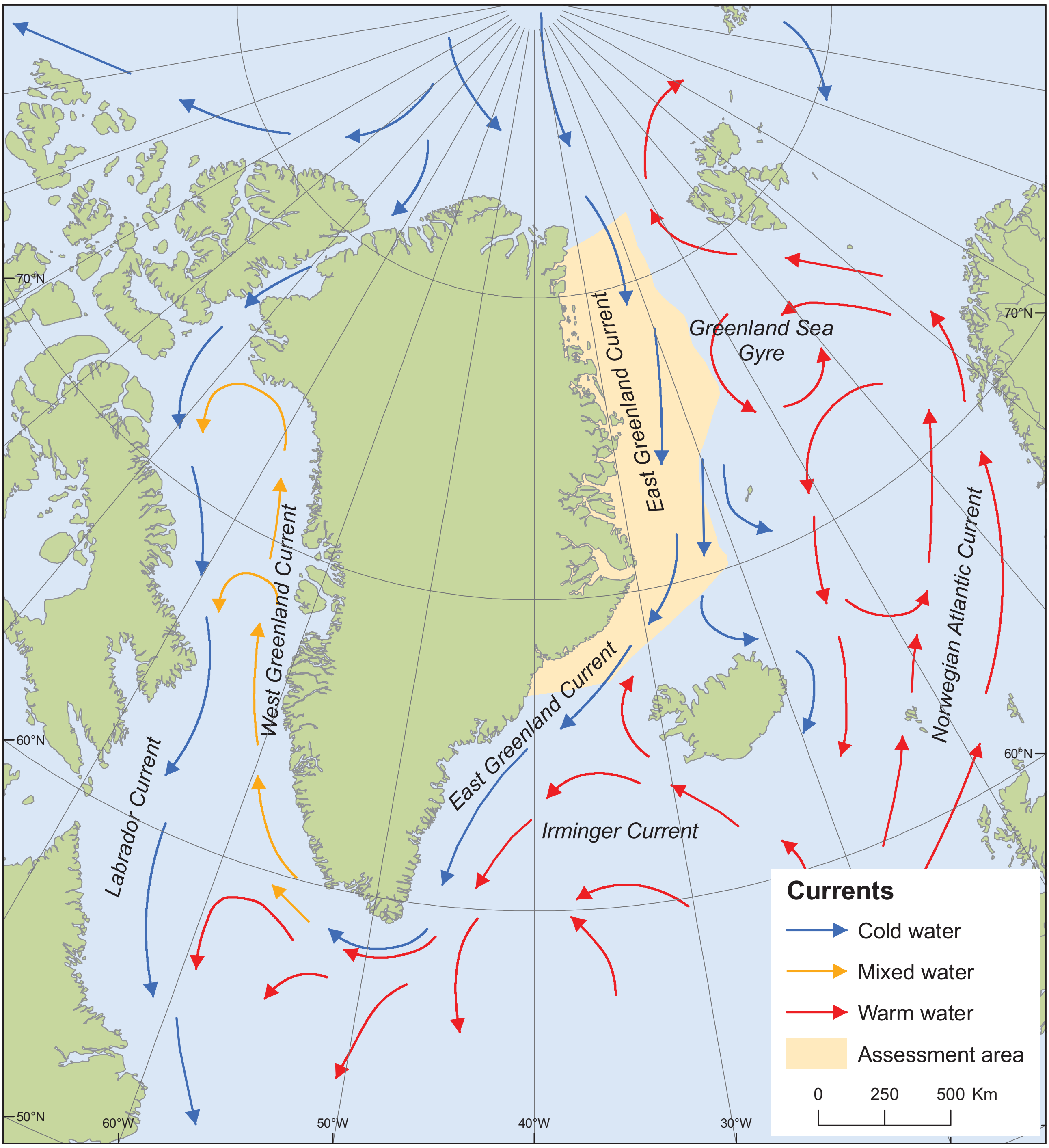
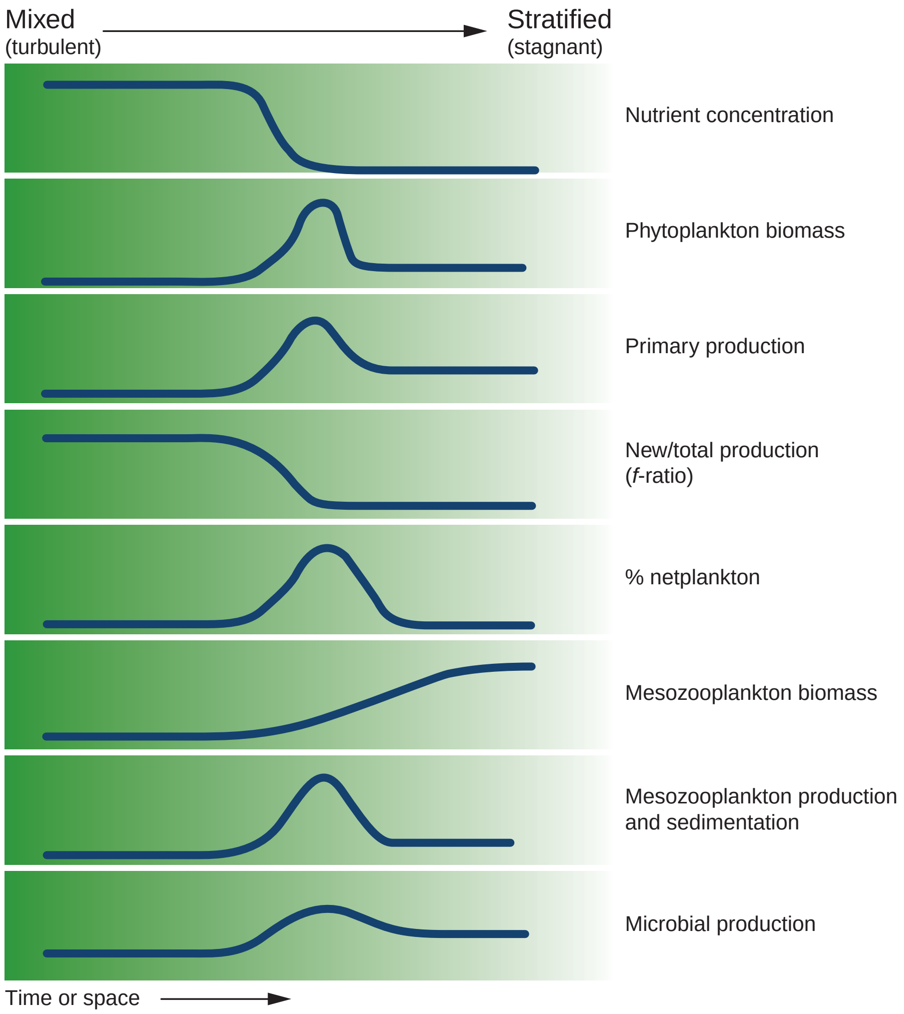



**Figure 2.** Major sea surface currents in the northern Atlantic.

### 3.1.2 Hydrodynamic discontinuities

Hydrodynamic discontinuities are areas where different water masses meet with sharp boundaries and steep gradients between them (Figure 3). They can comprise upwelling events where nutrient-rich water is forced upwards to the upper layers, fronts between different water masses or ice edges (inclusive marginal ice zones). Upwelling occurs often along the steep sides of the banks driven by the tidal current, with upwelling thereby usually alternating with downwelling. Hydrodynamic simulations performed as part of the Disko West assessment programme revealed some significant upwelling areas. It is not known whether such upwelling events occur off East Greenland, but it is likely.

**Figure 3.** Hydrographic discontinuities are often sites of enhanced biological activity. This can be defined in time, e.g. the shift from mixed water in the winter to stratified water in the spring or in space when two water masses meet or at the marginal ice zone where the frontal zone will provide better growth conditions for plankton and the succeeding links in the food web (Legendre & Demers 1984).




## 3.2 The coasts

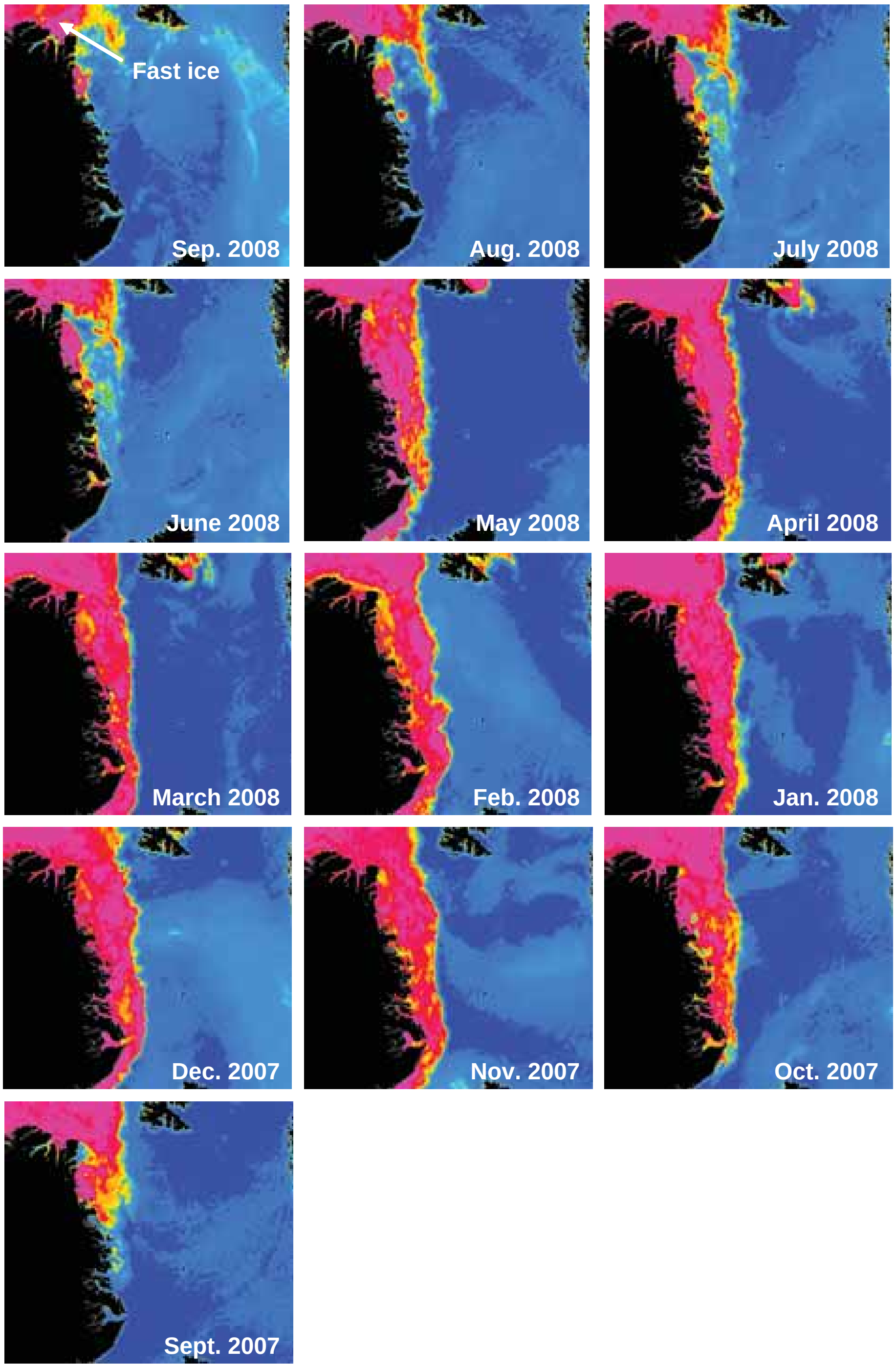
The coasts of the assessment area are very diverse. Rocky shores made up from bedrock, basalts or sedimentary rocks are frequent, but also low shores of loose sediments are widespread. Large glaciers, more or less active (calving), reach the coast at many sites.

There are many fjords penetrating far into the mainland, particularly in the central part. The Scoresby Sund is one of the largest fjord complexes in the world.

## 3.3 Ice conditions

Two types of sea ice occur in the assessment area: fast ice, which is stable and anchored to the coast, and drift ice, which is very dynamic and consists of floes of varying size and degree of density. In addition to sea ice, icebergs originating from calving glaciers are very frequent in some areas. As part of the preparations for oil activities in the assessment area, BMP has initiated a study by DMI which will include descriptions of sea ice distribution, thickness and movements of the drift ice (Hvidegaard *et al*. 2008).

**Figure 4.** Distribution of seaice in the Greenland Sea Sept. 2007 to September 2008. Images based on Multichannel Microwave Radiometer (AMSR and SMMR; (Source DMI). Red and magenta indicate the very dense ice (8-10/10); while yellow indicate somewhat looser ice. The loosest ice (1-3/10) is not recorded. Note the differences between September 2007 and September 2008.




### 3.3.1 The drift ice

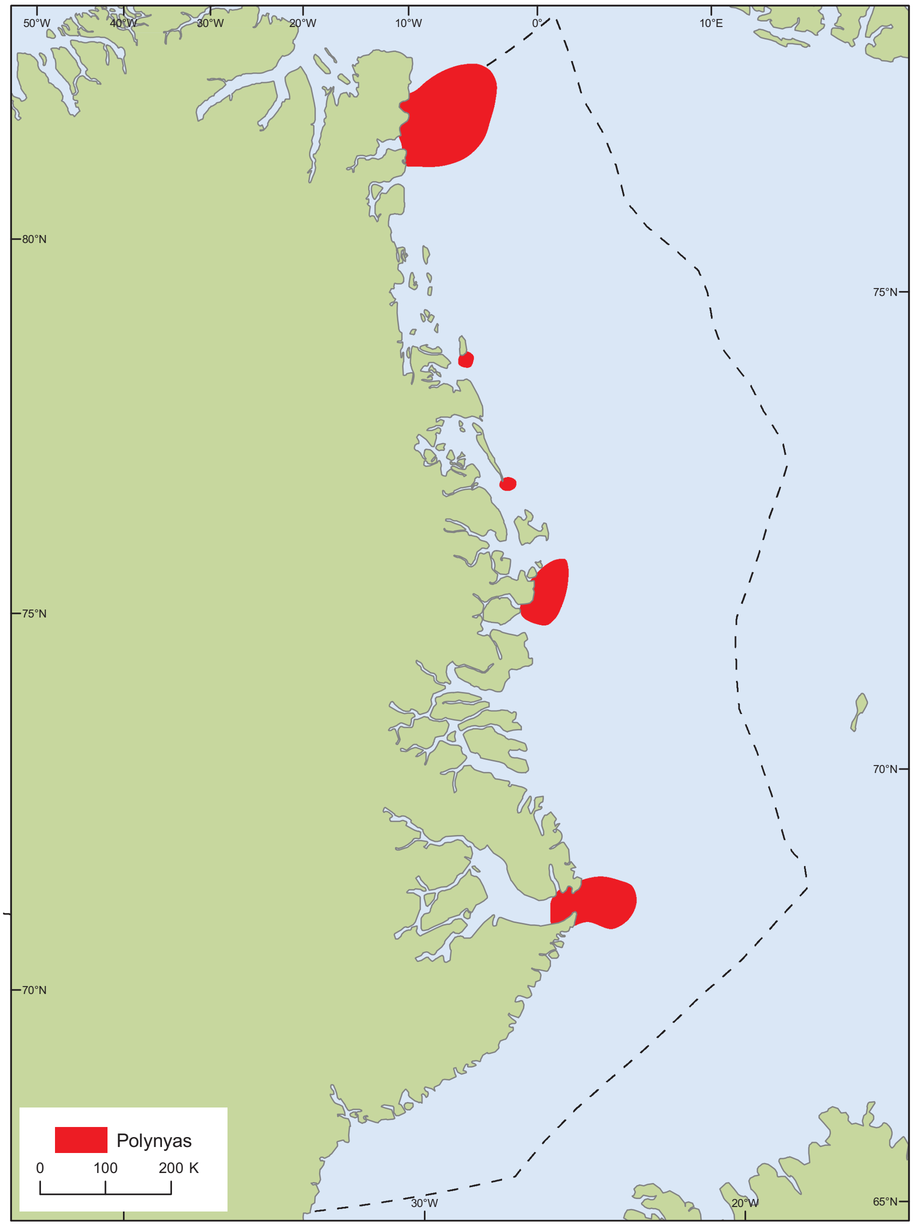
The drift ice is transported by the East Greenland Current along the coast. It is usually very dense and difficult to navigate, except for the summer months August and September. Some of the recent summers although have had very light ice conditions, e.g. 2008 (Figure 4).

The drift ice consists of a mixture of multi-year and first-year ice with scattered icebergs from the glaciers on the coast.

### 3.3.2 The fast ice

The fast ice covers the fjords and a shelf along the outer coast. The fjord ice disappears usually during June and July, and also the ice shelves along the

Figure 5. The most prominent polynyas in the assessment area.




outer coasts melt. However in some areas a stationary or semi-permanent shelf made up from fast ice and consolidated drift ice is present throughout the summer. The most prominent is found between Germania Land and Hovgaard Ø and in July 2008 was 100 km wide. The coastal waters and the fjord to the west of this shelf usually become ice free in summer. The shelf is very obvious in Figure 16. A few fjords are also covered with permanent ice throughout the summer, e.g. Carlsberg Fjord.

### 3.3.3 Polynyas and shear zone

Polynyas are open waters in otherwise ice-covered waters. They are predictable in time and are of a high ecological significance. The most significant polynyas of the assessment area are the North East Water (NEW) off Kronprins Christian Land, the waters off Wollaston Forland and the mouth of the Scoresby Sound. There are also some much smaller polynyas along the coast (Figure 5).

Moreover, a shear zone may occur (with open cracks and leads) between the land-fast ice and the drift ice and this can very well be as important to marine mammals and seabirds as a similar shear zone is in Northwest Greenland, particularly in spring when the populations are migrating northwards. The importance of this shear zone is unknown in the assessment area.

### 3.3.4 Icebergs

Icebergs differ from sea ice in many ways:

– they originate from land
– they produce fresh water on melting
– they are deep-drafted and with appreciable heights above sea level
– they are always considered as an intense local hazard to navigatio and offshore activity

Icebergs from the Northeast Greenland outlet glaciers between 78º 00’ N and 79º 30’ N differ from bergs from other parts of Greenland in that they are larger and basically due to their large horizontal scale compared with their vertical scale. Icebergs from the two major glacial outlets in this particular area, 79-Fjorden Glacier and Zachariae Glacier, are more like Arctic Ocean ice islands. Due to the presence of a semi-permanent or stationary sea-ice cover in the shore region these bergs can be trapped for decades in Jøkelbugten. However, through the summers of 2002 and 2003 the East Greenland sea ice retreated dramatically. The semi-permanent sea-ice cover broke up and many of the trapped bergs began drifting; numerous of them several kilometres wide and in the region of 50 m high.

Icebergs from other glaciers in the assessment area are generally smaller than the icebergs from glaciers in Northwest Greenland.

The general movement of icebergs from the Northeast Greenland glaciers is southwards along the coast, where they are transported by the East Greenland Current.

# 4 Biological environment

## 4.1 Primary productivity

### 4.1.1 General context

From an Arctic perspective, the shelves around Northeast Greenland are 'outflow shelves' (*sensu* Carmack & Wassmann 2006), i.e. regions where the dominant flow is of cold, nutrient-poor water from the Arctic Ocean into the North Atlantic. Such regions are generally less productive than 'inflow shelves' such as the Barents Sea. Furthermore, arctic waters are primarily 'beta oceans' (*sensu* Carmack & Wassmann 2006), where the most important permanent stratification mechanism is a salinity gradient. Beta oceans generally have a brief and intense phytoplankton bloom immediately after ice break-up, characterised by high (transient) biomass and a grazing food web dominated by large copepods, but relatively low total primary production integrated over depth and season. However, this general picture is modified by the presence of large polynyas, where early ice break-up and availability of nutrients lead to locally very high production.

The ice-free period in high arctic areas around Northeast Greenland is generally 2–3 months, but in polynyas may be > 6 months. Large areas off Northeast Greenland are dominated by heavy drift ice throughout most summers. Three sources contribute to total primary production: phytoplankton, ice algae embedded in fast or pack ice, and benthic algae. The relative importance of the three sources is likely to vary geographically with depth and extent of ice cover. In Lancaster Sound in High Arctic Canada, Welch *et al.* (1992) estimated that phytoplankton contributed 90 %, ice algae 10 % and benthic algae 1 % of the total primary production. Similarly, Søreide *et al.* (2006) found that the primary carbon source for pelagic grazers in marginal ice zones of the Barents and Greenland seas was phytoplankton, but that the contribution from ice algae was locally important. Ice algae are also expected to be relatively unimportant producers in polynyas (Michel *et al.* 2002).

In addition to the magnitude of total primary production, it is important to know the proportion of the produced organic carbon that is recycled through the microbial loop, and the proportion available to pelagic consumers that is 'lost' when sinking to the bottom and thus becoming food for benthic fauna (benthic-pelagic coupling). Several studies have attempted to quantify the various pathways of organic carbon through planktonic ecosystems in the Arctic, but general conclusions have been difficult to achieve. This is partly because primary production varies considerably among the different Arctic regions, due to differences in hydrography and thus physical forcing.

The assessment area is highly heterogeneous in terms of ice cover and thus primary productivity. Large parts of the area is dominated by heavy drift ice throughout most summers, leading to low productivity and causing great logistical challenges for scientific studies. Existing studies have thus concentrated on three areas where the open-water season is longer and productivity is higher: the North East Water Polynya in the north of the assessment area, the extensive fjord systems along the Greenland coast, and the marginal ice zone in the Greenland Sea, close to the eastern edge of the assessment area. In the following, we review published studies of primary productivity in the assessment area, and supplement this with a series of maps of satellite-derived estimates of surface chlorophyll concentration.

### 4.1.2 The North East Water Polynya (NEW)

This large (~45,000 $km^2$) and important polynya is very remote and access is difficult, and as a consequence the only major study of physical and biological processes remains the extensive summer cruises in 1992 and 1993 (Hirche & Deming 1997). It is likely that conditions have changed substantially in the last 15 years, due to e.g. decreasing summer ice cover in the Greenland Sea and Fram Strait, but the description here is necessarily based mainly on the 1992/3 studies. The most open part of the polynya, with high primary production dominated by diatoms, was generally located around the northern limit of the assessment area, whereas the southern part was characterised by higher ice cover, no surface stratification, lower primary production and dominance by flagellates, all typical of a non-bloom situation (Pesant *et al.* 1996). Stable isotope analyses indicated that benthic-pelagic coupling in NEW was strong, i.e. that a large fraction of primary production was exported to the benthic community rather than being consumed by pelagic organisms (Hobson *et al.* 1995). However, detailed studies of production and grazing of both large and small phytoplankton indicated that a large part of late-season production was advected out of the polynya *sensu stricto* to neighbouring ice-covered areas, where it subsidised local heterotrophic planktonic and benthic communities (Pesant *et al.* 1998, Pesant *et al.* 2000). Food web dynamics in NEW seem largely to be regulated by advective processes, and horizontal exchanges are important relative to vertical and internal flows. The microbial components form a almost closed loop, recycling dissolved organic matter with little connection to the rest of the food web and weak seasonal variations (Berreville *et al.* 2008). In this regard NEW differs from the North Water Polynya (NOW) off Northwest Greenland, probably due to differences in their seasonal longevity, i.e. the longer-lived NOW polynya having more time to develop complex trophic interactions.

### 4.1.3 Fjord ecosystems in Northeast Greenland

The coastline of the assessment area is highly indented with many large fjord systems. Only one of these has been subject to extensive scientific studies, namely Young Sound (~74° N). Rysgaard & Nielsen (2006) summarise results of detailed studies of most ecosystem components since 1994, and a long-term monitoring programme (MarineBasis) was initiated in 2003 (Rysgaard *et al.* 2007). Primary production in the shallow part of Young Sound was dominated by macrophytes, but also included substantial contributions from benthic microalgae and phytoplankton, whereas production by ice algae was unimportant. Phytoplankton biomass and productivity was similar to other Arctic areas. However, in both shallow and deeper parts of the fjord, total community respiration was substantially higher than local primary production, implying that the heterotrophic community was subsidised by terrestrial runoff as well as advection from the Greenland Sea (Rysgaard & Nielsen 2006).

### 4.1.4 The Greenland Sea and the marginal ice zone

A large part of the assessment area is covered by dense drift ice during most summers, and for logistical reasons very few studies have been conducted here. In contrast the marginal ice zone (MIZ), which is often located close to the eastern edge of the assessment area, is relatively well studied. Gradinger & Baumann (1991) found that phytoplankton biomass was very low and dominated by flagellates in the drift ice, but much higher and dominated by diatoms and the prymnesiophyte *Phaeocystis pouchetii* in the MIZ (*cf.* Hirche *et al.* 1991). Based on several cruises in the open Greenland Sea, Richardson *et al.* (2005) found that primary production peaked in May and was dominated by diatoms, and that flagellates including *Phaeocystis* were more important later in summer. Production was highest, with evidence for recurring blooms throughout the summer along the ice edge, where diatom dominance was also most pronounced. A subsurface peak in phytoplankton biomass was found at most stations. Estimated overall mean production was 81 g C $m^{-2}$ $yr^{-1}$.

### 4.1.5 Satellite-derived maps of estimated surface chlorophyll concentration

In Figure 7 a series of maps are presented showing estimated monthly (April-September from 2003 and 2007) mean surface chlorophyll concentration, based on data from the MODIS Aqua satellite.

Several important caveats apply to these maps. Firstly, the satellite sensor can only detect chlorophyll at the surface, and the resulting images thus only produce reliable indices of total chlorophyll concentration if there is a consistent relationship between surface and total chlorophyll. This is not likely to be the case, and the maps should be interpreted with this in mind. Secondly, there is some uncertainty regarding the scale of conversion of satellite readings to chlorophyll concentrations, so absolute estimated concentrations should not be given much weight. Relative spatial and temporal patterns are likely to be more reliable. Thirdly, although the maps represent monthly means, data are still missing for some areas (shown as white on the maps). White areas may represent, for example, sea-ice areas with too little incident light to give proper readings (mainly in northern areas in September), or areas with very high cloud concentration. In many cases, the ice edge can be reliably detected from these maps, but, for instance, irregular white areas north of Iceland in August-September are more likely to represent extremely high cloud concentration.

Despite the high annual and seasonal variation in ice cover, some spatiotemporal patterns were recurrent between years. For example, surface chlorophyll concentrations tended to be very high in June (in some years including May and / or July) along the ice edge in the eastern part of the assessment area, although actual values varied strongly between years. These high and variable concentrations may represent widespread *Phaeocystis* blooms. Less intensive surface blooms were seen in some years in the fjords, as ice cover breaks up in July-August. In contrast, satellite data consistently showed relatively low levels of surface chlorophyll in the North East Water polynya.

### 4.1.6 Important and critical habitats

The information on primary productivity is generally too sparse to identify localised important and / or critical areas, except for the polynyas.

## 4.2 Zooplankton

### 4.2.1 General considerations

Zooplankton has an important role within marine food webs (Figure 6) since it provides the principal pathway to transfer energy from primary producers (phytoplankton) to consumers at higher trophic levels, such as fish and marine mammals. Zooplankton not only supports the large, highly visible components of the marine food web but also the microbial community (Figure 6). Regeneration of nitrogen through excretion by zooplankton is crucial for bacterial and phytoplankton production. Zooplankton products (faecal pellets) also sustain diverse benthic communities such as sponges, echinoderms, anemones, crabs and fish, when sinking slowly down to the seabed.

In the Arctic, marine zooplankton is not only governed by low temperatures but also by extremes in solar radiation and associated cycles in pelagic primary production. The absence of light during winter and the almost continual presence of light for four months per year have a strong influence on food availability and on the life cycle of Arctic organisms. Specific adaptations are required, such as the capacity to store lipid when food is plentiful and to overwinter on these stores. The ability to synthesise and / or store lipids is a critical aspect in the life cycle, since these depots not only provide energy during starvation in winter but also the materials for egg production and naupliar development (Smith & Schnack-Schiel 1990 and references therein).

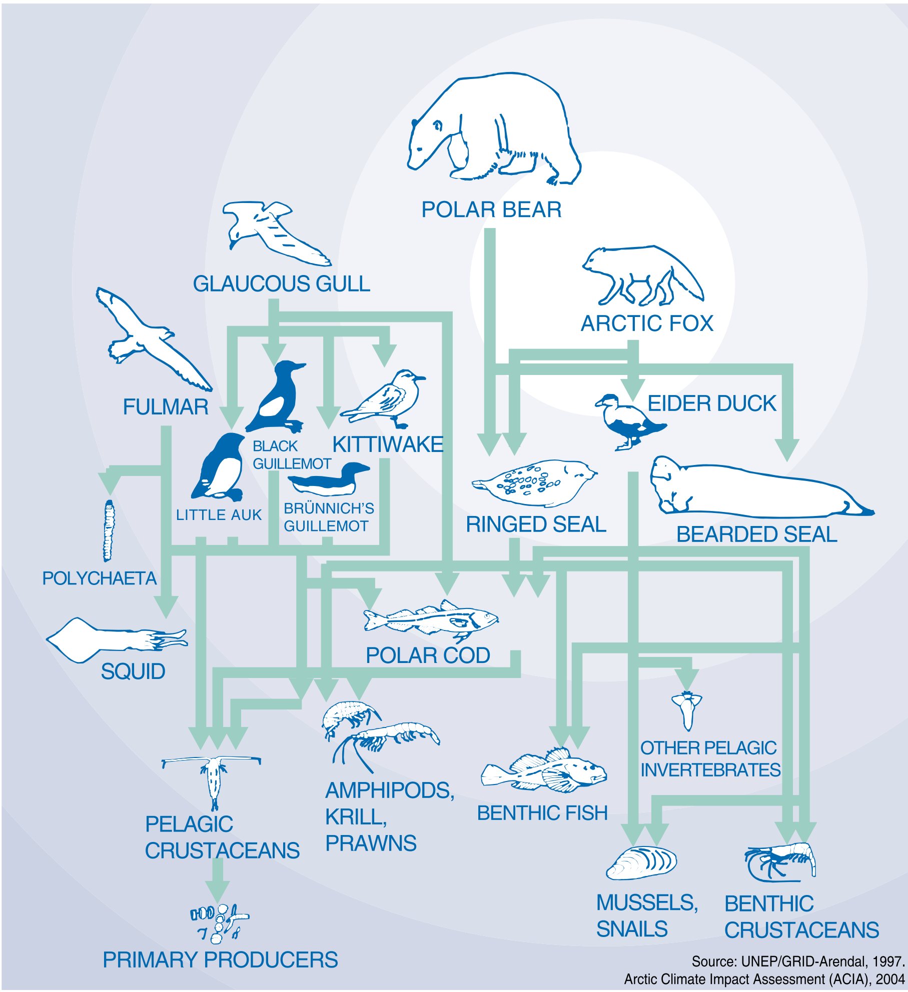



**Figure 6.** A schematic description of the interactions in the marine Arctic environment.

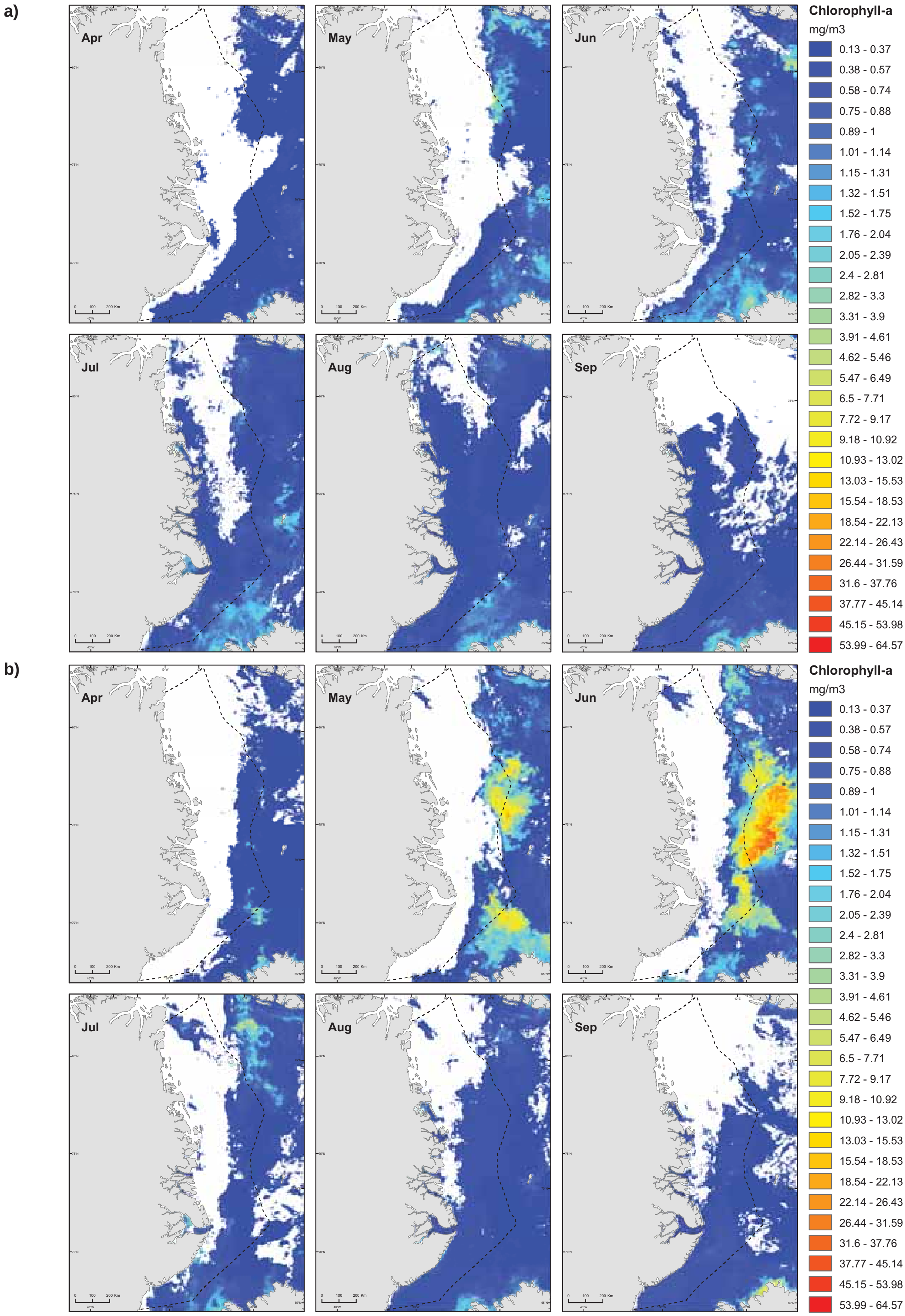



**Figure 7.** Estimated monthly mean surface chlorophyll concentration in the period April–September 2003 (**a**) and 2007 (**b**) in the western Greenland Sea. The maps are based on level 3 data from the MODIS Aqua satellite sensor and downloaded from OceanColorWeb (http://oceancolor.gsfc.nasa.gov). The spatial resolution used was 4 km, and 16-bit satellite readings were converted to chlorophyll concentrations using the equation: Chl (mg/m$^3$) = exp10((0.00005813776*scaledreading)-2). White areas represent lacking data, due to e.g. sea ice, lack of light or high cloud concentration. The dashed line shows the limit of the assessment area.

Earlier studies on the distribution and functional role of meso-plankton in the pelagic food web off Greenland, mainly in relation to fisheries research, have revealed the prominent role of the large copepod, *Calanus*. The species of this genus feed on algae and protozoa in the surface layers and accumulate surplus energy in the form of lipids which are used for over-wintering at depth and to fuel reproduction the following spring. Their life cycles have been estimated to be of 2–4 years (Hopcraft *et al.* 2005).

Meanwhile, general aspects of the life histories of the *Calanus* species are known. Two species, *Calanus hyperboreus* and *Calanus glacialis*, have been characterized as arctic species (Smith & Schnack-Schiel 1990). One of them, *Calanus hyperboreus*, undergoes a 3-year life cycle, reproducing at depth early in the year (November–March). The females release their eggs throughout the winter and some eggs ascend early enough to mature into copepodite (larvae) stage I and exploit the spring bloom and develop into copepodite stages II and III. Larger copepodites (C IV and C V) and females also ascend to feed during spring after overwintering at depth (Tremblay *et al.* 2006). This specific reproduction and overwintering strategy is seen as ecological advantage compared with other copepod species.

The other, *Calanus glacialis*, probably follows a 2-year life cycle, reproducing during spring and summer in the upper water column and using both stored reserves and available food. During overwintering both species utilize lipid reserves stored during the productive summer (Ashjian *et al.* 2003 and references therein). The other main copepod species, *Calanus finmarchicus*, was first characterised as a boreal species but now is generally regarded as a North Atlantic species. The life cycle duration for this species is still debated, but *C. finmarchicus* is known to overwinter in diapause in deep water. This species is imported into the Arctic Ocean by the main inflow of Atlantic water running through the Fram Strait, so its distribution in the Arctic Ocean is associated with the circulation of Atlantic waters. Thus patterns of its dispersal in the Arctic basins should be associated with patterns of flow of Atlantic water into the Arctic Ocean. The other major species, *Metridia longa*, was classified by several authors as an Arctic deep-water species that overwinters as a stage V copepodite and an adult (Smith & Schnack-Schiel 1990, Thibault *et al.* 1999, and references therein).

Vertical distributions of the *Calanus* species are influenced strongly by ontogenetic vertical migrations that occur between the dark winter season and the light summer season when animals move into surface depths. Other smaller species, such as *Oithona similis*, *Pseudocalanus* spp., and *Microcalanus pygmaeus*, are often found in large numbers. They exhibit a shorter generation time and more sustained reproduction, suggesting that their importance in ecosystem productivity could be greater than implied by their biomass alone (Hopcraft *et al.* 2005).

Although copepods are typically predominant in Arctic marine systems, there is a broad assemblage of other holoplanktonic groups and their role has yet not fully been understood. Larvaceans (Appendicularians), for example, have been shown to be abundant in Arctic seas. These soft-bodied filter feeders are capable of much higher ingestion rates, faster growth and reproduction than crustaceans, allowing them to respond more rapidly to shifts in primary production. During times when larvaceans are abundant, the efficiency with which primary production is exported to the benthos may be greatly increased (Hopcraft *et al.* 2005). Other important and common predatory groups are chaetognaths, amphipods, ctenophores and cnidarians. Arctic chaetognaths may represent considerable biomass, have long life cycles (e.g. 2 years) and are thought to be important in controlling *Calanus* populations. Hyperiid amphipods (e.g. the genus *Parathemisto*) can also be common in arctic waters (Mumm 1993, Auel & Werner 2003), with 2- to 3-year life cycles, and a similar potential to graze a notable proportion of the *Calanus* population (Auel & Werner 2003). In turn, seabirds and marine mammals are often feeding on pelagic amphipods. Thus, hyperiid amphipods play a key role in the Arctic pelagic food web as a major link from mesozooplankton secondary production to higher trophic levels such as seabirds and marine mammals (Auel *et al.* 2002). Also euphausiids (krill) can be very numerous and constitute important food for seals, whales and seabirds (Figure 6).

In general, life cycles of Arctic zooplankton are prolonged compared with populations of closely related species at lower latitudes, and often exceed 1 year (Mumm *et al.* 1998). Zooplankton concentrations are often highest in the upper 500 m. However, as described above, especially the predominating *Calanus* species perform extended seasonal migrations from the surface to deeper layers for overwintering (Mumm *et al.* 1998).

Most of the higher trophic levels rely on the lipids accumulated in *Calanus* mainly as wax esters. Those can be transferred through the food web and incorporated directly into the lipids of predators through several trophic levels. For instance, lipids originating from *Calanus* can be found in the blubber of sperm whales who fed on fish and squid (Smith & Schnack-Schiel 1990). Consequently, many biological activities – e.g. spawning and growth of fish – are synchronised with the life cycle of *Calanus*. In larvae of the Greenland halibut (*Reinhardtius hippoglossoides*) and sandeel (*Ammodytes* sp.) from the West Greenland shelf, copepods were the main prey during the main productive season (May, June and July). They constituted between 88 % and 99 % of the ingested prey biomass (Simonsen *et al.* 2006).

The possible linkages between hydrographical processes and plankton variability were studied in the Disko Bay and across important fishing banks off the west coast of Greenland (Munk *et al.* 2003). The relationship between hydrographical characteristics and plankton distribution differed among species and apparently specific plankton communities were established in different areas of the shelf. Ichthyo- and zooplankton communities also differed in the dominance of species with polar versus temperate origin. It was suggested that the flow of major currents and the establishment of hydrographical fronts are of primary importance to the plankton communities in the West Greenland shelf area, influencing the early life of fish. Other studies in the Disko Bay have revealed that with onset of the phytoplankton bloom in spring and appearance of *Calanus* populations, biological production increases in the surface waters (Söderkvist *et al.* 2006). Highest abundance of shrimp and fish larvae was observed in early summer in association with the peak abundance of their plankton prey. Moreover, plankton dynamics and thus shrimp and fish larvae distribution were closely linked with the prevailing hydrography in the area, indicating that the productive cycle is highly pulse-like in nature, which is characteristic for Arctic marine ecosystems.

In connection with hydrodynamic discontinuities, i.e. spring blooms, fronts, upwelling areas or at the marginal ice zone, high biological activity in the surface waters can be expected. In case of massive anthropogenic impacts (such as oils spills) the most severe ecological consequences are to be expected in seasons with high activities of the pelagic food web (i.e. spring and summer). On a horizontal scale the most important areas are the fronts in association with the transition zone between different water masses. Later in the season, when the biological activity is more scattered or concentrated at the pycnocline, ecological damage from an oil spill is assumed to be less severe (Söderkvist *et al.* 2006).

In the assessment area, plankton vulnerability to anthropogenic impacts is also likely to depend on season and on biological activity. However, environmental conditions (e.g. currents, temperature and ice occurrence) are different from those in better studies areas, and therefore the diversity and activity of the pelagic food web, including zooplankton, presumably also differs.

### 4.2.2 Zooplankton in the assessment area

In some coastal areas and fjords, zooplankton structure and distribution has been studied already in the 1930s by Ussing (1938). Later, quantitative measurements of phyto-plankton and zooplankton were made at Scoresby Sound, mostly at Rosenvinge Bay (70° N, 22° 03' E), one or two miles offshore Scoresbysund (Digby 1953 1954). Copepods were numerically the most dominant group. In a more recent study, a very similar copepod community in terms of species composition and biomass was found in Young Sound (Rysgaard *et al.* 2006). In terms of biomass, the standing stock was dominated by the three *Calanus* species, *C. glacialis*, *C. hyperboreus* and *C. finmarchicus* (Rysgaard & Nielsen 2006). Their functional role was revealed by comparing data from studies prior to sea-ice break with those taken during different open-water periods in the summer and in the winter. During sea-ice cover the water column in the outer Young Sound was strongly heterotrophic and sustained by organic material originating from the open sea. During open-water periods, the grazing community was completely dominated by copepods (Nielsen *et al.* 2007).

### 4.2.3 The East Greenland Sea

The main outflow of the Arctic Ocean into the North Atlantic occurs through the Fram Strait and the Greenland Sea. The Greenland Sea consists of different water masses (see also section 3.1.1), with consequences for the plankton community.

The distribution of zooplankton was investigated during summer 1983 in the marginal ice zone of the East Greenland Sea. Nutrient levels, especially inorganic nitrogen, were extremely low, and probably limited the growth of phytoplankton during this period. Generally, zooplankton biomass was similar to other polar regions and species distributions indicate the origin of the two major water masses in this area (Smith *et al.* 1985). Other studies have indicated that the zooplankton community on the East Greenland shelf and slope is composed of Arctic species transported south by the East Greenland Current (EGC), and a variation of Atlantic species injected in the area via the Return Atlantic Current (Hirche *et al.* 1994). Furthermore, it was shown that zooplankton distribution was influenced by the Greenland Sea Gyre (the large gyre in the central Greenland Sea), which also contributes to the existence of the Northeast Water Polynya (NEW).

The temporal and spatial distribution of the main zooplankton communities was analysed showing that *Calanus* spp. dominated the copepod community in all water masses during early summer (Møller *et al.* 2006). Later in the summer, when the majority of the *Calanus* spp. population descended, smaller species such as *Pseudocalanus* spp. took over and kept the copepod biomass high. This trend was particularly pronounced in the Arctic Surface Water. In the same study, the role of the non-*Calanus* components of the zooplankton community was documented. They were responsible for 70–99 % of the total zooplankton grazing on phytoplankton during summer and were crucial to the recycling and respiration of primary production (Møller *et al.* 2006). *Calanus* spp. may, however, also contribute to the vertical export of carbon through their vertical migration and the production of large-sized faecal pellets. With the inclusion of small copepods and protozooplankton, grazing impact on the primary production was clearly higher than for *Calanus* spp. alone (Møller *et al.* 2006 and references therein).

### 4.2.4 Northeast Water Polynya (NEW)

During 1991 and 1993 the Northeast Water Polynya on the northeast Greenland continental shelf and the surrounding ice-covered areas were studied intensively.

Zooplankton biomass in the ice-covered region off Northeast Greenland was dominated by copepods with 84 % biomass of all taxa, followed by chaetognaths (Hirche *et al.* 1997). The large Calanus species, i.e. *Calanus glacialis*, *C. hyperboreus* and *C. finmarchicus* made up to 91 % of the biomass, which was in accordance with earlier investigations in the area (Hirche *et al.* 1994, Hirche *et al.* 1997). These species are commonly associated with Polar Water on Arctic shelves (*C. glacialis*), Arctic Water in the Greenland Sea (*C. hyperboreus*) and Atlantic Water in the North Atlantic Current (*C. finmarchicus*). In the NEW, *C. glacialis* inhabited areas of low current speeds on Belgica and Ob Bank, *C. hyperboreus* dominated shelf slopes and trough stations, while *C. finmarchicus* was most abundant in the Return Atlantic Current along the shelf slope and also at the eastern Belgica Trough (Hirche *et al.* 1997).

However, biomass was low and only 10 % of the phytoplankton carbon was grazed, which was in agreement with earlier studies (Hirche *et al.* 1994). The meso- and macroplankton appeared to be only minor contributors to the overall carbon flow within the NEW polynya system. It was suggested that a large portion of the organic matter is not utilised in the water column, but is exported to the benthos where it supports a rich community. High sedimentation rates in the NEW polynya were reported from Belgica Bank (Piepenburg 1988) and benthic distribution patterns in the NEW usually reflected pelagic regimes (Piepenburg *et al.* 1997). Further evidence for a high benthic biomass is given by the large stocks of benthos-feeding mammals and birds, such as walruses and eider ducks (Hirche *et al.* 1994). Other studies confirmed the low standing stock of mesoplankton in the NEW and it was suggested that this might be a typical feature for this region (Ashjian *et al.* 1997).

The production of copepod eggs and nauplii and the occurrence of polar cod (*Boreogadus saida*) larvae have been seen as an adaptation to match the hatching and first feeding of cod larvae with their main prey. Polar cod spawn under the ice in winter and the buoyant eggs rise to the ice–water interface (Fortier *et al.* 2008). Consistent with this hypothesis, hatching occurs from mid-May to mid-July in the Northeast Water polynya, coinciding with the opening of the polynya and the short season of intense biological production (Fortier *et al.* 2006). In spring, first-feeding larvae (<8 mm long) prey on eggs of large calanoid copepods (16 %) such as *Calanus hyperboreus*, *C. glacialis* and *Metridia longa*, and on nauplii (80 %), primarily *Oithona similis*, *Pseudocalanus* spp. and *Microcalanus pusillus* (Michaud *et al.* 1996).

Matching the first feeding of larvae with the brief maximum production of copepod eggs and nauplii in early summer has been identified as a dominant force constraining the reproduction strategy of polar cod (Fortier *et al.* 2008). However, in August / September, the diet of Arctic seabirds, such as the abundant little auk (*Alle alle*), shifts to polar cod pelagic juveniles. The larger the young polar cod are at the end of the summer, the less vulnerable they appear to be to avian predation in early fall and cannibalism over the winter. In the Northeast Water in 1993, a spring cohort (14 May to 15 June) of larvae was hatched under the ice at sub-zero temperatures and survived poorly (Fortier *et al.* 2006). A summer cohort (21 June to 21 July) was hatched at above-zero temperatures and survived well.

The different studies performed in the Northeast Water and the Greenland Sea clearly indicate the central role of zooplankton in the assessment area and the direct links to hydrography and environmental features.

Climate change is likely to change primary production from strongly pulsed to prolonged production of diatoms (rich in poly-unsaturated fatty acids) with consequences for the higher trophic levels (Kattner *et al.* 2007). Presently, Arctic ecosystems are dominated by diatom feeding *C. glacialis* and *C. hyperboreus*, both are favoured food for specialised Arctic seabirds, such as the little auk (*Alle alle*). A prolonged production period with a mixed diatom-dinoflagellate community will result in a food chain based on *C. finmarchicus – Metridia longa*, leading to minke whales (*Balaenoptera acutorostrata*) via Atlantic herring. In other scenarios more competition is expected between *C. hyperboreus* and *C. glacialis* with *C. finmarchcus*, assuming a more productive ecosystem due to reduced ice cover (Kattner *et al.* 2007).

Arctic plankton is also a conduit for the uptake, processing, and transformation of carbon dioxide. Changes in the amount of carbon that flows and cycles through this food web will change the amount of carbon retained in the ocean or respired back into the atmosphere. These changes may fundamentally alter the structure of Arctic ecosystems, including the assessment area.

### 4.2.5 Important and critical areas

Existing knowledge on zooplankton is not sufficient to designate any important or critical areas within the assessment area, except for the polynyas as such.

## 4.3 Benthos

Benthic macrofauna species are an important component of coastal ecosystems. They consume a significant fraction of the available production and are in turn an important food source for fish, seabirds and mammals.

This is also the case in the Arctic, where approximately 20 % of the world's shelf areas are located (Menard & Smith 1966), and where a high standing stock of benthic macrofauna is found even though input of food is low and highly seasonal. This is possible because large parts of the Arctic consist of relatively shallow shelf areas with tight pelago-benthic coupling.

Furthermore, the low temperature reduces the energy requirements of benthic species, allowing a relatively high biomass to exist despite the low primary production (Sejr & Christensen 2007). In areas with low temperatures and a stable physical environment, benthic species with long life span are favoured, allowing accumulation of a large biomass over decades in spite of low annual production. Food availability is one of the major driving forces influencing biomass and composition of benthic assemblages in the Arctic.

A fundamental conclusion from findings of various benthic surveys conducted in the recent past has been that there is not just one typical Arctic benthos community but a wide variety found in different regions and distinct depth zones. Benthic zonation is often accompanied by an exponential decline in benthic diversity along a shelf-slope-basin gradient (Piepenburg 2005). In addition to depth, additional factors such as sediment heterogeneity, disturbance, food availability, geographical setting, sea-ice cover, particle load from land and hydrographical regime also influence benthic diversity and species composition.

Compared with plankton, which show high spatial and temporal variability in biomass, the macrobenthos are a predictable food source for higher trophic levels such as walrus (Born *et al.* 2003), bearded seal (Hobson *et al.* 2002) and eider (Richman & Lovvorn 2003).

The majority of benthic species have a life span of 5 to 10 years. In Arctic areas, however, the life span of large species such as sea urchins and bivalves may exceed 50 years. Due to the long life span, changes in the benthic community often occur over several years and if the community is disturbed it may take decades for the system to recover.

In areas with low temperatures and a stable physical environment, benthic species with long life span are favoured, allowing accumulation of a large biomass over decades in spite of low annual production. Food availability is one of the major driving forces influencing biomass and composition of benthic assemblages in the Arctic.

### 4.3.1 Benthic fauna and its role in the KANUMAS East area

The Kanumas East area covers a wide range of physical habitats extending from the tidal zone to almost 3,000 m depth. It ranges from the innermost parts of the large fjord systems strongly influenced by glacial run-off to the open ocean.

Primary production in the KANUMAS East area is generally controlled by sea ice that limits light availability. As a consequence annual primary production is low and confined to a short period in summer. Food is an important constraint on benthic growth and reproduction, and patterns of macrobenthic biomass often reflect the variations in primary production in the overlaying water column. For example, benthic biomass is higher underneath polynyas (Piepenburg *et al.* 1997). Another example how food availability governs benthic biomass is the depth zonation found in Young Sound where a high biomass of bivalves is found at a depth of 20 m to 40 m, which corresponds with the depth of the chlorophyll maximum in summer (Sejr & Christensen 2007). In addition to food supply, level of disturbance is also an important factor influencing benthic biomass and distribution. Typical sources of disturbance are sedimentation of inorganic particles either from rivers or glaciers or grounding sea ice. Hence benthic biomass is likely to be lower in the inner parts of the fjords or on shallow banks where larger ice floes ground. Thorson (1933, 1934) reported a benthic biomass in the range 200–500 g per wet weight $m^{-2}$ from East Greenland fjords.

So far, investigations concerning benthic communities, their distribution and functions, have been focused on the Northeast Water Polynya at the northern limit of the assessment area, where multidisciplinary studies including the macrobenthos have been conducted (Piepenburg & Schmid 1996, Weslawski *et al.* 1997). Benthic life has also been studied along the East Greenland continental margin at two down-slope transects at 75° N (200-2700 m depth) and at 79° N (200-2000 m depth) during 1994 / 1995 (Schnack 1998), and in the western Fram Strait (78°-80° N, 4°30'-14° W) in summer 1985 (Piepenburg 1988) (Figure 8 A). In these studies seabed imaging has been applied to describe benthic communities living on the sediment surface (epibenthos; Piepenburg *et al.* 1997). A few studies have also used Agassiz trawls to estimate benthic diversity (Mayer & Piepenburg 1996) and up to 80 species were found (Figure 8 B). These were mainly crustaceans, echinoderms, molluscs and polychaetes and their presence was sediment and depth dependent (Figure 8 C). Multivariate analyses of megabenthic species distribution revealed a distinct depth zonation (Piepenburg *et al.* 1997). Shallow shelf banks (< 150 m), characterised by coarse sediments, numerous stones and boulders as well as by negative bottom-water temperatures, housed a rich epifauna (30 to 340 individuals per $m^2$, Figure 8 B). It was strongly dominated (80 % to 98 % by number) by the brittle stars, *Ophiocten sericeum* and *Ophiura robusta (*Piepenburg *et al.* 1997).

On the East Greenland continental slope at 75° N, a total of 91 different epibenthic species were identified, and up to 50 species at single locations (Figure 8 D). Using classification and ordination analyses, three faunal zones were distinguished which correspond to different depth regions of the continental margin: shelf break (190 to 370 m), upper slope (760 to 800 m) and lower slope (1,400 to 2,800 m), which differed clearly in species composition (Figure 8 E).

The Young Sound in the central part of the assessment area is another region where macrobenthic fauna and other aspects of this ecosystem have been investigated in past years (Rysgaard & Glud 2007). In addition, a long-term marine monitoring program was initiated in Young Sound in 2003. Based on the findings from these studies our current knowledge regarding macrobenthos distribution and role in the ecosystem is summarised below:

In the shallow coastal zone bivalves are a dominant component of the benthos. At depths between 5 and 20 m the genus *Astarte* is often found at abundances of 100–300 individuals per $m^2$. In the tidal zone sea ice often destroys flora and fauna, and the effect of ice can extend down to 5 m. Also in fjords with a large input of freshwater a low saline surface layer can also influence the benthos of the upper 0–5 m. At depths from 10 to 50 m, large

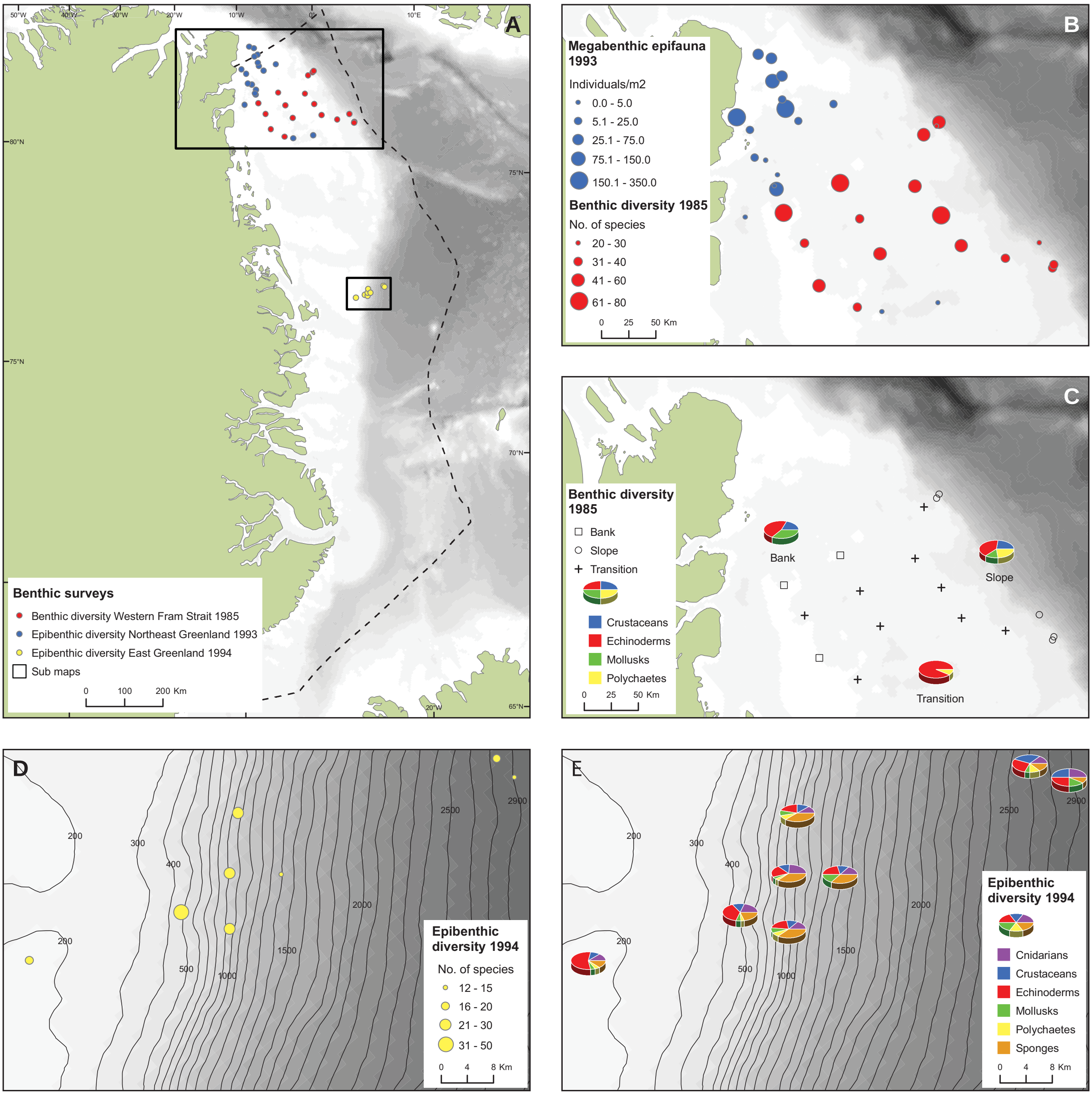



**Figure 8.** Distribution of benthos sampling stations in the assessment area. See text for details.

species such as *Mya truncata*, *Hiatella arctica* and *Serripes groenlandicus* can be found at abundances of 50-100 individuals per m$^{-2}$ (Figure 9). Below 50 m depth total biomass drops significantly and the bivalves are replaced by polychaetes (Sejr *et al.* 2000). As in many other Arctic regions, brittle stars are the most dominant group with a biomass in the range of 400–600 mg C m$^{-2}$ (Piepenburg 2000, Piepenburg & Schmid 1996). Generally, the benthic fauna consists of boreal / Arctic species as well as of those which have been described as being confined to the Arctic proper (Piepenburg & Schmid 1996).

From an ecosystem point of view the benthos is of importance because it harbours a significant fraction of the biodiversity. It is not unusual that up to 200 different macrofauna species are found per m$^2$. Moreover, benthos plays an important role in the food web. It is well established that espe-

**Figure 9.** Photo of the seafloor in Young Sound showing the diverse infaunal and epifaunal community (at approximately 30 m depth).

cially bivalves are an important food source for walruses (Born *et al.* 2003) and eiders (Lovvorn *et al.* 2004). Undoubtedly, the benthos is equally important for bottom-living fish and shrimp but this effect has not yet been thoroughly quantified for the KANUMAS area.

In this respect the coastal region at depths from 0 to approximately 75 m is of particular importance, since this is the region where the benthos can be expected to play a significant role as a source of food for fish, seabirds and mammals. Furthermore, this depth range is most likely to be influenced by potential oil spills. Besides the coastal areas it is also essential to improve the knowledge of benthic life and its dynamics in the deeper areas in relation to release of drill cuttings and mud and to placement of structures.

### 4.3.2 Important and critical areas

The existing knowledge on distribution, diversity and abundance of the benthos in the assessment area is still too sparse to identify especially important and or critical habitats.

## 4.4 Ice fauna and flora

The drifting ice in the assessment area provides habitat for a specialised ecosystem: the sympagic flora and fauna or the epontic ecosystem (Booth 1984). This consists of algae living in or on the ice, of small crustaceans as copepods and amphipods and of two fish species, the polar cod (*Boreogadus saida*) and the Arctic cod (*Arctogadus glacialis*). The distribution and density of the sympagic communities is extremely patchy (Gutt 1995, Camus & Dahle 2007).

Very little is known about the sympagic flora and fauna in the assessment area, and it is not possible to designate important areas. But the system is of high concern in the Barents Sea in relation oil spill and extensive research projects have recently been initiated in Norway (Camus & Dahle 2007).

## 4.5 Fish

The occurrence and abundance of non-commercial fish species in this part of the Arctic has not been studied very much. From the data available so far it appears that fish diversity on the East Greenland shelf is clearly lower than in sub-Arctic or boreal regions. According to Muus (1981) about 26 species can be found on the Northeast Greenland shelf. Most of them belong to the Cottidae, Zoarcidae and Lipariae, which predominantly are benthic living species (Dunbar 1985). They are of minor commercial value but play an important role in the Arctic ecosystem (Atkinson & Percy 1992), being an important food source for many Arctic seabirds and seals (Dorrien 1993 and references therein).

During a cruise of RV 'Polarstern' in summer 1990 (ARK 7/2), the distribution of fish at the continental margins of Northeast Greenland was studied (Figure 10). The region is characterised by the cold East Greenland Current coming from the Arctic Ocean and flowing southerly along the east coast of Greenland. The investigations were focused on the North East Water Polynya, which opens regularly each spring. Using an Agas-

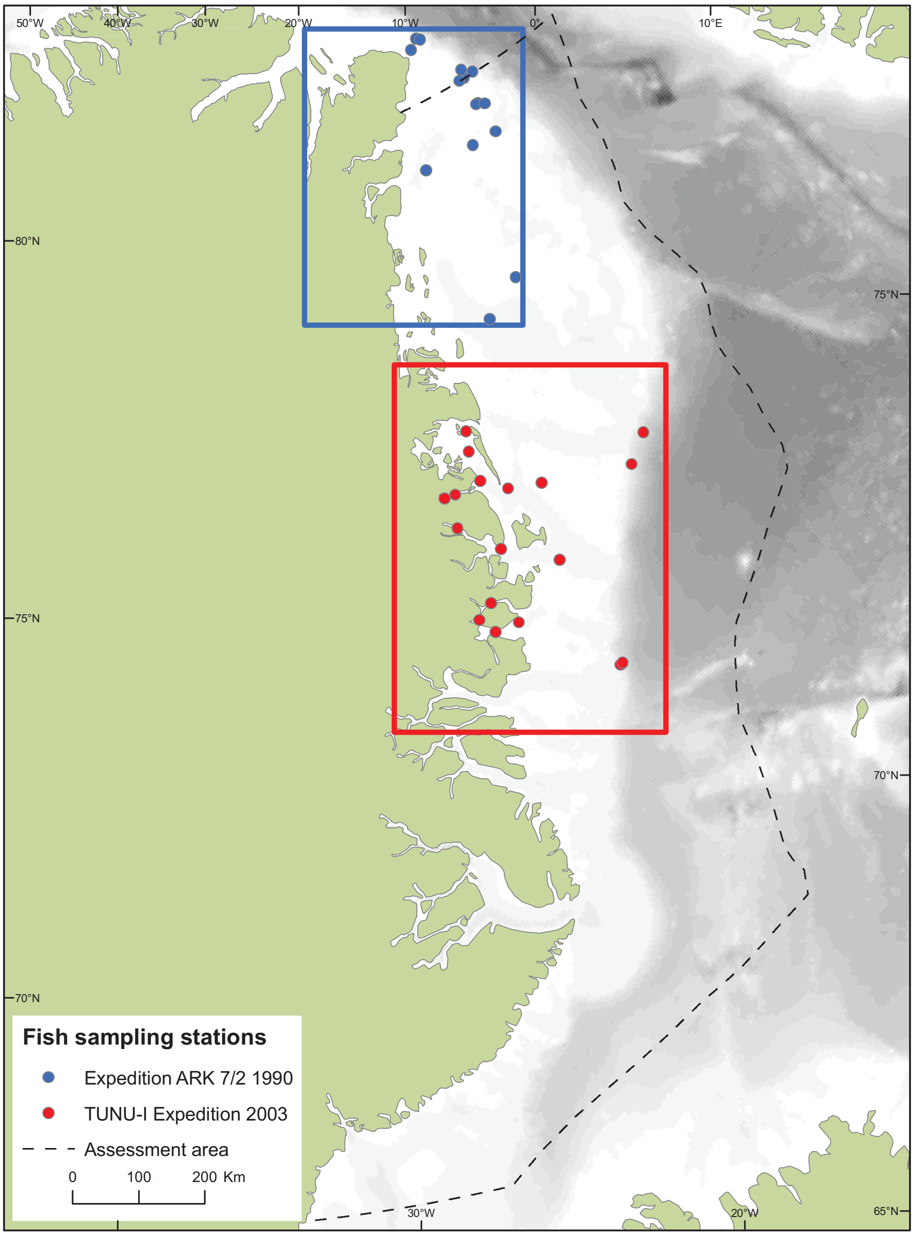



**Figure 10.** Sampling stations during the Polarstern cruise ARK 7/2 in 1990 and during the TUNU-1 cruise in 2003.

siz trawl, a large bottom trawl and an underwater camera, 21 stations off Northeast Greenland (75° to 82° N) were sampled (Dorrien *et al.* 1991).

In total, 23 fish species were found (Figure 11). At most of the sampling sites the following 5 species showed the highest numbers: Arctic cod (*Arctogadus glacialis*) (up to 5,000 indiv. / $km^2$), *Artediellus atlanticus* (up to 45,00 indiv. / $km^2$), *Icelus bicornis* (up to 4,000 indiv. / $km^2$ ), *Triglops nybelini* (up to 2000) and *Liparis fabricii* (up to 4,000 indiv. / $km^2$). The abundance of the other species was usually lower (Dorrien 1993).

Both the Arctic cod or ice cod (*Arctogadus glacialis*) and its near relative the polar cod (*Boreogadus saida*), were present in the polynya (Figure 11). *A. glacialis* was the most abundant fish species in the trawl catches in the northernmost part of the study area, where it probably replaces *B. saida* (Dorrien *et al.* 1991).

In a more recent multidisciplinary study in 2003 (TUNU-MAFIG) diversity of marine fishes in the fjords and coastal waters of Northeast Greenland between Danmarkshavn (77° N) and Eskimonæs (74°) was studied (Figure 10). At each station, species composition and abundance was estimated (Figure 12). In total, 33 species belonging to 13 families were recorded (Christiansen 2003). The most species rich families were the Zoarcidae (8 species), Liparidae (6 species) and Cottidae (5 species), whereas the most frequent species were *Liparis fabricii*, polar cod (*Boreogadus saida*), and Arctic cod (*Arctogadus glacialis*).

About 70 % of the fish species analysed were 'Arctic' or 'mainly Arctic', according to common zoogeographical classification (Karamushko *et al.* 2003). The total number varied between 36 and 10,780 specimens for a standardised one-hour trawl haul (Figure 12). On most stations (excluding those in deeper water), *Boreogadus saida* and *Arctogadus glacialis* were the absolute dominant species (up to 95 % by number and biomass).

There was a clear latitudinal cline with the *A. glacialis* being most abundant at higher latitudes compared with *B. saida*. Generally the two cod species formed the most important part of the Northeast Greenland marine ecosystem (Karamushko *et al.* 2003). These cod species are generally considered as ecological key species due to their abundance and importance as food for seabirds and marine mammals.

Current climatic changes – higher temperatures, less sea ice and increased freshwater discharges into the fjords – may have adverse effects on the physiological performance and thermal behaviour and potentially the distribution range of some of the fish species (Christiansen *et al.* 1997, Clarke 2003), but may favour others.

Only two species of fish have been exploited commercially in the assessment area, and only in the southernmost part.

### 4.5.1 Important fish species

**Greenland halibut *Reinhardtius hippoglossoides***
The Greenland halibut is a sub-Arctic or Arctic species. Although it is a flatfish, it lives and feeds mainly pelagically, typically in deep water along continental slopes. It is often found in the vertical, transitional layers between warmer and colder water masses at temperatures of 1-2° C (Alton *et*

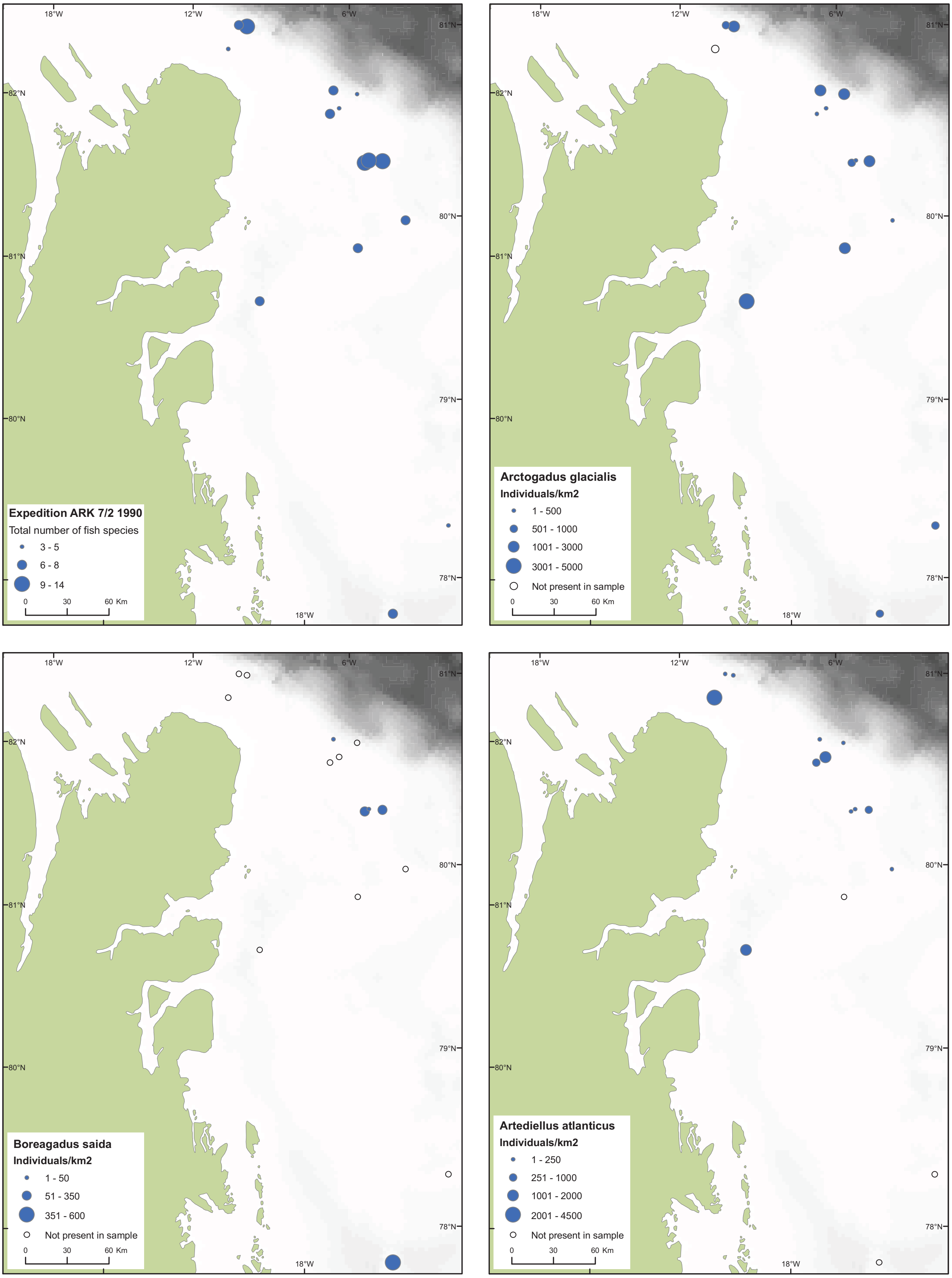



**Figure 11A.** Occurrence of some abundant species in the northern part of the assessment area in 1990 (Dorrien 1993). Dots represent sampling stations.

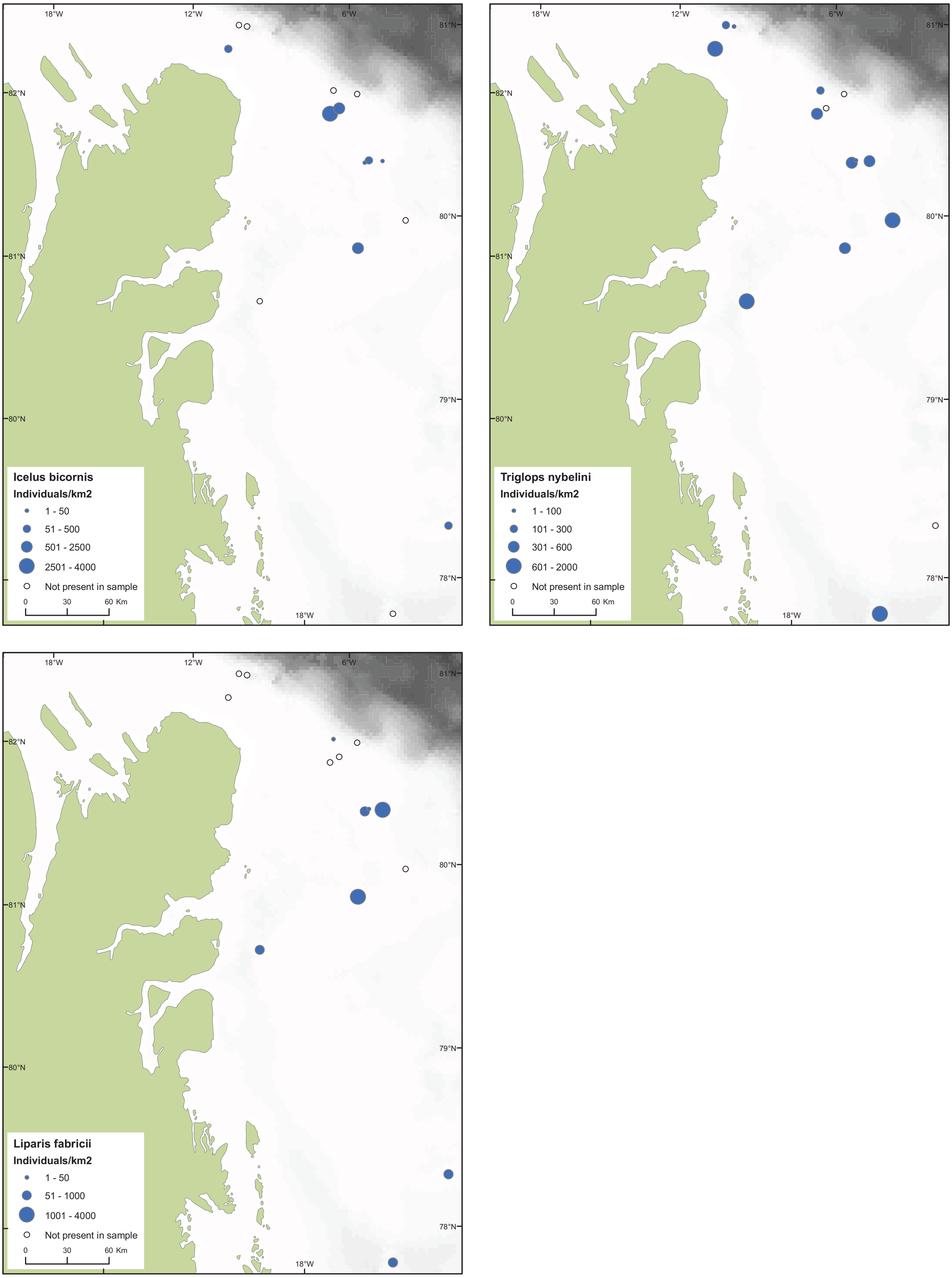



**Figure 11B.** Occurrence of some abundant species in the northern part of the assessment area in 1990 (Dorrien 1993). Dots represent sampling stations.

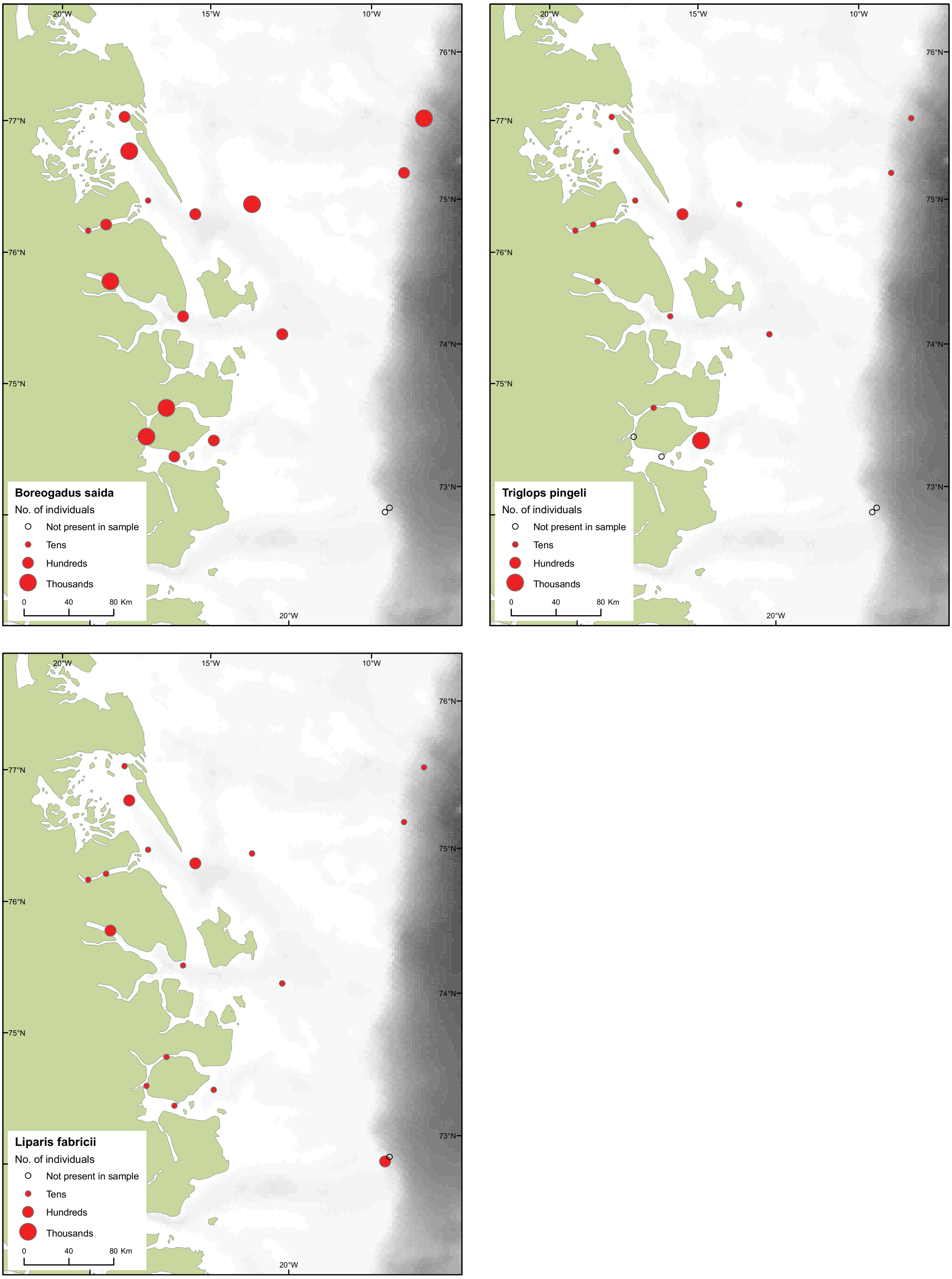



**Figure 12A.** Occurrence of the most abundant fish species during the TUNU-I Expedition 2003 (Christiansen 2003). Dots represent sampling stations.

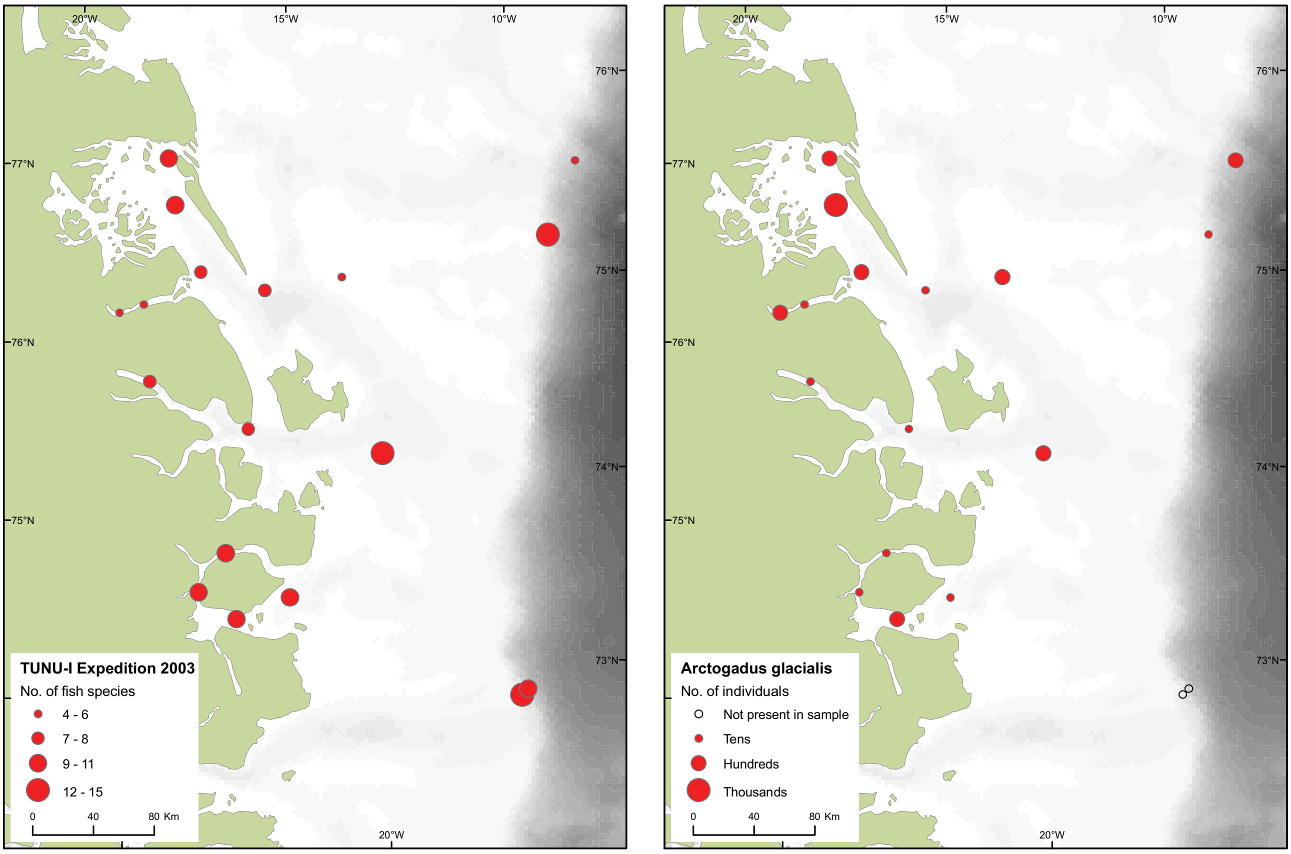



**Figure 12B.** Occurrence of the most abundant fish species during the TUNU-I Expedition 2003 (Christiansen 2003). Dots represent sampling stations.

*al.* 1988, Godø & Haug 1989, Bowering & Brodie 1995). Greenland halibut spawns a large number of pelagic eggs in winter. The eggs have a long maturation period, and they and the larvae when they hatch drift with the currents to nursery areas.

Greenland halibut occurs in the assessment area (see section on commercial fisheries), but the biology of these fish is unknown. They probably belong to the Iceland / Greenland stock also found further south in the Denmark Strait.

In 2006 a bottom trawl survey covered the offshore area from 67° to 72° N and the outer part of Scoresby Sound fjord at depths down to 1,500 m (Jørgensen *et al.* 2007). Greenland halibut was caught in the entire area, although catches were generally low. The species was almost absent in areas with bottom temperatures below zero, mainly found in the eastern part of the survey area. In 1988 in the same offshore area a joint Japan / Greenland survey also caught Greenland halibut in most of the area. The catches were generally small except a few large catches in the southern part of the area. (Jørgensen & Akimoto 1989).

Results from other recent biological surveys indicate that no other species than Greenland halibut are of commercial interest. However, predicted climatic changes with higher temperature, less sea ice and an increase in freshwater discharges into the fjords will probably lead to a change in the ecosystem favouring species of more commercial interest.

### Polar cod *Boreogadus saida*

Polar cod is a pelagic or semi-pelagic species with a circumpolar distribution in cold Arctic waters. It may form large aggregations and schools in some areas, often in the deeper part of the water column or close to the bottom in shelf waters. It occurs also in coastal waters and is often associated with sea ice where it may seek shelter in crevices and holes in the ice.

Polar cod spawn fairly large eggs in ice-covered waters in winter (November-February). The eggs float under the ice during a long incubation period. The larvae hatch in late spring when the ice starts to melt and the seasonal plankton production resumes. Most polar cod live to spawn only once (Cohen *et al.* 1990).

Polar cod is largely a zooplankton-feeder eating copepods and pelagic amphipods (Panasenko & Sobolova 1980, Ajiad & Gjøsæter 1990). As they grow larger they also take small fish. In coastal waters they feed on epibenthic mysids (Cohen *et al.* 1990) and in the ice they take ice-associated amphipods (Hop *et al.* 2000).

Polar cod play a very important role in the Arctic marine food web and constitute an important prey for many marine mammals and seabird species, notably ringed seal, harp seal, thick-billed murre, northern fulmar, black-legged kittiwake and ivory and Ross's gulls.

### Capelin *Mallotus villosus*

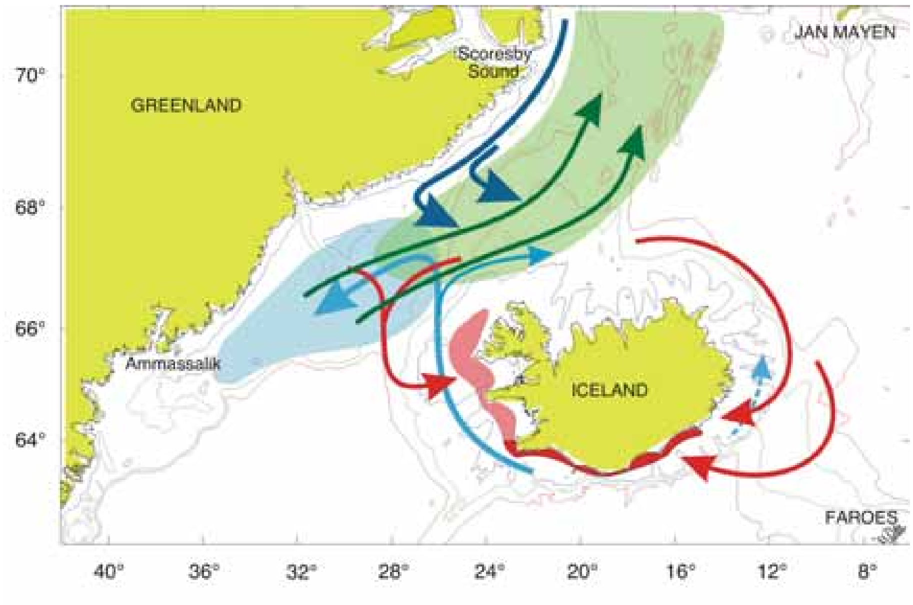
The capelin is a small pelagic schooling fish. It is a cold-water species that occurs widely in the northern hemisphere. The capelin in the Iceland-East Greenland-Jan Mayen area is considered to be a separate stock. Unlike other commercial stocks, adult capelin undertake extensive feeding migrations north into the cold waters of the Denmark Strait and Iceland Sea during summer. Total annual catch from this stock has decreased in recent years from 1,600,000 tonnes in 1996 / 1997 to 200,000 tonnes in 2007 / 2008. Capelin is a very important forage species for several commercial fish, as well as whale and seabird species where they occur.

Around the mid-1990s a rise in both temperature and salinity was observed in the Atlantic water south and west of Iceland. In the same period capelin shifted both their larval drift and nursing areas far to the west to the colder waters off East Greenland, the arrival of adults on the wintering grounds on the outer shelf off North Iceland was delayed, and migration routes to the spawning grounds off south and west Iceland became located farther offshore from North and East Iceland and do not reach as far west along the south coast as was the rule in most earlier years (Figure 13).

### Arctic char *Salvelinus alpinus*

Arctic char is the most northern ranging freshwater fish and it is found throughout the circumpolar region. It is widespread in Greenland including in the most northern areas (Muus 1990). Arctic char occur in different life history types. Resident populations live their whole lives in lakes and rivers, while anadromous populations migrate to the sea during summer to feed and move back to rivers and lakes in the autumn to spawn and winter. Migratory Arctic char constitute an important resource for local consumption and play a significant role in the nutrition of the human population of Greenland (Riget & Böcher 1998).

**Figure 13.** Likely distribution and migration routes of capelin in the Iceland/Greenland/Jan Mayen area in the last 3-4 years. Green: Feeding area; Light blue: Area for juveniles; Red: Main spawning grounds; Lighter red colour: Lesser important W-Iceland spawning areas; Light blue arrows: Larval drift; Dark green arrows: Feeding migrations; Dark blue arrows: Return migrations; Red arrows: Spawning migrations. Depth contours are 200, 500 and 1000 m (ICES 2008).



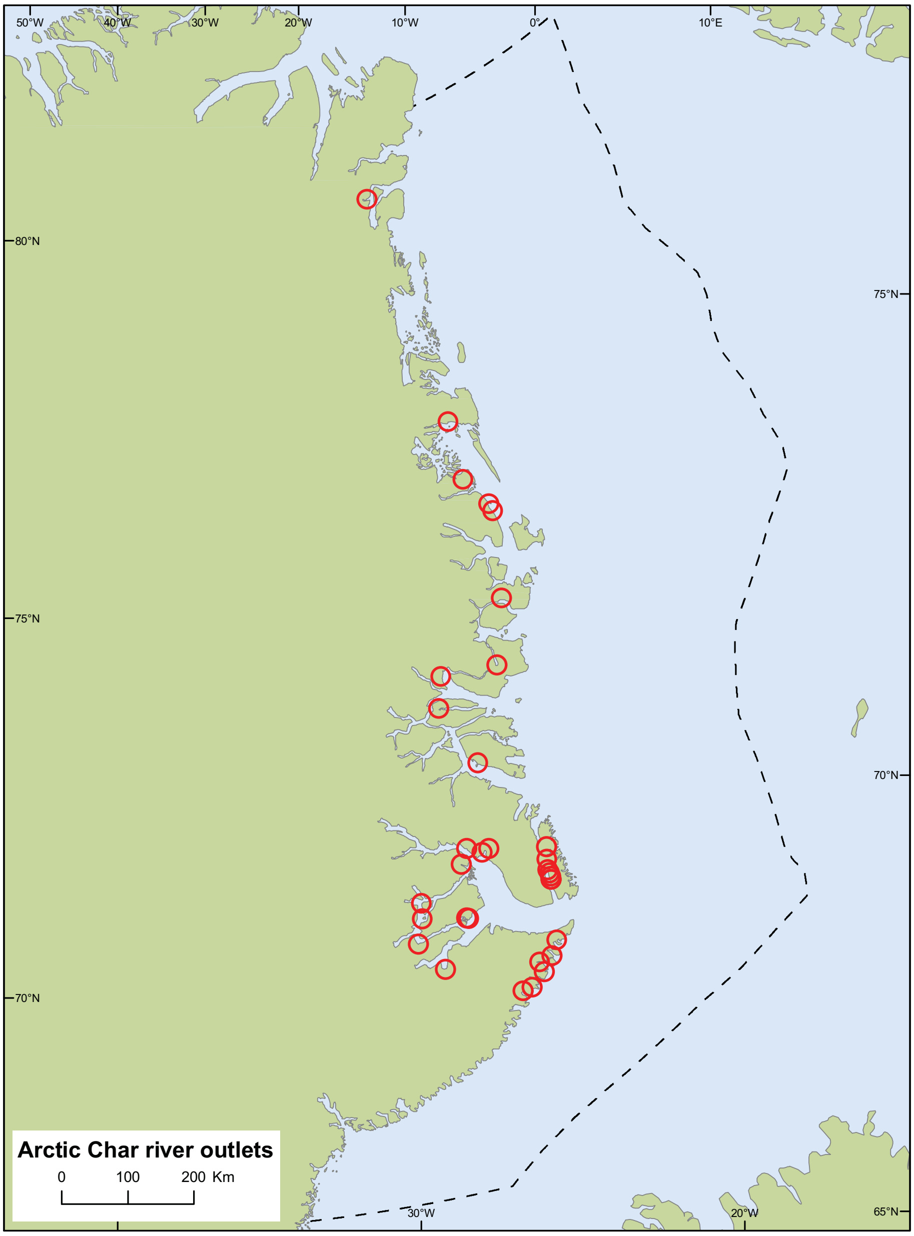

To follow is a short description of the life history of the anadromous population. Life history characteristics such as growth rate, age of first seaward migration, age of maturity, and time of year for seaward and upstream migration vary considerably due to the extensive distribution of this population. In general, it must be expected that higher latitudes with a shorter growing season, lower temperatures and variability in food resources will result in a slower growth rate and later maturity than at lower latitudes (Malmquist 2004).

The eggs of the char winter in gravel in deep river pools or in lakes. The fry emerge in April–May and live off their yolk sac for about a month before feeding on small plankton organisms along the margins of rivers or lakes (Muus 1990). The young char called 'parr' remain in freshwater for several years before their first migration to the sea. At length 12–15 cm, corresponding to an age of 3 to 6 years depending on growth conditions, they begin their annual migration to the sea (Riget & Böcher 1998). The young char undergo morphological and physiological changes that make them able to live in saltwater. The seaward migration generally coincides with the spring freshet, which occurs in May-June, depending on the latitude. After their first seaward migration, the char return to rivers and lakes to winter and spawn. The anadromous char mature at a size of 35–40 cm (Muus 1990), corresponding to an age of 5–7 years.

At sea, Arctic char mainly stay in coastal areas, not far (approximately up to 25 km) from the river they derived from (Muus 1990). Tagging experiments carried out in Southwest Greenland showed that only few char were recaptured more than 50 km from the tagging location (Nielsen 1961). However, there are examples of tagged fish movements over considerably longer distances (up to 300 km) along the coasts of Alaska (Furness 1975). Both tagging experiments mentioned above showed that char populations from different rivers mix largely at sea.

At sea, the char feed intensively on small fish, fish larvae, zooplankton and crustaceans. In a study carried out in Young Sound, East Greenland the most important food items were amphipods and mysids (50 %) followed by fish and fish larvae (20 %) and copepods (11 %) (Rysgaard *et*

**Figure 14.** Outlets of rivers where anadromous Arctic char spawn and winter (red circles). There are probably much more in the assessment area, but no comprehensive reviews have been published. (Sources: Grønlands Fiskeri- og Miljøundersøgelser 1986, Sandell & Sandell 1991, Petersen 1993, Mikkelsen 1994, Rysgaard *et al*. 1998, Aastrup *et al*. 2005, NERI unpubl.).




*al.* 1998). Most of the growth of Arctic char takes place during their stay in the sea, and the growth rate is also considerably faster than for lake resident populations. Investigations carried out in a river in Southwest Greenland showed that the annual growth rate for the resident river part of the population was only a couple of centimetres, while the anadromous part of the population showed a 5 cm annual growth (Grønlands Fiskeri-undersøgelser 1982).

Both spawners and non-spawners migrate back to the rivers and lakes in June–September to winter in freshwater after having spent 2–4 months at sea. Based on results from tagging experiments it appears that spawning char seek to their natal spawning rives while non-spawning char may wander into non-natal river systems (Craig & McCart 1976). Mature and large char move back into streams before the smaller juvenile fish (Craig & McCart 1976). During their stay in freshwater they probably do not feed or only feed little.

**Critical habitats**
In an oil spill context the river mouths and their adjacent coastal areas, where migrating char assemble before they move upstream, are the most sensitive habitats. The published knowledge on these sites in the assessment area is fragmentary, and there is no doubt many more sites than shown on the map (Figure 14).

## 4.6 Seabirds

Seabirds locally and in ice-free areas are very numerous in the assessment area and constitute an important link between the productive marine ecosystem and the relatively low productive terrestrial ecosystem, as they transport nutrients from the sea to the breeding colonies in land. About 13 species breed within the assessment area, and some of these occur in very high concentrations or are rare and threatened. The occurrence of the seabirds is governed by the presence of sea ice, which is why they are scarce in large regions in summer and almost absent in winter but, on the other hand, very numerous in areas with predictable open waters in spring and summer. However, lack of data also characterise the distribution maps shown in Figures 15, as large regions have not been surveyed for breeding seabirds.

Knowledge on birds associated with the marine environment varies between regions. Some coastal areas are well known from the reports of natural history expeditions since the late 19th century (Bay 1894, Manniche 1910, Degerbøl & Møhl-Hansen 1935, Pedersen 1926, 1930, 1934, 1942, Meltofte *et al.* 1981b, Hjort 1976b, Hjort *et al.* 1983, Elander & Blomqvist 1986, etc, Gilg 2005) and from work carried out by local residents (Meltofte 1975, 1976, Forchhammer 1990, Forchhammer & Maagaard 1990 etc), while other areas, e.g. the Blosseville Coast, are almost unknown from an ornithological point of view. The offshore areas are much less well known than the coastal areas. Norwegians have studied the waters between Svalbard and Greenland (Mehlum 1989) in summer, and in the early 1990s extensive studies were carried out in the Northeast Water Polynya, including bird studies (Falk & Møller 1995, 1997, Falk *et al.* 1997). However, reports from the migration periods and the winter are very few (e.g. Hjort 1976, Brown 1984, Petersen 1995). To supplement these published data NERI and GINR conducted aerial surveys along the coasts and in offshore areas in spring and summer 2008 and have worked up unpublished observation from some seismic data acquisition surveys in 1994, 1995, 2006 and 2007 (Figure 16).

Most of the breeding seabirds are colonial breeders and these constitute 12 species in the assessment area. The largest concentrations of breeding colonial seabirds are found on the coasts of the Scoresby Sound polynya, where an estimated 3.5 million little auks breed in a large number of colonies (Figure 15). This area also holds the only breeding sites for thick-billed murre (Figure 15). The second most important polynya, in a seabird context, the Northeast Water in the northern part of the assessment area also holds significant seabird breeding colonies, mainly northern fulmars and common eiders but also important and rare species such as ivory gull and Ross's gull. A third important polynya is the waters east of Wollaston Forland where large numbers particularly of eider occur.

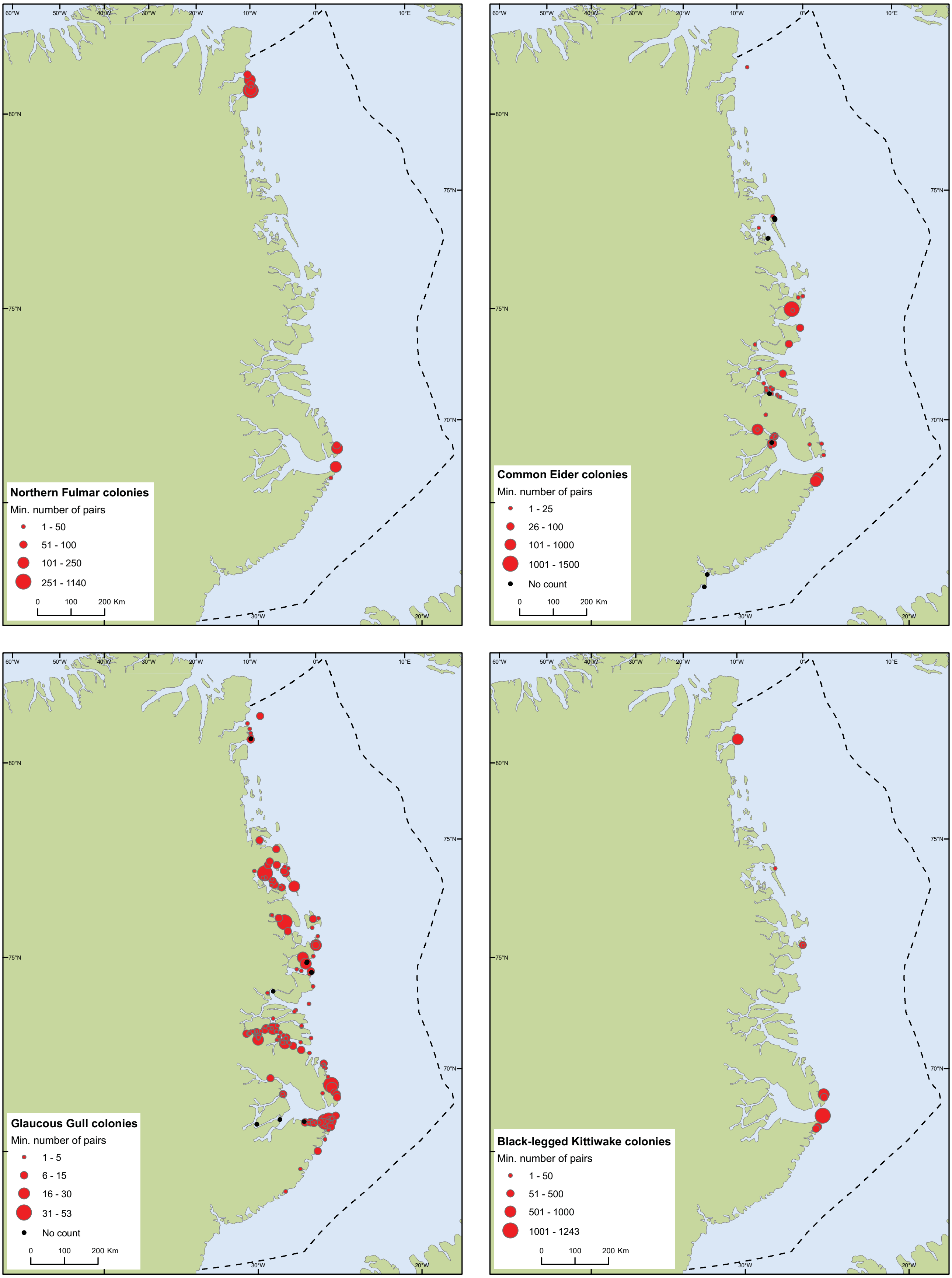



**Figure 15A.** Distribution and size of breeding colonies for seabirds in the assessment area. Large areas are not surveyed properly, and many of the known colonies have not been counted precisely. This is for example the case for all the little auk colonies in and near the entrance to Scoresby Sound. These colonies account for at least 3.5 million pairs in total.

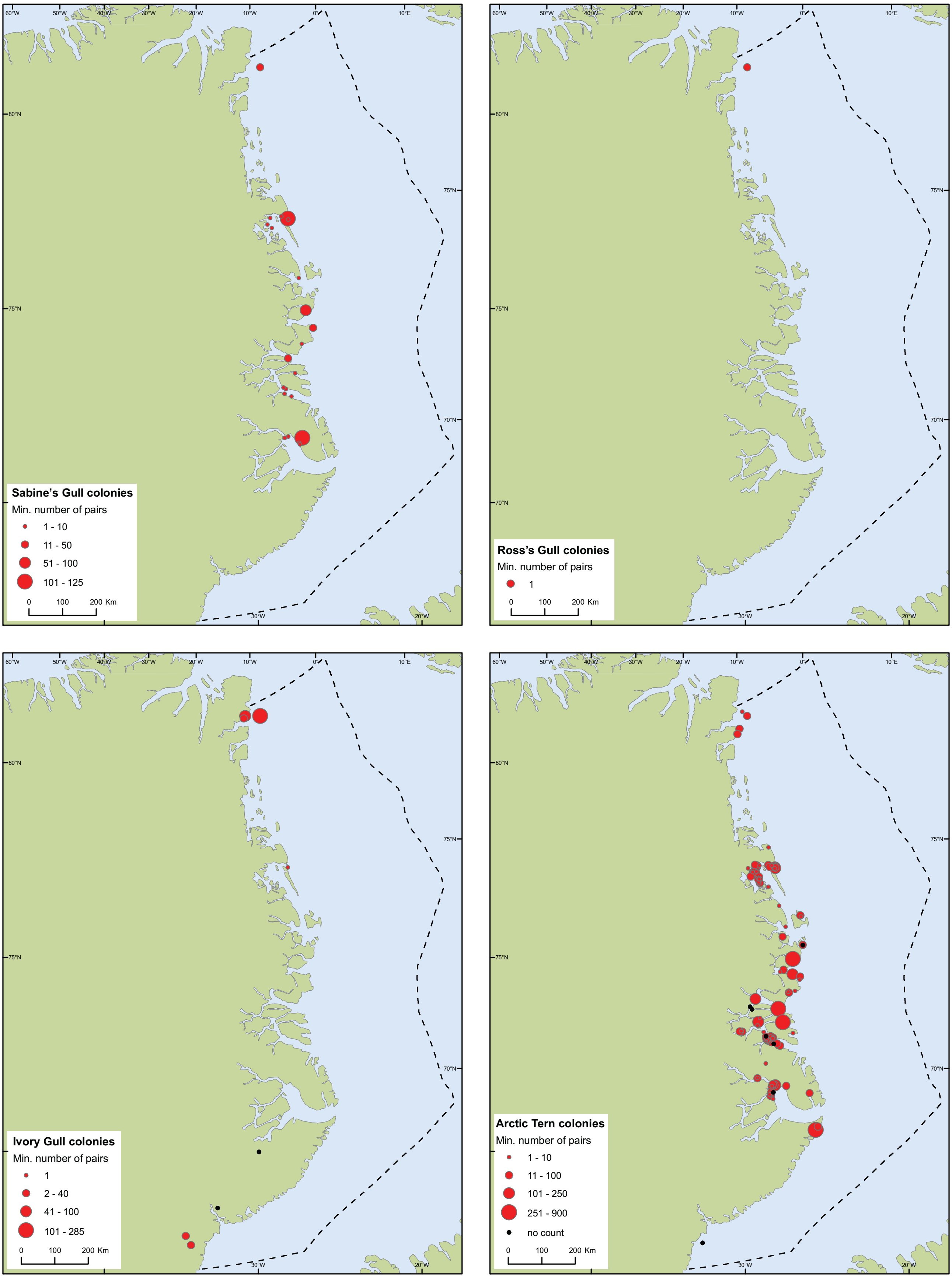



**Figure 15B.** Distribution and size of breeding colonies for seabirds in the assessment area. Large areas are not surveyed properly, and many of the known colonies have not been counted precisely. This is for example the case for all the little auk colonies in and near the entrance to Scoresby Sound. These colonies account for at least 3.5 million pairs in total.

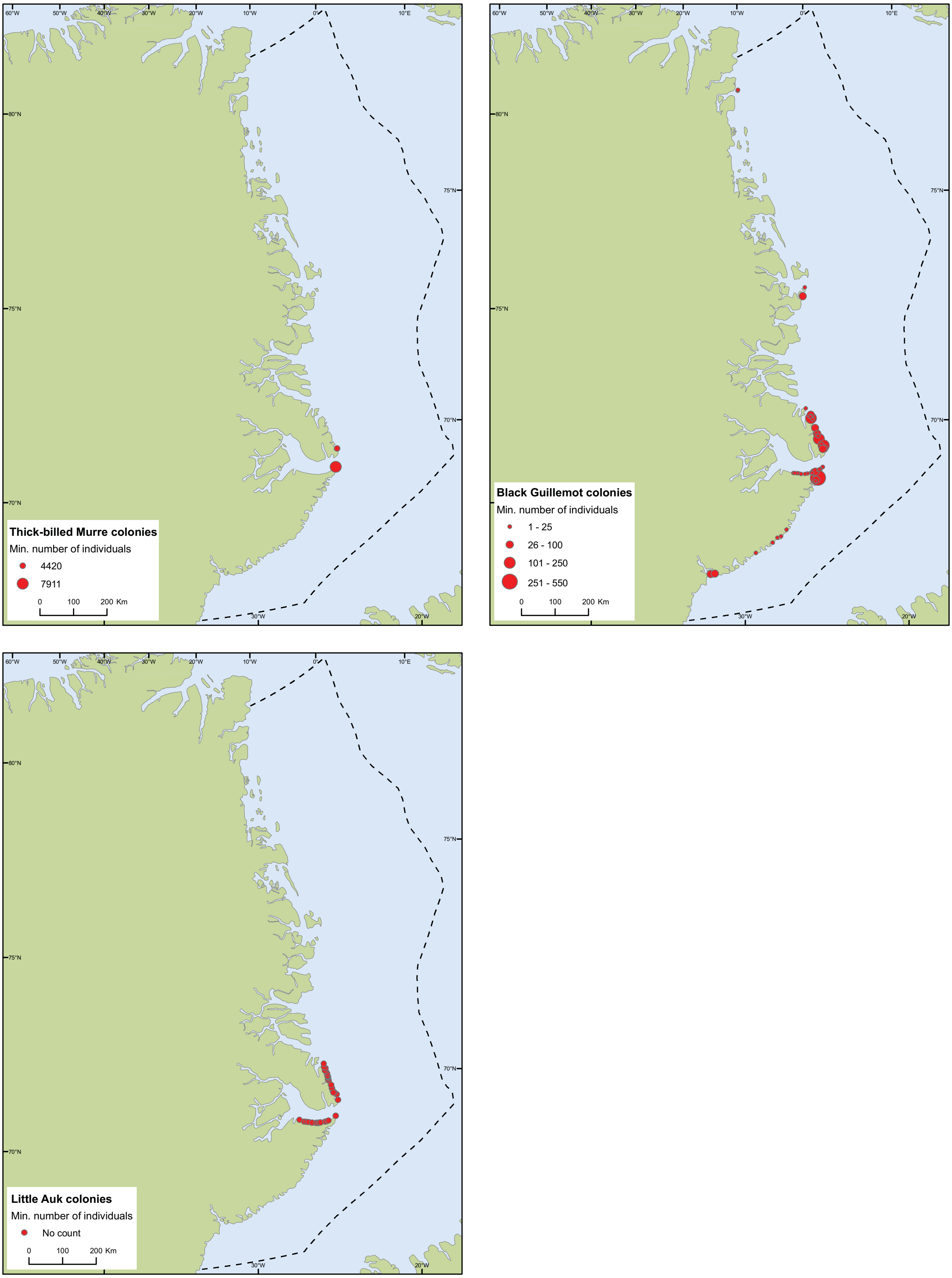



**Figure 15C.** Distribution and size of breeding colonies for seabirds in the assessment area. Large areas are not surveyed properly, and many of the known colonies have not been counted precisely. This is for example the case for all the little auk colonies in and near the entrance to Scoresby Sound. These colonies account for at least 3.5 million pairs in total.

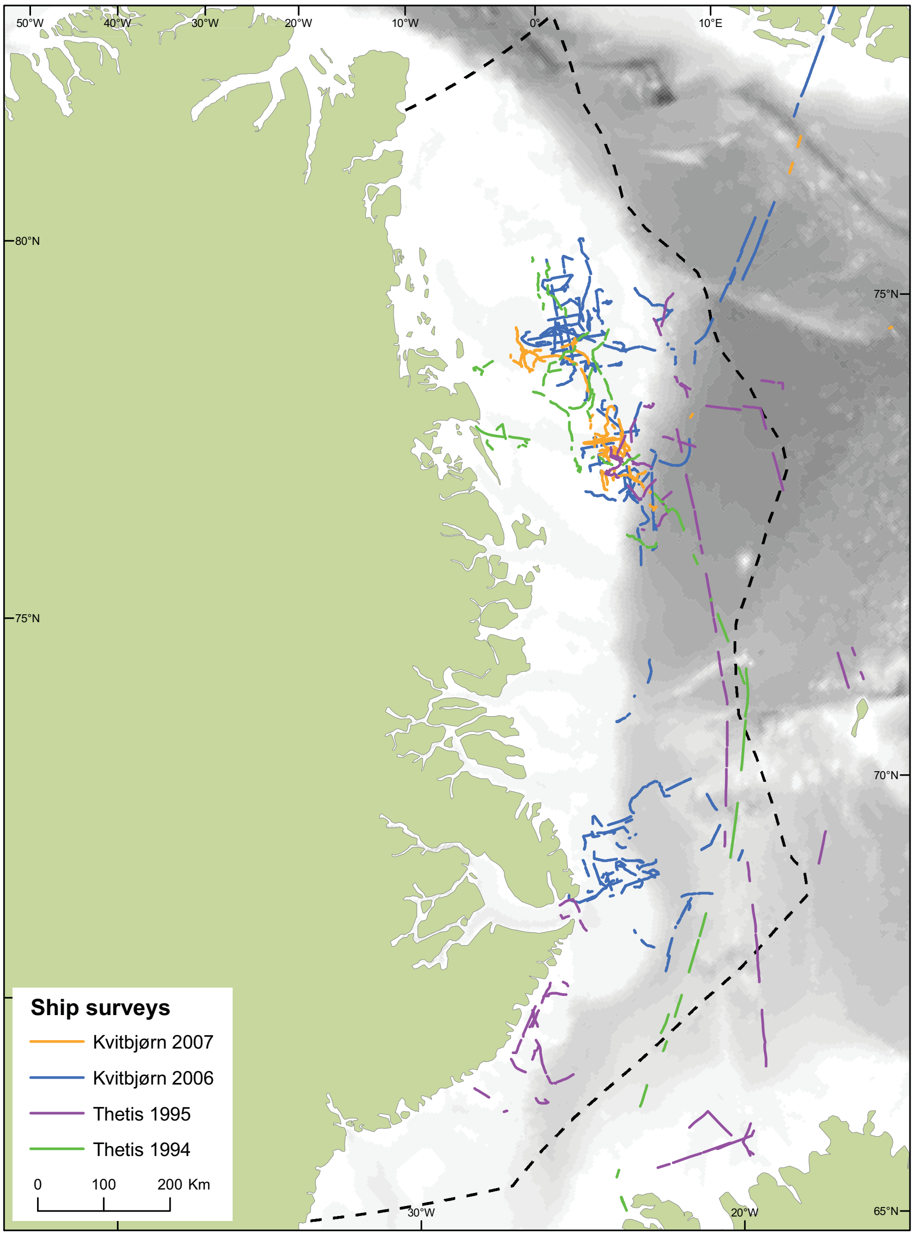



**Figure 16.** The survey routes (transects) of the four ship-based seabird studies, carried out from ships acquiring seismic data in the assessment area in 1994, 1995, 2006 and 2007. Distance sampling methods was applied (Buckland *et al*. 2001).

Besides the true seabirds, a number of species utilise the marine environment during some critical phases of their annual life cycle. These are species utilising freshwater habitats during breeding time; divers and ducks. These species depend on coastal habitats with early ice break-up, for example coastal polynyas, river outlets and narrow straits with strong tidal currents, which are presumed to hold concentrations of both migrant seabirds and inland waterbirds (red-throated diver *Gavia stellata*, king eider *Somateria spectabilis*, long-tailed duck *Clangula hyemalis* and perhaps grey phalaropes *Phalaropus fulicarius*) waiting for lakes and freshwater habitats to become accessible after the winter.

Other inland birds like geese and shorebirds also utilise habitats which could be exposed to marine oil spills. These habitats are mainly salt marshes and tidal mud flats, where many birds occasionally aggregate.

In autumn, large numbers of seabirds from Svalbard presumably pass through the offshore regions of the assessment area. The most numerous are likely to be thick-billed murres, little auks and in 2007 it was documented by satellite telemetry that ivory gulls are among the species moving this way (Link). (O. Gilg pers. comm., Byrkjedal & Madsen 2008). Also high numbers of black guillemots may use this flyway (Figure 21).

In winter, seabirds are almost absent from the area, although common eiders, king eiders, long-tailed ducks and black guillemots have been reported in the very restricted areas with open waters (Boertmann 1994).

An overview of the seabird species occurring in the assessment area is given in Table 1.

Besides the published accounts, unpublished data from NERI studies are included in the following. These comprise date from four seismic surveys carried out in the assessment area mainly between 74° N and 78° N in 21 July-14 Aug. 1994, 12 Aug.-12 Sep. 1995, 13 July-11 Oct. 2006 and 22 Aug.-22. Sep. 2007. These surveys took place in more or less ice-covered waters (Figure 16).

Several seabird studies were initiated as a part of the EIA process in order to collect new background knowledge:

Two aerial surveys carried out along coasts and ice edges in the spring and summer of 2008. They were specifically designed for collecting data of seabird distribution and abundance in relation to impact assessment of future oil activities (Figure 17). Preliminary results are presented in Figure 18.

**Table 1.** Overview of selected species of birds from the assessment area. b = breeding, s = summering, w = wintering, m = moulting, mi = migrant visitor, c = coastal, o = offshore. Importance of study area to population (conservation value) indicates the significance of the population occurring within the assessment area in a national and international context as defined by Anker-Nilssen (1987).

| Species | Occurrence | | Habitat | Red-list status in Greenland | Importance of study area to population | VEC |
|---|---|---|---|---|---|---|
| Fulmar | b/s/w | year-round | c & o | Least Concern (LC) | low | + |
| Common eider | b/m | summer | c | Least Concern (LC) | high | + |
| King eider | b/m | summer | c (in spring) | Least Concern (LC) | medium | + |
| Long-tailed duck | b/m | summer | c (in spring) | Least Concern (LC) | medium | + |
| Grey phalarope | b/mi | summer | c (in spring) | Least Concern (LC) | low | |
| Arctic skua | b | summer | c | Least Concern (LC) | low | |
| Black-legged kittiwake | b/s/mi | summer | c & o | Vulnerable (VU) | low | + |
| Glaucous gull | b/s/mi | summer | c | Least Concern (LC) | low | |
| Sabine's gull | b | summer | c | Near Threatened (NT) | low | + |
| Ross's gull | b/s | summer | c & o | Vulnerable (VU) | low | + |
| Ivory gull | b/s/w | year round | c & o | Vulnerable (VU) | high | + |
| Arctic tern | b | summer | c | Near Threatened (NT) | low | + |
| Thick-billed murre | b/s/mi | summer | c & o | Vulnerable (VU) | high | + |
| Black guillemot | b/s/w | year round | c & o | Least Concern (LC) | low | |
| Atlantic puffin | b | summer | c & o | Near Threatened (NT) | low | |
| Little auk | b/mi | summer | c & o | Least Concern (LC) | high | + |

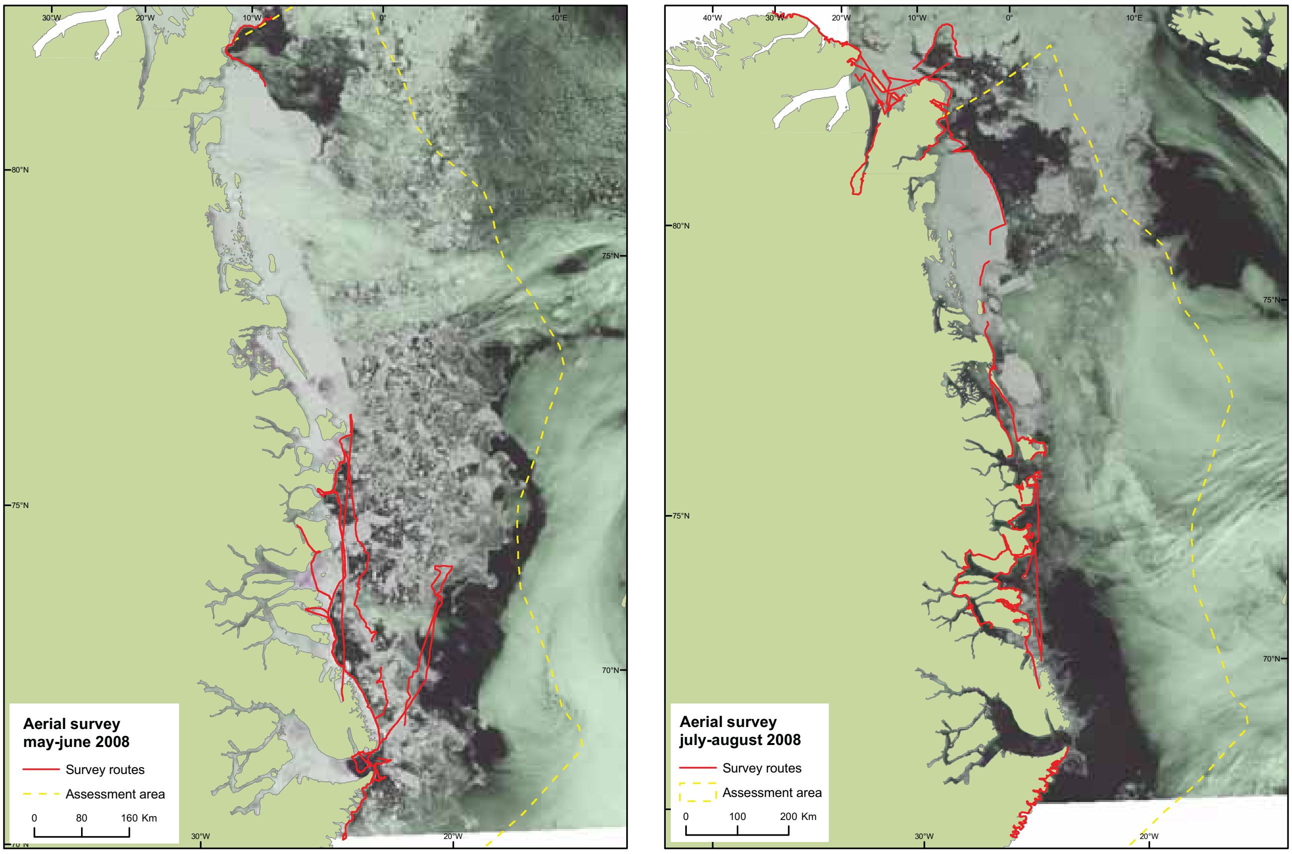



**Figure 17.** Aerial survey routes superimposed on images showing the ice distribution (MODIS, source University of Dundee and DMI). No simultaneous ice images were available for the May/June survey, and an image from mid-June was applied. Some ice edges had withdrawn somewhat since the flights, e.g. in Scoresby Sund. The ice image from the July/August survey is from late July.

Satellite tracking of seaducks (common eider and long-tailed duck) for identification of important habitats and migration routes.

Geolocator deployment on little auks in order to indentify migration routes and winter quarters.

Geolocator deployment on common eiders

### 4.6.1 Important bird species occurring in the assessment area

This section gives an account of important birds in the assessment area. Species designated as VECs (Valued Ecosystem Components) are listed in Table 1.

**Northern fulmar *Fulmarus glacialis***
*Breeding distribution*: Small breeding colonies are located in and near the mouth of Scoresby Sound. Compared with colonies in other part of the north Atlantic, these are small and hold up to a few hundred pairs (Meltofte 1976). A few colonies have been claimed to be have been present further north along the coast, at Hvalros Ø (Stemmerik 1990) and Home Foreland (Bay & Boertmann 1989), but these have not been confirmed in later visits (Gilg *et al.* 2005, NERI 2008 survey). However, much larger concentrations of breeding fulmars occur at the North East Water shores where more than 2,500 pairs were counted in six colonies on the coasts of Holm Land and Amdrup Land (Falk *et al.* 1997). Breeding birds are present on the cliffs from April and the fledglings leave the nesting ledges in early October (Falk & Møller 1997).

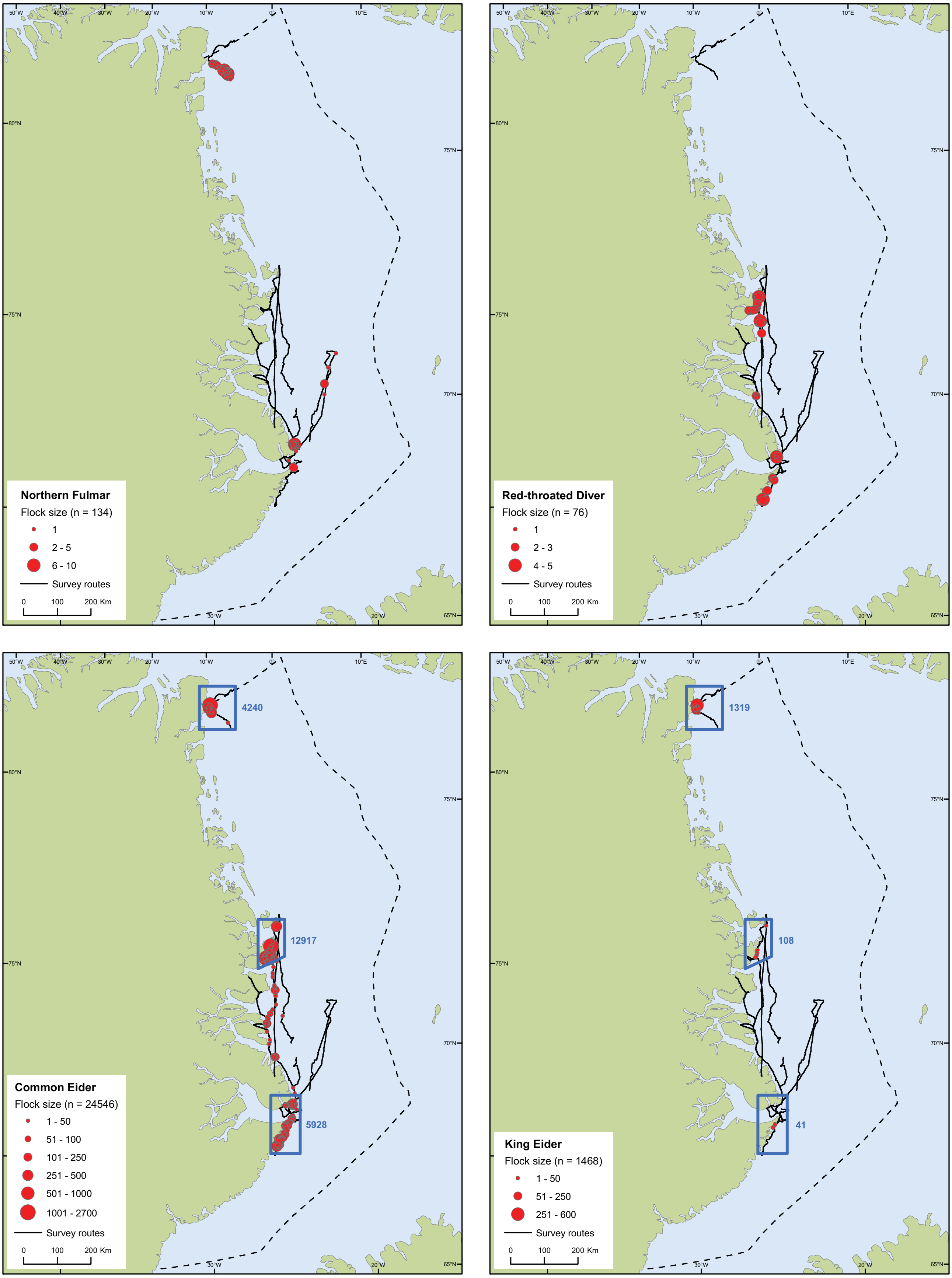



**Figure 18A.** Maps showing the distribution and numbers of selected seabird species observed during the NERI 2008 aerial survey in May and June. n = the total number of individuals counted during the surveys. For common eider the numbers of birds are given inside the framed areas. See also Figure 17 showing the survey routes and ice conditions.

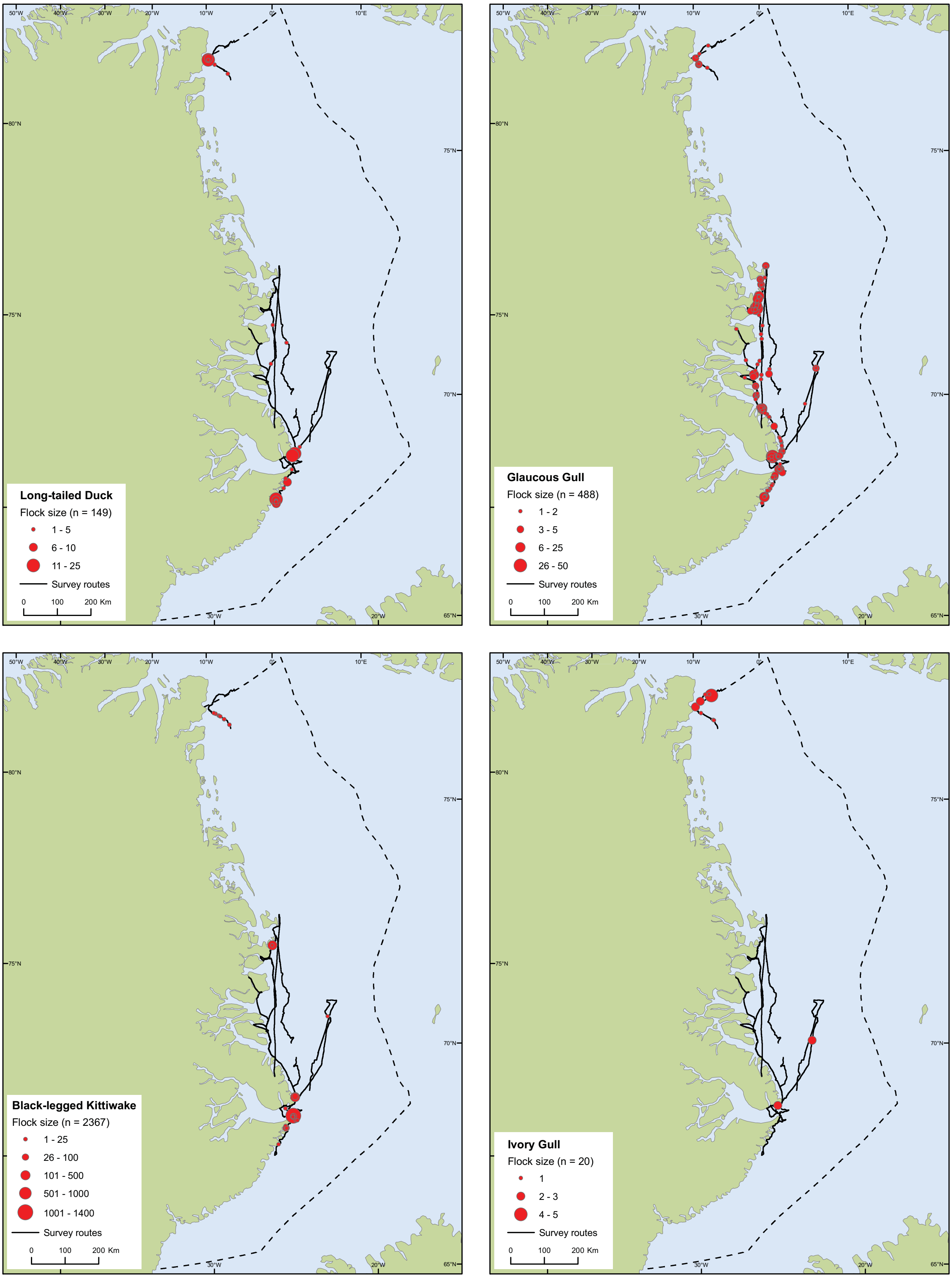



**Figure 18B.** Maps showing the distribution and numbers of selected seabird species observed during the NERI 2008 aerial survey in May and June. n = the total number of individuals counted during the surveys. For common eider the numbers of birds are given inside the framed areas. See also Figure 17 showing the survey routes and ice conditions.

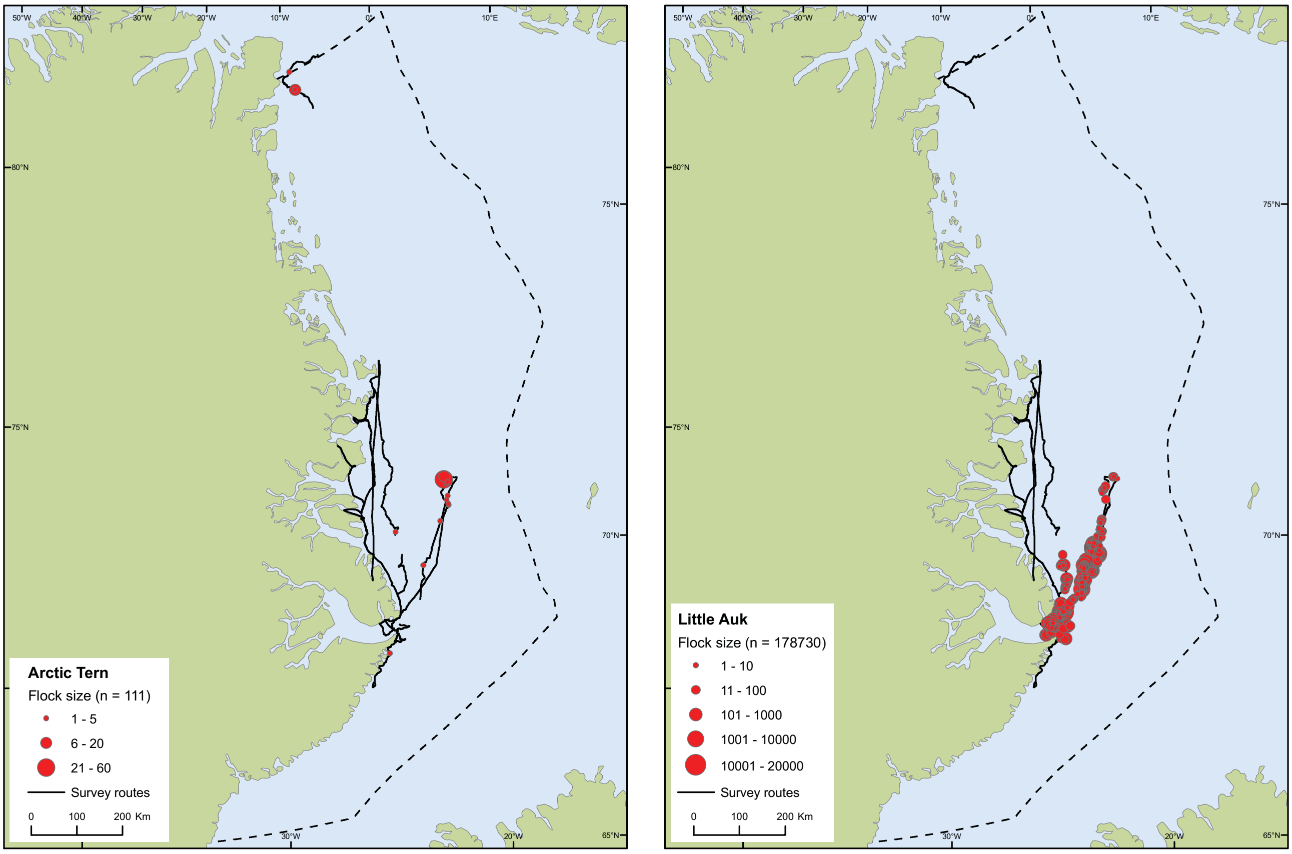



**Figure 18C.** Maps showing the distribution and numbers of selected seabird species observed during the NERI 2008 aerial survey in May and June. n = the total number of individuals counted during the surveys. For common eider the numbers of birds are given inside the framed areas. See also Figure 17 showing the survey routes and ice conditions.

*Offshore distribution*: Fulmars occur everywhere but in relatively low concentrations in the open-water areas in summer from April to September or October (e.g. Meltofte 1975). During the seismic surveys in 1994, 1995 and again in 2006 and 2007 they were recorded in very low densities, except for at one location east of the entrance of Scoresby Sund (Figure 15). Almost the same picture was apparent during the aerial surveys in 2008, where the highest concentrations were found along the southern ice edge of the Northeast Water polynya. The results of Norwegian surveys indicate that densities of fulmars are low in the western Greenland Sea compared to the eastern part off Svalbard and the Barents sea, and that the highest concentrations in the western part was located in the Northeast Water (Mehlum 1989, 1997). In early spring (February-April) and possibly also in winter, fulmars occur in the open waters east of the drift ice belt (Brown 1984).

*Conservation status*: The fulmar population in the assessment area has a favourable conservation status and is not considered as threatened, neither nationally nor internationally (categorised as of 'Least Concern' (LC) on the Greenland Red List).

*Biology*: Fulmars are surface feeders, feeding on fish, crustaceans, etc and in areas with fishery discards. They feed when swimming on the surface and are also able to perform short dives.

*Sensitivity and critical areas*: The breeding colonies are sensitive because many fulmars often rest on the water surface below the breeding cliffs. Recurrent offshore concentration areas are not known but may occur, e.g.

along the marginal ice zone in spring. No offshore concentrations were located during the NERI 2008 surveys in May / June and July / August.

**Geese *Anser* and *Branta* spp.**

Geese usually utilise inland habitats but may stage, moult and feed in coastal habitat of which salt marsh is the most important. There are several species of geese in the assessment area: Snow geese (*Anser caerulescens*), brent geese (*Branta bernicla*), barnacle geese (*Branta leucopsis*), pink-footed geese (*Anser brachyrhynchus*) and Canada geese (*Branta canadensis*). The most important and numerous are pink-footed geese and barnacle geese, which breed and occur in large, non-breeding flocks and spend the summer moulting. Besides the risk of being exposed to oil spills in the marine habitats, geese are especially sensitive to disturbance during moulting (Mosbech & Glahder 1991). Just north of the assessment area, brent geese utilise coastal habitats both for moulting and for rearing chicks. These brent geese belong to a small and 'Near Threatened' (NT) population (unfavourable conservation status) breeding only in Northeast Greenland, Svalbard and Franz Josef Land.

**Common Eider *Somateria mollissima***

*Breeding distribution*: Breeding common eiders occur along most of the coasts close to the Greenland Sea. Many breed dispersed, but there are also several breeding colonies, some holding thousands of pairs (Figure 15). Most colonies are found on small islands and skerries, while solitary breeders also occur on mainland coasts. The total breeding population is roughly estimated at around 10,000 pairs. This estimate seems to be confirmed by the aerial survey in 2008.

The largest colony known in the area is found at the military outpost Daneborg (up to 3,000 nests depending on the timing of snowmelt), where they seek shelter from fox predation among the tethered sledge dogs (Meltofte

*Non-breeding occurrence*: Common eiders arrive in April and May to the open-water areas of the assessment area (even in the north), and from here they disperse to the coasts as soon as these become ice free, for example, in early June at Zackenberg and Danmarkshavn (Meltofte 1975, 1976, Hansen *et al.* 2007). At first the common eiders assemble in pre-breeding congregations before they move to the breeding sites. At least 2,500 common eiders were counted in such pre-breeding flocks off Kilen in Kronprins Christian Land in 1993 (Falk *et al.* 1997). During the NERI survey in spring 2008 about 2,600 were recorded in this area and more than 10,000 were counted in the Wollaston Forland polynya.

Common eiders assemble in moulting flocks during the summer (July). The flocks consist of males and non-breeding females. Meltofte (1976) describe the occurrence of moulting common eiders in the Scoresby Sound area, where the flocks occur from early July. However, knowledge on the distribution and abundance of these moulting birds is very sparse for other parts of the assessment area. The NERI survey in July and August 2008 indicates that moulting common eiders occur in small flocks distributed along the coasts with the highest recorded concentrations in the fjords of the Blosseville Coast (south of 70°) (Figure 19). During a survey in mid-June GINR also recorded common eiders along the Blosseville Coast, indicating that they occur in very great numbers throughout the entire coast

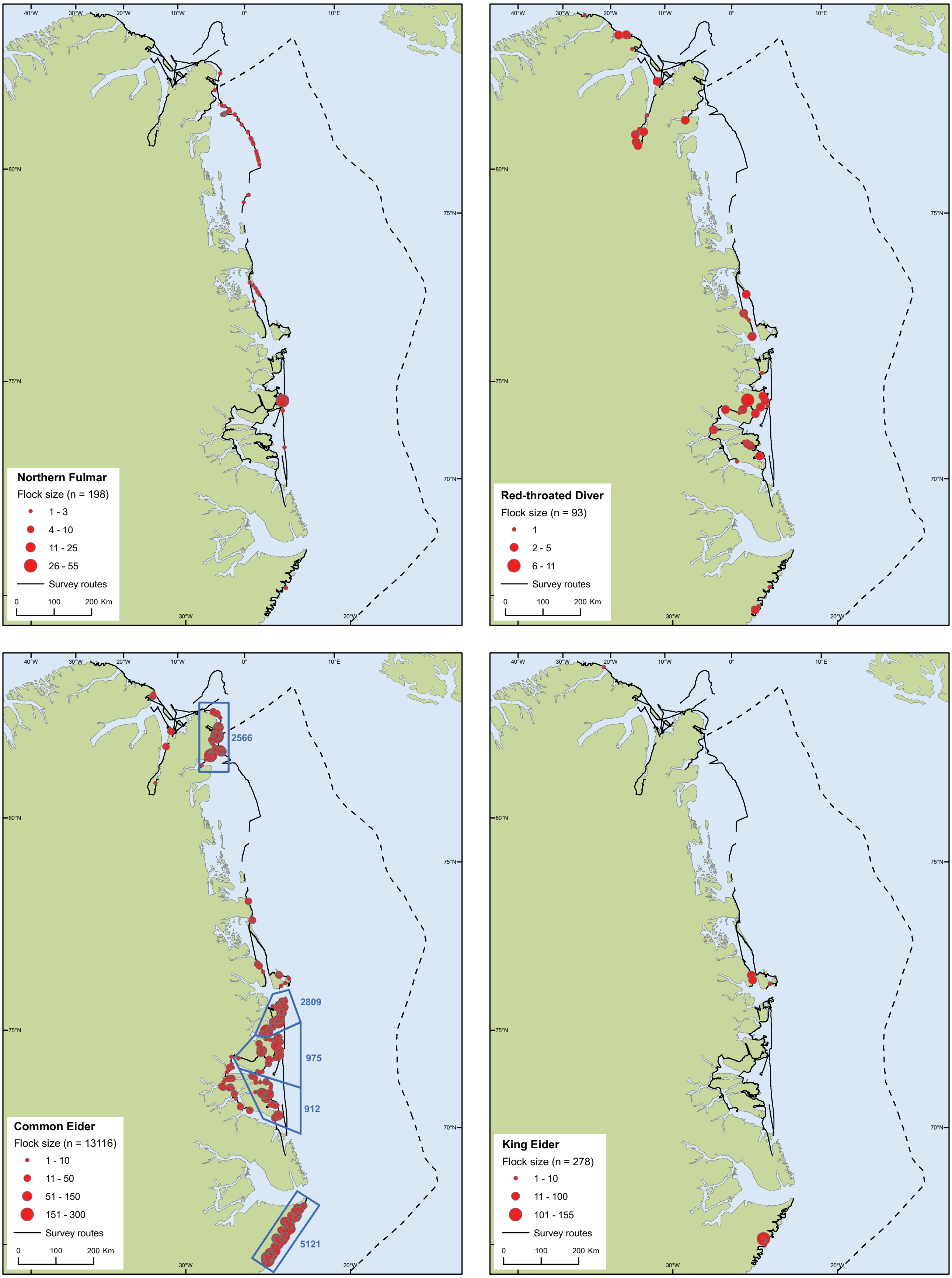



**Figure 19A.** Maps showing the distribution and numbers of selected seabird species observed during the NERI 2008 aerial survey in July and August. n = the total number of individuals counted during the surveys). For common eider the total numbers of birds (males, females and chicks) are given inside the framed areas. See also Figure 17 showing the survey routes and ice conditions.

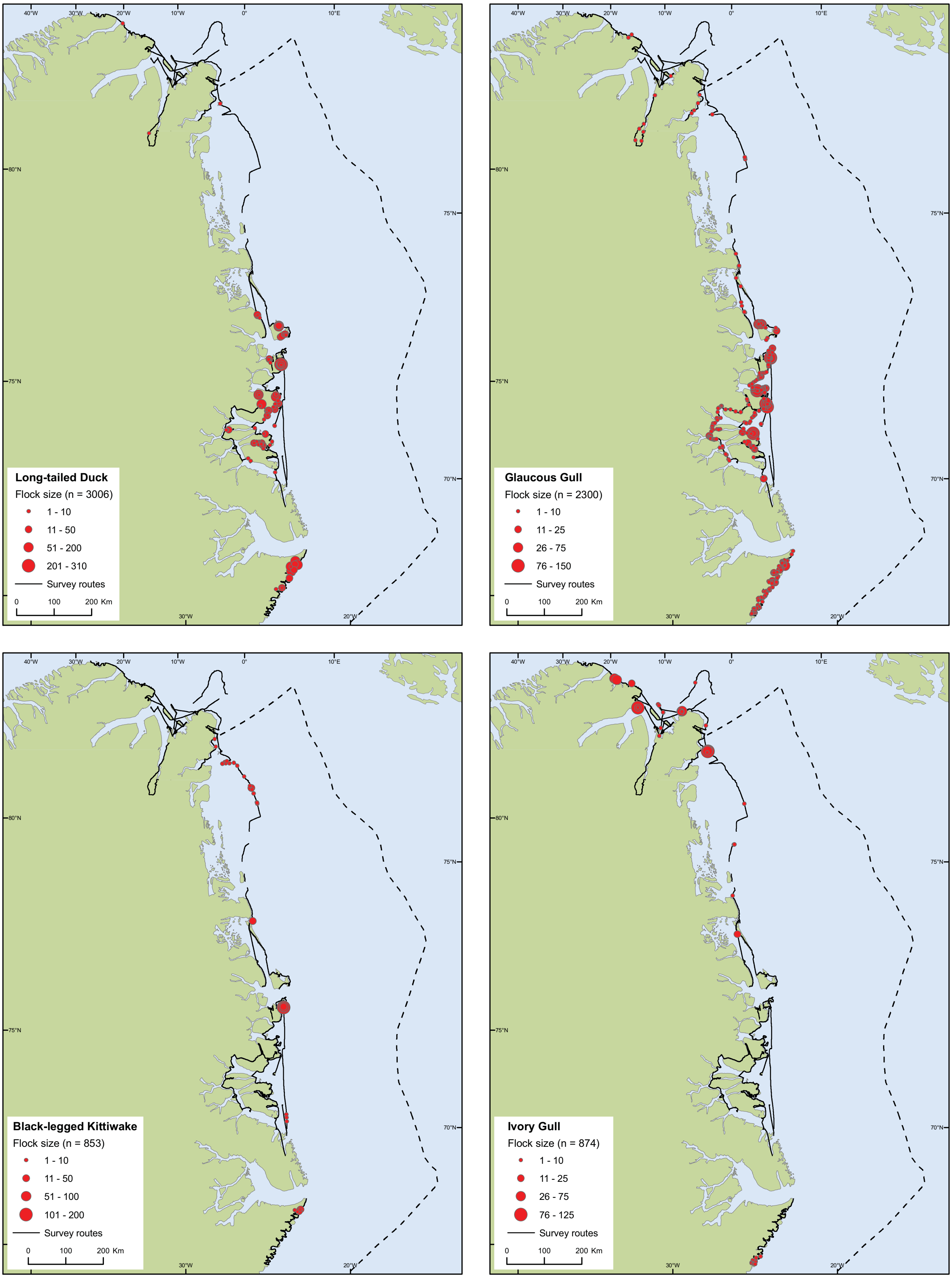



**Figure 19B.** Maps showing the distribution and numbers of selected seabird species observed during the NERI 2008 aerial survey in July and August. n = the total number of individuals counted during the surveys). For common eider the total numbers of birds (males, females and chicks) are given inside the framed areas. See also Figure 17 showing the survey routes and ice conditions.

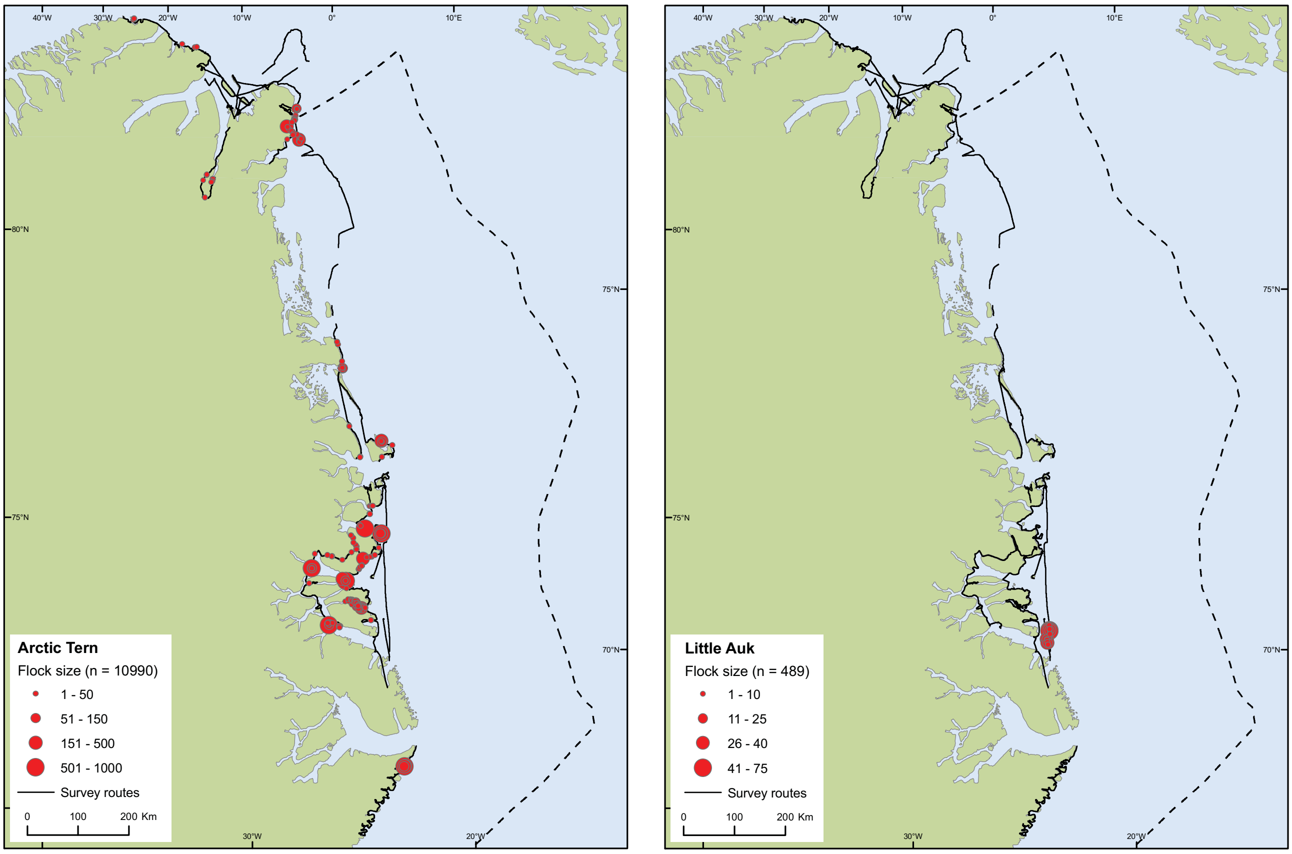
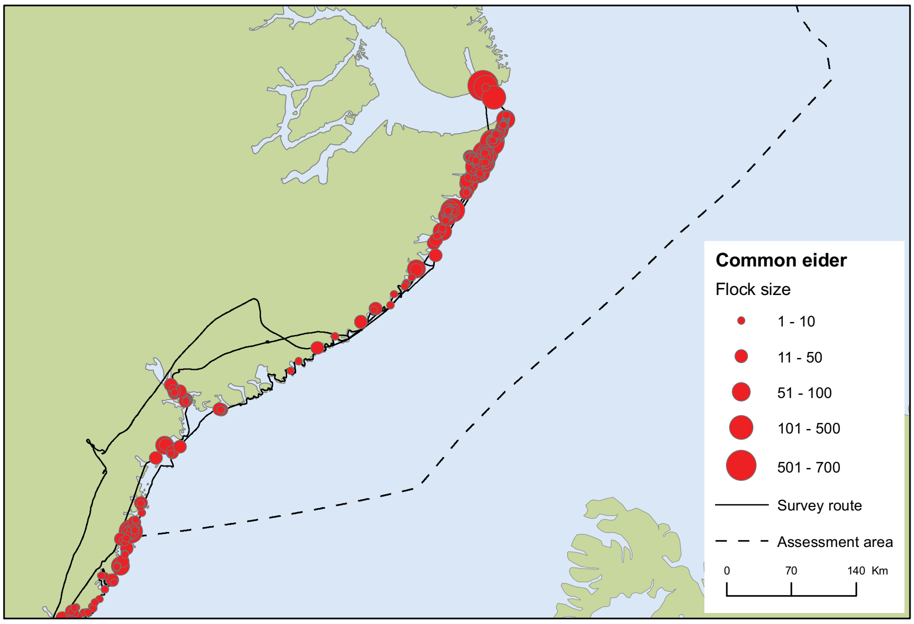



**Figure 19C.** Maps showing the distribution and numbers of selected seabird species observed during the NERI 2008 aerial survey in July and August. n = the total number of individuals counted during the surveys). For common eider the total numbers of birds (males, females and chicks) are given inside the framed areas. See also Figure 17 showing the survey routes and ice conditions.

**Figure 20.** Distribution and abundance of common eider observed during the aerial GINR survey along the Blosseville Coast 20 July 2008. Black line is the flying route (GINR unpublished).




(Figure 20). Satellite tracking of common eiders has confirmed the winter quarters in Iceland and documented the migration routes during more than a year (see Box 1).

## Box 1

### Satellite tracking of common eider

The eider colony in Daneborg is by far the largest eider colony in East Greenland totalling about 2,000 pairs. In June 2007 six female and four male common eiders in the eider colony in Daneborg were equipped with implanted satellite transmitters.

Nine eiders were tracked to Iceland where they wintered (Box Figure 1). Males departed for Iceland about 20 days earlier than females (median day of departure 4 August and 23 August, respectively). During both the autumn and the following spring migration the eiders did not stage for any significant time between the Daneborg area (within 100 km from Daneborg) and Iceland.

Before eiders took off for Iceland, the tracked eiders staged scattered along the south coast of Wollaston Forland including Sandøen, but also further to the West and South at Tyrolerfjord, Grantafjord (74° 17' N, 22° 05' W), Finsch Øer and at Hold With Hope near Holland Ø (73° 35' N, 20° 30' W).

Eiders arrived back in Greenland in the second half of May 2008 (median 22 May; range 10 May – 1 June) Both females and males arrived at the south coast of Wollaston Forland and at Sandøen, with some locations also on the east coast of Wollaston Forland (Box Figure 2). At the end of July 2008 six of the nine satellite-tracked eiders were still being tracked and one had been shot near Scoresbysund in May 2008 during spring migration.

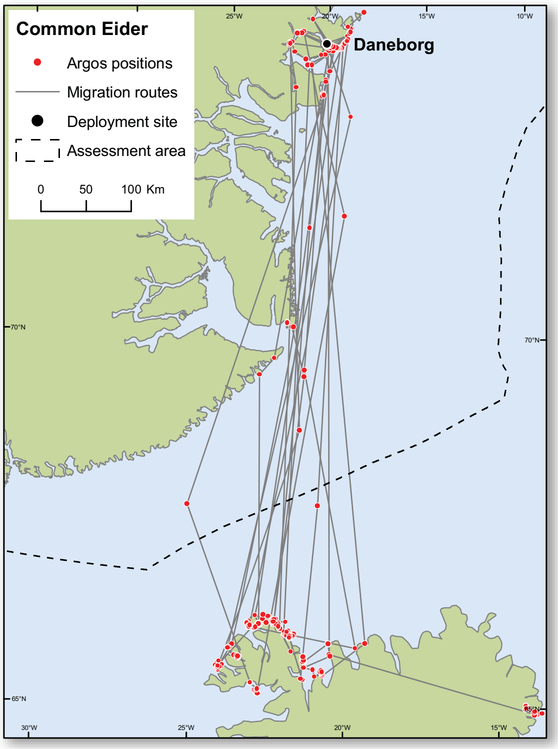



**Figure 1.** Locations and track lines for nine common eiders tracked from the Daneborg colony from June 2007 to August 2008 when six eiders where still transmitting locations. Argos positions are the tracking locations of the birds.

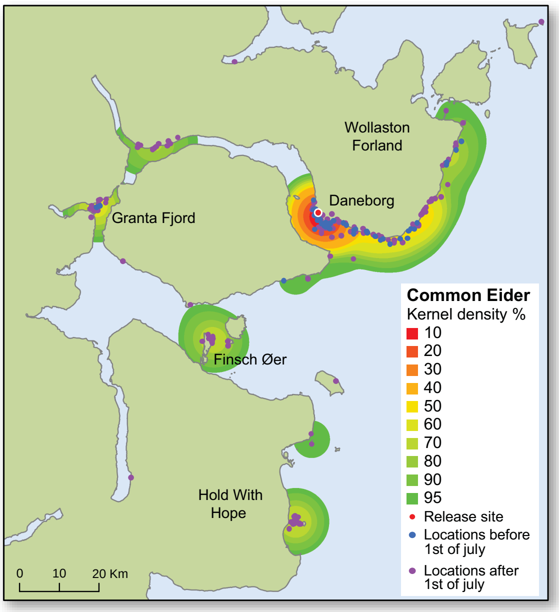
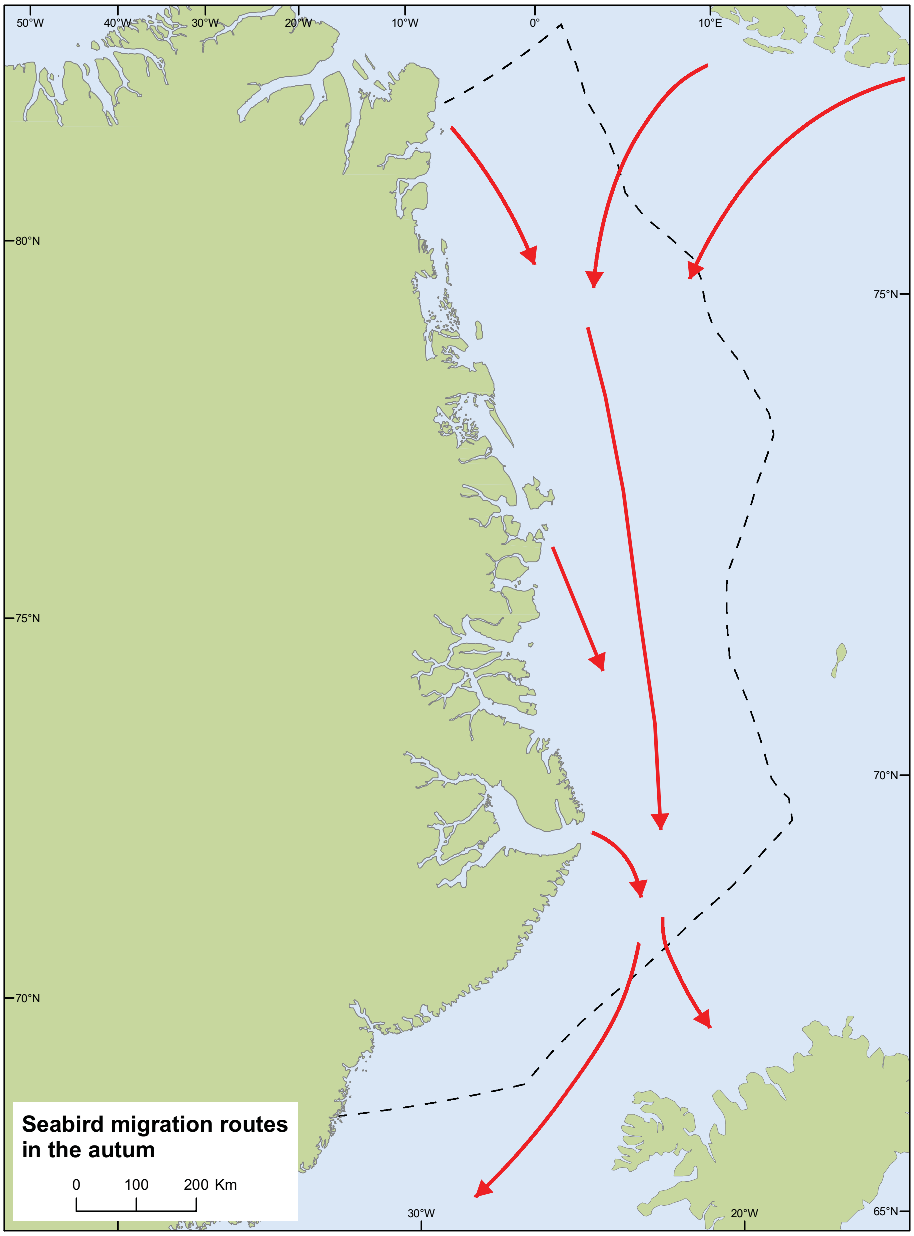



**Figure 2.** Kernel Home range for the common eiders tracked from the Daneborg colony. Locations before 1 July including pre-breeding locations are shown by blue dots and locations after 1 July (both years) including post-breeding locations are shown by purple dots. The Kernel home range presents an estimation of the probability of finding an animal in a defined area based on the Argos satellite location points that have been collected over a period of time. Thus 95 % of the locations are found within the 95 % probability contour.

*Sensitivity and critical areas*: The most sensitive occurrences will be the large breeding colonies, pre-breeding congregation areas and moulting areas where many birds potentially can be exposed to an oil spill. Particularly moulting birds are sensitive because they cannot escape oiled areas. Besides oil spills both colonies and moulting sites are also sensitive to disturbance.

*Conservation Status*: The common eider population of East Greenland has a favourable conservation status, is not considered as threatened and is listed as of 'Least Concern' (LC) on the Greenland and the global Red Lists.

Figure 21. Expected autumn migration routes for seabirds in the assessment area. At least 2 million little auks, 2 million thick-billed murres, an unknown number of black guillemots and probably thousands of ivory gulls migrate through the assessment area each year. All these breed in Svalbard but also birds from Arctic Russia may migrate through the assessment area.




*Biology*: Eiders are diving ducks feeding on the seabed down to about 30 m depth and mainly on molluscs, crustaceans and echinoderms. They are therefore confined to coastal waters. After pairing males assemble in flocks and, due to moult, they become flightless for a three-week period during which they are confined to the water and nearby land.

### Kittiwake *Rissa tridactyla*

*Breeding distribution*: Breeding colonies are found at a few sites along the coast of the assessment area. Most (n= 5) are found on the coasts of the Scoresby Sound polynya with Kap Brewster as the largest numbering about 1,400 nests in 2004 (Meltofte 1976, Falk *et al.* 1997b, Gilg *et al.* 2005). Further north three small colonies were found on Hvalros Ø in 1999 (Gil *et al.* 2005, confirmed by the NERI 2008 survey), and small and not annually occurring colonies are known from Dove Bay (one in 2008) and at the Northeast Water polynya (873 nests counted in 1993) (Boertmann 1994, Falk & Møller 1995, Falk *et al.*1997, Gilg *et al.* 2005).

*Offshore distrubution*: Offshore, non-breeders occur in flocks here and there and occasionally in large concentrations May-September; for example, in the Scoresby Sound polynya (Meltofte 1976, Gilg *et al*. 2005). The Norwegian surveys 1980–1984 found only few kittiwakes in the western part of the Greenland Sea and mainly in the Northeast Water (Mehlum 1989), and during the NERI surveys in July / August only few were recorded in offshore areas. Low densities were also recorded by the seismic surveys with some higher densities off the mouth of Scoresby Sound. Kittiwakes are usually absent from the assessment area in winter, but may occur in small numbers during unusual weather conditions (Brown 1984, Forchhammer 1990).

*Biology*: Kittiwakes are surface feeders living from small fish such as polar cod (*Boreogadus saida*) and crustaceans (Mehlum 1989), which they take when swimming on the surface or from short dives. They are considered as pelagic seabirds, only associated with the coast when breeding.

*Conservation status*: Nationally kittiwake is considered threatened and categorised as 'Vulnerable' (VU) due to its decline in West Greenland. However, the small East Greenland population seems to be increasing (Gilg *et al.* 2005). Internationally it is not considered threatened and is categorised as being of 'Least Concern' (LC). However a general decline in most of the North Atlantic range gives reason for concern.

*Sensitivity and critical areas*: The breeding colonies are most sensitive in the assessment area. Many birds assemble on the surface below the breeding cliff and are potentially exposed to oil spills. Disturbance is another potential impact on these breeding sites. Offshore concentrations probably also occur, but have not been described in detail and will probably not be predictable.

### Sabines gull *Larus sabini*

*Breeding distribution*: This gull breeds in small colonies mainly on low islands in company with Arctic terns. At least 13 colonies were known before 2008 from the assessment area and one more lies just to the north (Figure 15) (Boertmann 1994, Gilg *et al.* 2003, 2005, Hansen *et al.* 2007). The NERI 2008 survey in July / August confirmed the presence of most of these and located some more breeding colonies The best-known colony within the assessment area is Sandøen in Young Sound. The highest number of brids recorded was 300 in 1999 (Levermann & Tøttrup 2007, Egevang & Stenhouse 2007).

Sabine's gulls arrive in the breeding colonies in June when open waters prevent foxes from accessing the breeding islands. However the gulls arrive somewhat earlier (late May) in the open-water areas, e.g. the Northeast Water, where more than 200 were recorded during the NERI 2008 survey on 3 June. They leave again when the chicks are fledged in August.

*Offshore distribution and concentrations*: Very little information is available on offshore distribution, but the very few observations from the seismic surveys indicate that the birds move out of the assessment area rapidly during autumn migration.

*Conservation status*: Sabine's Gull is included on the Greenland Red List as 'Near Threatened' (NT), due to the small national population size. It is however of favourable conservation status and its numbers seem to be increasing. Internationally it is not red-listed and is considered as of 'Least Concern' (LC).

*Biology*: Sabine's gulls are surface feeders living from small fish and invertebrates which they take in flight or during shallow dives, and they feed mainly close to the breeding colony and are confined to the coastal habitats during breeding. When migrating they are true pelagic seabirds.

*Sensitivity and critical areas*: Sabine's gulls are most sensitive at the breeding colonies, and disturbance is the most severe threat.

### Glaucous gull *Larus hyperboreus*

*Breeding occurrence*: This is the most widespread and common breeding seabird within the coastal part of the assessment area (Figure 15). Small breeding colonies (usually below 50 pairs) and solitary pairs usually occur at steep cliffs facing the sea or on low islands. Breeding concentrations are often found in areas with high numbers of other breeding seabirds; for example, at the little auk colonies in the Scoresby Sund area.

The glaucous gulls arrive at the breeding sites in Aril and May, and leave again when the waters freeze over in the autumn (Meltofte 1975, 1976).

*Offshore distribution*: Glaucous gulls were relatively rare in the western Greenland Sea compared with Svalbard waters during the Norwegian summer surveys in 1980-1984 (Mehlum 1989) and were only recorded in the Northeast Water. During the seismic surveys glaucous gulls were widespread in the survey areas (Figure 22).

*Conservation status*: The glaucous gull population in the assessment area is of a favourable conservation concern and the Greenland population as a whole is not considered as threatened, either nationally or internationally.

*Biology*: Glaucous gulls are omnivorous and act as top predators in the Arctic ecosystem by taking seabird eggs, chicks and even adult little auks and kittiwakes. They often feed when swimming on the surface. Glaucous gulls are attracted to human activities where discards can be an important food source. They are usually confined to the coastal environment, but may occur far offshore.

*Sensitivity and critical areas*: Glaucous gulls are less sensitive to oil spills than many other seabirds staying for longer periods on the water surface. The population is dispersed (many small colonies; Figure 15); therefore, relatively few individuals will be affected by an oil spill.

### Ross's gull *Rhodosthetia rosea*

*Breeding occurrence*: This gull is a very rare species, breeding regularly in Greenland only at a two sites. Henrik Krøyer Holme in the Northeast Water Polynya is one of these sites (Egevang & Boertmann 2008). Here a few pairs have been recorded among the ivory gulls and Arctic terns during recent visits to the islands (Figure 15).

*Biology*: Very little is known about the phenology and biology of this species in Greenland. Breeding birds are probably confined to the coastal environment, while non-breeders and migrating birds occur in the marginal ice zones of polynyas and in the drift ice.

*Offshore occurrence*: Non-breeders occur in relatively high numbers in the Northeast Water during summer (Falk *et al.* 1997, Meltofte *et al.* 1981a), and small flocks were also seen during the seismic surveys (Figure 18).

*Conservation status*: The Ross's gull is considered as threatened in Greenland and categorised as 'Vulnerable' (VU) on the national Red List. Internationally it is not red-listed ('Least Concern' (LC)).

*Sensitivity and critical areas*: The breeding site on Henrik Krøyer Holme is particularly sensitive to disturbance.

**Ivory Gull *Pagophila eburnea***

This gull is the most Arctic of all the seabirds. It is associated with ice-covered waters always near predictable open water areas, such as polynyas and shore leads.

*Breeding concentrations*: Breeding colonies are placed either on steep cliffs, often on remote nunataks, on low gravel islands, beaches or even moraine covered ice floes. The most important breeding site in the assessment area is Henrik Krøyer Holme in the Northeast Water, where up to 300 (2003) pairs breed (Figure 15). Several new breeding colonies were found during the NERI 2008 survey in July and August in and just north of the assessment area (Figure 19).

*Biology*: Very little is known on the biology of the Greenland ivory gulls, but recently (2007) individuals have been equipped with satellite transmitters to track their migration, and results from this study are expected soon. Ivory gulls are surface feeders, living from small fish and crustaceans taken in leads and pools in the ice. They also feed on remains from polar bear kills and are attracted to human activities that create open waters in the ice and to garbage and discards for example at military outposts.

*Offshore distribution*: Post-breeding migration takes place from late August and birds move south in the drift ice belt off the East Greenland shore in small flocks. Substantial numbers have been recorded, e.g. in early September 1975 when hundreds were observed migrating south (Hjort 1976b) and likewise hundreds were observed in mid-October in the marginal ice zone at about 74° N (Byrkjedal & Madsen 2008). Bench & Hjort (1990) also reported ivory gulls from the drift ice in October. During the seismic surveys ivory gull was among the most frequently seen species (Figure 22). The birds seen in autumn in the assessment area are probably of a combined origin from Northeast Greenland, Svalbard and Russia (Bensch & Hjort 1990). This has recently been confirmed by satellite tracking (Link). These birds head for winter grounds along the ice margin in the Labrador Sea (Orr & Parsons 1982), but some also winter on the ice off Southeast Greenland, and they are also present in the Greenland Sea in February–April (Brown 1984). In mid- and late-May 2002 many hundreds were observed migrating north in the East Greenland Current between 65° and 75° N (H. Kylin pers. comm.), indicating spring migration. However, a few birds may arrive to the breeding colony at Station Nord as early as April (Sirius Sledge Patrol pers. comm.). During the Norwegian summer surveys 1980–1984, ivory gull was the most abundant seabird species in

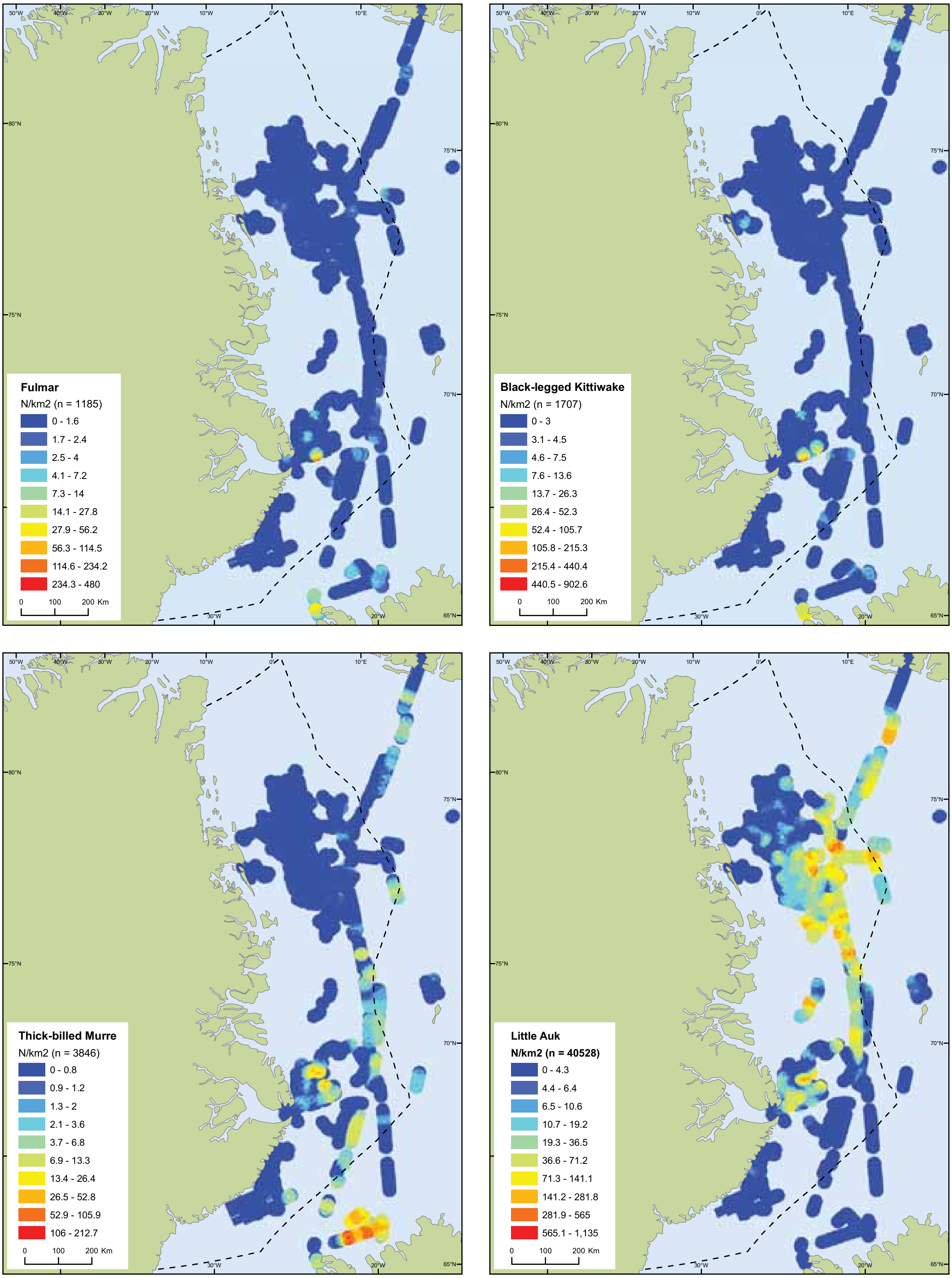



**Figure 22A.** Seabird observations during the four seabird surveys in 1994, 1995, 2005 and 2006. For fulmar, kittiwake, thick-billed murre and little auk densities have been calculated. For other species all observations are shown as dots. n = the total number of individuals counted during the surveys.

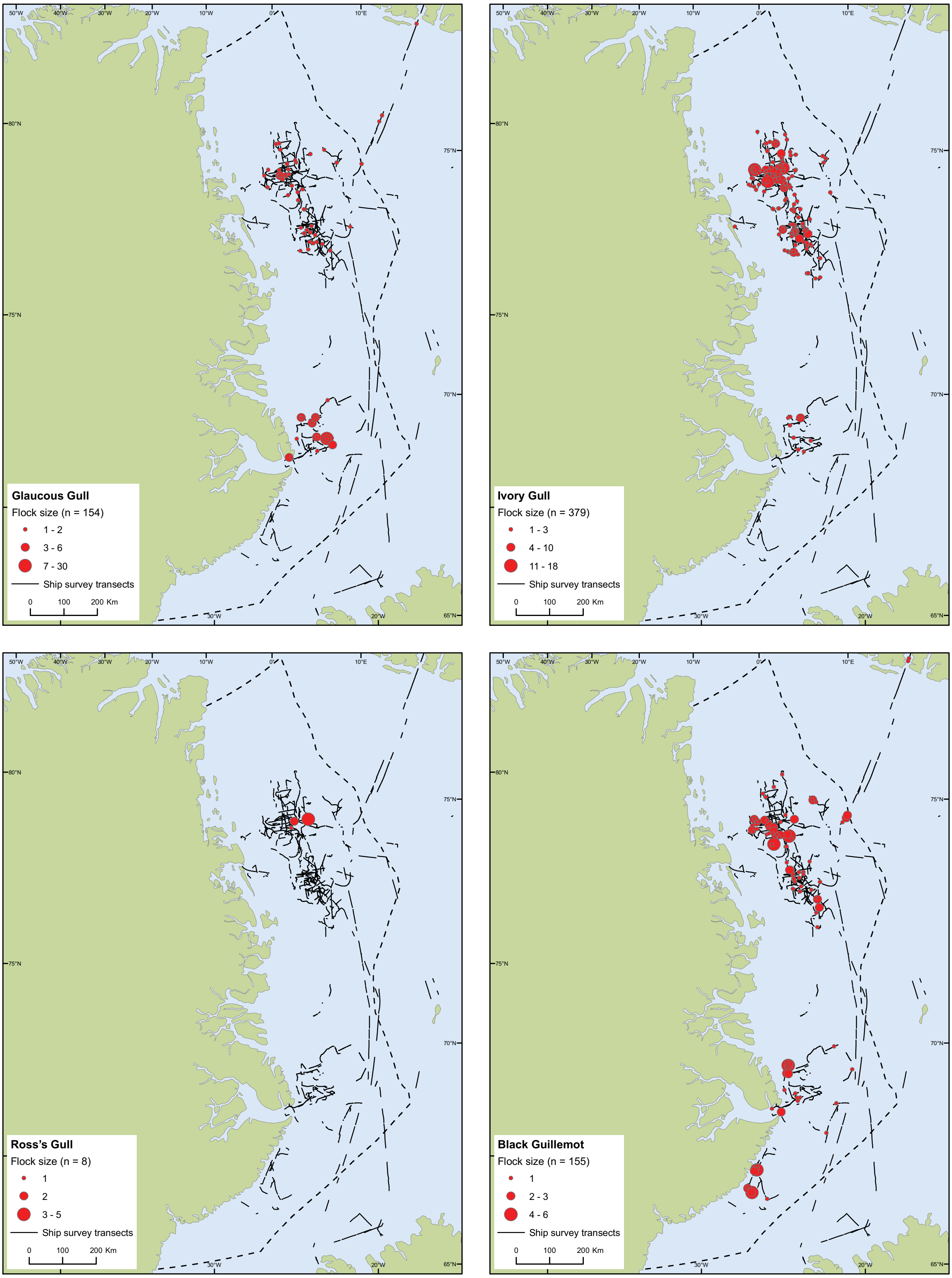



**Figure 22B.** Seabird observations during the four seabird surveys in 1994, 1995, 2005 and 2006. For fulmar, kittiwake, thick-billed murre and little auk densities have been calculated. For other species all observations are shown as dots. n = the total number of individuals counted during the surveys.

the waters off Northeast Greenland and always in close association with the drift ice (Mehlum 1989).

*Conservation status*: The global ivory gull population has an unfavourable conservation status (Gilchrist *et al.* 2008)), as the global population is small (estimated at 14,000 pairs) and regional declines are evident. Moreover the birds in Russia and Svalbard display high contaminat loads (Gilchrist *et al.* 2008) and a general population decline is expected due to climate change. Ivory gull was therefore recently red-listed as 'Near Threatened' (NT) (BirdLife International 2006). In Greenland, the ivory gull is considered as threatened and categorised as 'Vulnerable' (VU) on the national Red List.

*Sensitivity and critical habitats*: Ivory gulls spend only little time on the water surface and are therefore not as sensitive to oil spills as many other marine birds. But as the species is relatively rare and populations seem to be decreasing (at least in Canada) even mortality of a relatively small number of birds may have population effects. However, the breeding colonies are sensitive to disturbance, particularly low level helicopter flights. But on the other hand under certain circumstances ivory gulls are able to habituate to disturbance (e.g. the colony at Station Nord is very close to the air strip situated there).

**Arctic tern *Sterna paradisaea***

*Breeding distribution*: Many breeding colonies are located along the shores of the assessment area (Figure 15). Most are small, but a few hold more than 500 pairs. Moreover, there are many Arctic terns breeding at inland sites at lakes. The breeding colonies are concentrated at polynyas and areas with early ice break-up, such as the outer parts of sounds and fjords: e.g. Vega Sound, Young Sound, Dove Bay and Henrik Krøyer Holme.

*Offshore distribution*: Arctic terns arrive to the coastal waters in early to mid-June, and leave soon after the chicks have fledged in late August to early September. During the NERI 2008 survey flocks arrived in the outer parts of the offshore drift ice 2 June. During the breeding season terns mainly stay close to the breeding sites and very few were observed during the Norwegian surveys in 1980–1984 (Mehlum 1989). During migration, Arctic terns move through the offshore areas, but this is brief and rapid, and very few were seen during the aerial NERI survey May/June 2008 (Figure 18), which took place during the peak spring migration period.

*Biology*: Arctic terns are surface feeders, catching fish and crustaceans by plunge diving from the air. In the breeding season Arctic terns are confined to coastal waters, but during migration they also occur far offshore.

*Conservation status*: The Greenland population is considered as 'Near Threatened' (NT) on the national Red List due to a considerable population decline in West Greenland. However in East Greenland including the assessment area Arctic tern has a favourable conservation status. Internationally it is categorised as of 'Least Concern' (LC).

*Sensitivity and critical areas*: Terns rarely rest on the water, and are therefore less vulnerable to oil spill than many swimming seabird species. The breeding colonies however are particularly sensitive to disturbance.

## Thick-billed murre *Uria lomvia*

*Breeding distribution*: There are only two or three breeding colonies of this alcid within the assessment area (Figure 15). All are situated at the Scoresby Sound polynya (Meltofte 1976, Falk *et al.* 1997b). Two of the colonies have been surveyed a number of times in recent decades, and the large colony on Kap Brewster has shown a significant decrease: in 2005, it numbered maximum 9,500 birds. The other colony on the island, Raffles Ø is smaller and held about 2,200 birds in 2004. A third colony on the island, Steward Ø is small and probably abandoned as no birds were seen during the NERI 2008 surveys.

*Offshore distribution*: Murres are numerous in and near the Scoresby Sound polynya in summer, but further north in the assessment area only few occur, and in the Northeast Water they occurred sparsely in 1991–1994 (Mehlum 1989, Falk *et al.* 1997). In September numbers increase in the offshore areas (Figure 22) and high densities of thick-billed murres have been recorded in polar waters between Iceland and Greenland, with up to 30 bird / $km^2$ (Petersen 1995). This influx of birds consists mainly of breeders from Svalbard (approx. 850,000 pairs in 1975 Anker-Nilssen *et al.* 2000) on autumn migration to winter quarters off Southwest Greenland and Newfoundland. Probably all the breeding birds from Svalbard pass through the assessment area, both on spring and autumn migration. Winter observations are very few, but at least in late winter 1982 few were observed in the eastern parts of the assessment area (Brown 1984).

*Biology*: Thick-billed murres occur both in coastal and offshore waters. They are diving birds feeding on fish (capelin, polar cod) and large zooplankton, and they spend much time on the surface swimming. Chicks leave the nesting ledges when three weeks old and not yet fully grown, and together with the male bird (which becomes flightless due to flight feather moult) they perform a swimming migration more or less passively with the currents. This migration probably takes a considerable number of Svalbard birds into the assessment area.

*Conservation status*: The thick-billed murre population breeding in the assessment area has an unfavourable conservation status due to decline. In West Greenland many populations are also in decline, so the species is red-listed as threatened ‘Vulnerable’ (VU) in Greenland. Internationally it is considered as of ‘Least Concern’ (LC).

*Sensitivity and critical areas*: Murres are particularly sensitive to oil spills, because they spend most of their time on the water surface. They are sensitive moreover at the population level, because the population is decreasing, reducing the potential for post-spill recovery. The most sensitive occurrences in the assessment area are the breeding colonies in the Scoresby Sound polynya. Significant concentrations most likely occur offshore during the migrations periods, for example in the marginal ice zone, but information is limited.

## Black guillemot *Cepphus grylle*

*Breeding distribution*: The black guillemot is a rather common breeder on coasts near the Scoresby Sund polynya (Meltofte 1976, Gilg *et al.* 2005). Further north, colonies are scarce and associated with areas with early ice break-up or polynyas, e.g. at Hvalros Ø and at Holm Land (Falk *et al.* 1997, Gilg *et al.* 2005), and they are somewhat unstable in their occurrence, probably governed by the annual variation in ice distribution (Figure 15). A new breeding site was located on Jackson Ø during the NERI 2008 survey in July.

*Offshore distribution*: Very few black guillemots were reported by the Norwegian summer surveys in 1980-1984 in the northern part of the assessment area (Mehlum 1989. During the seismic surveys black guillemots were rather numerous in the drift ice, and also Byrkjedal & Madsen (2008) reports black guillemots in autumn. The number of birds recorded during these autumn surveys exceeds by far the numbers breeding in Northeast Greenland, indicating that birds move in from Svalbard. In winter Brown (1984) observed very few black guillemots and mainly in the marginal ice zone.

*Biology*: Black guillemots are diving birds, which stay for long periods on the surface. They feed on fish and invertebrates mainly in the extensive kelp beds along the shore, but offshore they feed on the fauna associated with drift ice and icebergs. They breed in small colonies in steep cliffs along the shores. The migration patterns of East Greenland birds are unknown.

*Conservation status*: Black guillemots are not threatened and are categorised as of 'Least Concern' (LC), both nationally and internationally. Although the breeding population is small in the assessment area, it most likely has a favourable conservation status.

*Sensitivity and critical habitats*: As swimming birds spending longer periods of time on the surface, black guillemots are vulnerable to oil spills, and the most sensitive occurrences are the breeding colonies along the coasts of the assessment area. However, there are few other human-induced threats to the population, making them less vulnerable at the population level than thick-billed murres.

### Little auk *Alle alle*

*Breeding distribution*: This species is by far the most numerous breeding seabird in the assessment area. The breeding distribution is however limited to the coasts near the Scoresby Sund polynya (Figure 15), where the population has been estimated at approx. 3.5 million pairs (Kampp *et al.* 1987). Breeding outside this region has been suggested at Hvalros Ø (74° 30' N) – not confirmed in 1999, 2005 and 2008 – and at Kap Dalton (69° 30' N) – not confirmed in 2008 (Stemmerik 1990, Gilg *et al.* 2005).

*Offshore distribution*: In summer, breeding birds undertake foraging flights up to approx. 100 km from the colonies (e.g. Gilg. *et al.* 2005), and within this range little auks can occur in very dense concentrations. However, further offshore little auks are much scarcer in summer, as shown by the Norwegian surveys in 1980-1984 (Mehlum 1989). Little auks probably move to Southwest Greenland and Newfoundland waters for the winter, but Brown's survey (1984) indicates that little auks are present also in winter (March), and then mainly in the marginal ice zone.

Birds from the very large breeding population in Svalbard (at least 1 million pairs; Anker-Nilssen *et al.* 2000), migrate through the assessment area from late August and return again in April (Brown 1984, Gilg *et al.* 2005). Concentrations were recorded by the seismic surveys (Figure 22) peformed in September. Surveys in October 2005 and 2007 by Byrkjedal &

Madsen (2008) did not find many little auks, suggesting that the migration had peaked earlier.

*Biology*: Little auks are diving birds feeding on large pelagic crustaceans – mainly *Calanus*-copepods. Little auks breed in very dense colonies in the talus rocks below steep cliffs. Off breeding season little auks occur usually far offshore.

*Conservation status*: The little auk population breeding in the assessment area is most likely of favourable conservation status, and the Greenland and the global populations are red-listed as of 'Least Concern' (LC).

*Sensitivity and critical habitats*: Little auks are very vulnerable to oil spills, and the most sensitive occurrences are the breeding colonies along the coasts of the assessment area. Large offshore aggregations will also be very sensitive, but their occurrence is not known and will probably depend on distribution of food.

**Other species**

Four species of skua (*Stercorarius*) occur frequently in the assessment area in the summer period. Breeding birds are confined to terrestrial and coastal habitats, but non-breeders and failed breeders move to offshore areas, and are usually common and widespread (Figure 22). They are all migrants and leave the assessment area for the winter period.

Several species of waterbirds breeding at the freshwater habitats of Northeast Greenland are dependent on the marine environment for spring staging in a vulnerable period of their life cycle. Before the freshwater habitats become free of ice and available, many waterbirds assemble together with true marine birds, in coastal areas were polynyas reach the coast or where the sea ice has melted, e.g. in river outlets or in straits with strong tidal currents. Species include red-throated diver (*Gavia stellata*), great northern diver (*Gavia immer*), long-tailed duck (*Clangula hyemalis*), red-breasted merganser (*Mergus serrator*), king eider (*Somateria spectabilis*), red-necked phalarope (*Phalaropus lobatus*) and grey phalarope (*Phalaropus fulicarius*). Many of these birds also forage in the marine environment during breeding. Later in the summer postbreeding and moulting birds also assemble in the marine environment of the assessment area.

The most numerous of these species are the king eider and the long-tailed duck. During the spring 2008 survey about 2,000 king eiders were observed in the Northeast Water Polynya, 100 at the Wollaston Forland Polynya and 40 at the Scoresby Sound Polynya (Figure 18). Long-tailed ducks were most abundant in the Scoresby Sound Polynya with about 100 birds followed by the Northeast Water with 40 birds (Figure 18). Red-throated divers were recorded in small numbers and very dispersed (Figure 18).

Long-tailed ducks were captured in the central part of the assessment area and equipped with satellite transmitters. The subsequent tracking of these birds is described in Box 2.

Another period when such birds may use the marine environment is during the summer, when they moult. The most numerous species are again long-tailed ducks and king eiders. During the NERI 2008 surveys in July and August moulting long-tailed ducks were located at many sites. Flocks

# Box 2

## Satellite tracking of long-tailed ducks from Myggbukta

Myggbukta is a pond-rich wetland on the south coast of Hold With Hope with a high density of breeding long-tailed ducks (Elander & Blomquist 1986). In mid-June 2007 six long-tailed ducks were equipped with implanted satellite transmitters at Myggbukta and tracked to wintering areas in Iceland and South Greenland (Figure 3). Birds were caught in mist nets as pairs during courtship flights (presumed to be pairs). One pair migrated to Iceland, one pair migrated to Julianehåbsbugten and one pair split between Iceland and Julianehåbsbugten with a detour along the coast of Southwest Greenland.

The long-tailed ducks were mainly located close to the deployment site for around two months before the autumn migration (Figure 1, 2).The long-tailed ducks started their autumn migration from the Myggbukta area in September, and five of the six birds did not stage for significant periods during migration, while one bird staged for a month (October) about 80 km south of Myggbukta.

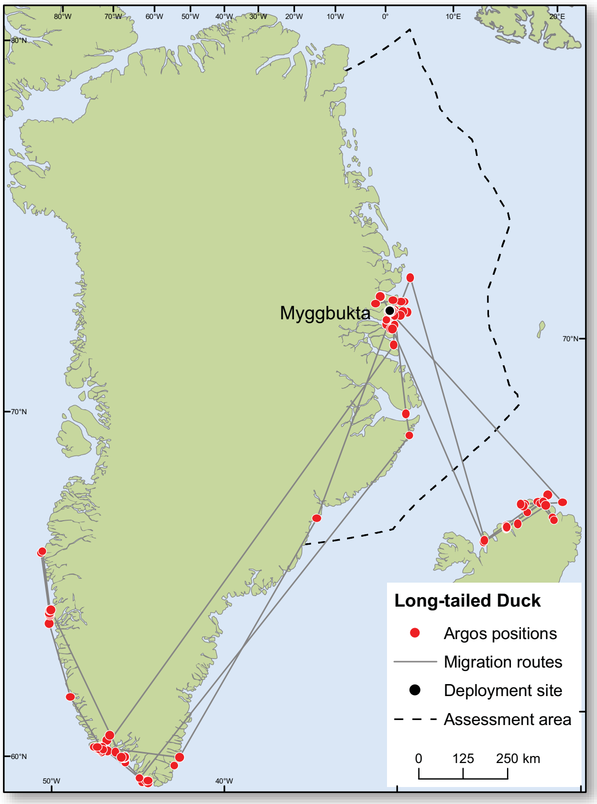
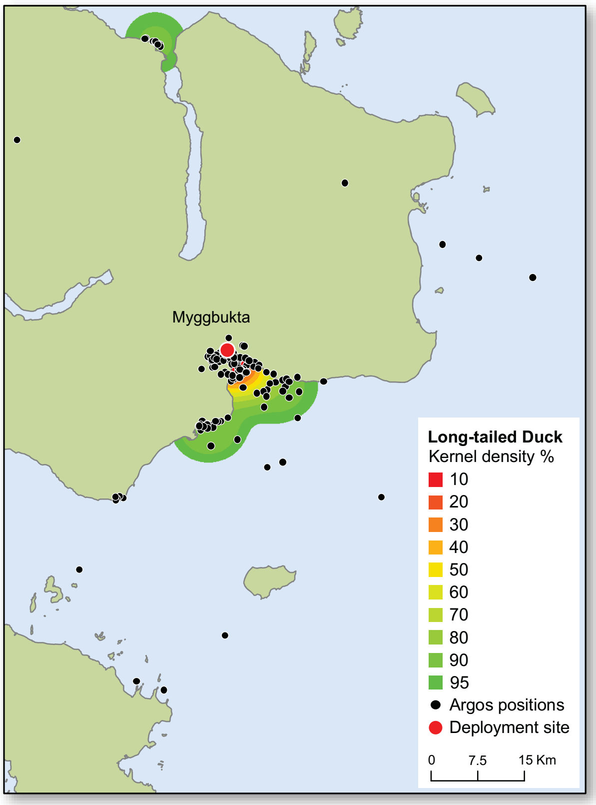



**Figure 1.** Locations and track lines for 6 long-tailed ducks tracked from the breeding area Myggbukta from June 2007 to wintering areas in Iceland (3 birds) and Julianehåbbugten in Southwest Greenland (3 birds). Argos positions are the tracking locations of the birds.

**Figure 2.** Kernel home range for the long-tailed ducks tracked in the Myggbukta breeding area from mid-June to the autumn migration in September. Only the home range in the marine habitat is shown. The Kernel home range presents an estimation of the probability of finding an animal in a defined area based on the Argos satellite location points that have been collected over a period of time. Thus 95 % of the locations are found within the 95 % probability contour.



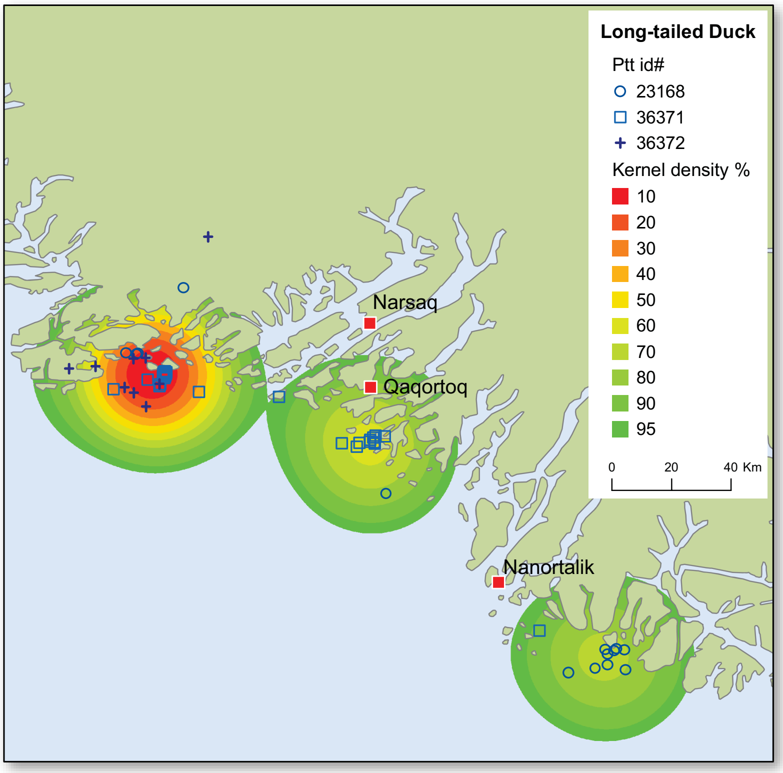




**Figure 3.** Kernel home range for 3 long-tailed ducks wintering in Julianehåbsbugten. Birds arrived in September 2007 (16/9, 17/9 and 2/10) and the last locations for the 3 birds were received 6/12, 2/1 and 10/3, respectively. PTT_36371 and PTT_36372 were marked as a pair. PTT indicates the transmitter identity.

were usually small with less than 100 birds but at a few sites, e.g. the coast of Wollaston Forland, more than 1,000 birds were recorded off a river outlet (Figure 19). Moulting king eiders were only seen on the Blosseville Coast, where a flock of approx. 150 were found in a fjord (Figure 19).

Some coastal habitats, such as sedimentary beaches, deltas and lagoons, also attract birds from terrestrial and freshwater habitats during the summer and migration periods, primarily shorebirds and geese.

### 4.6.2 Important and critical marine habitats for birds

Besides the breeding colonies described in the sections above, many other areas are important to seabirds within the assessment area.

Polynyas (Figure 5) are particularly important as staging and feeding areas in the spring when the sea elsewhere is covered with ice. Large numbers of seabirds assemble in such areas, mainly the mouth of Scoresby Sund, off Wollaston Forland and the Northeast Water (Meltofte 1976, Falk *et al.* 1997, NERI 2008 unpubl. data). These sites are of regional importance, holding birds from a large region for a short period.

In spring, open waters (besides the polynyas) at river outlets, straits, etc also provide feeding and staging possibilities to waterbirds in spring before the inland breeding habitats become accessible. Such sites may be important on a local scale. No such sites were seen during the 2008 spring survey.

Moulting ducks often assemble in undisturbed areas, and concentrations are known from the Scoresby Sund area (see above, common eider), but other moulting areas may be found within the assessment area. Such sites are particularly sensitive to disturbance, from e.g. low-level helicopter flights. During the 2008-survey, moulting common eiders were found dispersed along many coasts, but not in large concentrations. Most were found in the fjords of the Blosseville Coast, where the only concentration of moulting king eiders was also found. Moulting long-tailed ducks were seen at many sites, mainly in shallow bays and at river outlets. The highest numbers was approx. 1,000 at the coast of Wollaston Forland (Figure 18).

As mentioned above the marginal ice zone in the Greenland Sea may be a very important habitat for migrating seabirds in spring. The major part of these birds has their breeding grounds in Svalbard and wintering grounds in Southwest Greenland and Newfoundland waters. In the Barents Sea the marginal ice zone is designated as a particularly important area, e.g. due to concentrations of feeding seabirds in spring, and the marginal ice zone of the Greenland Sea may have a similar significance. As the drift ice in the Greenland Sea is less dynamic, at least in overall distribution (multi-year ice), than in the Barents Sea, a marginal ice zone may also occur (at least locally) in autumn and be similarly important. In autumn 2008, there was however very little drift ice in the assessment area and no ice edges were apparent (Figure 21).

## 4.7 Marine mammals

The marine mammals constitute another important element of the KANUMAS East ecosystem. Four species of seals, eleven species of whales, walrus and polar bear occur (Table 2). Polar bear and walrus are the best studied species within the assessment area, and therefore their accounts are more detailed and comprehensive than those for the other species.

**Table 2.** Overview of marine mammals occurring in the assessment area. Red List status from Boertmann (2008). Importance of study area to population (Conservation value) indicates the significance of the population occurring within the assessment area in a national and international context as defined by Anker-Nilssen (1987).

| Species | Period of occurrence | Main habitat | Distribution and occurrence in assessment area | Protection/ exploitation | Greenland Red List status | Importance of assessment area to population | VEC |
|---|---|---|---|---|---|---|---|
| Polar bear | Whole year | Mainly ice-covered waters | widespread | Hunting regulated | Vulnerable (VU) | High | + |
| Walrus | Whole year | Coastal waters | Low numbers, very localised | Hunting regulated | Near Threatened (NT) | High | + |
| Hooded seal | March-October | Whelp on drift ice | Numerous | Hunting unregulated | Least Concern (LC) | High | + |
| Harp seal | March-October | Whelp on drift ice | Numerous | Hunting unregulated | Least Concern (LC) | High | + |
| Bearded seal | Whole year | both in coastal and offshore waters | Widespread in low numbers | Hunting unregulated | Data Deficient (DD) | High | + |
| Ringed seal | Whole year | Whole area, usually in ice | Common and widespread | Hunting unregulated | Least Concern (LC) | High | + |
| Bowhead whale | Whole year? | MIZ | Widespread, very few | Protected since 1932) | Critically Endangered (CR) | High | + |
| Minke whale | June-October | Ice-free waters | Unknown* | Hunting regulated | Least Concern (LC) | Pot. medium | |
| Sei whale | June-October | Ice-free waters | Unknown* | Protected | Data Deficient (DD) | Pot. medium | |
| Blue whale | July-October | Ice-free waters | Unknown* | Protected (1966) | Data Deficient (DD) | Pot. medium | + |
| Fin whale | June-October | Ice-free waters | Unknown* | Hunting regulated | Least Concern (LC) | Pot. medium | |
| Humpback whale | June-October | Ice-free waters | Unknown* | Protected (1986) | Least Concern (LC) | Pot. medium | |
| Pilot whale | June-October | Outside the ice-covered areas | Unknown* | Hunting unregulated | Least Concern (LC) | Probably low | |
| White-beaked dolphin | June-October | Outside ice-covered areas | Unknown* | Hunting unregulated | Not Applicable (NA) | Probably low | |
| Killer whale | June-August | Mainly ice-free waters, whole area | Unknown* | Hunting unregulated | Not Applicable (NA) | Unknown | |
| White whale | Summer | Fjords and shallow waters | Very rare | Hunting unregulated | Critically Endangered (CR) | Low | |
| Narwhal | Whole year | Fjords, ice edges | Common | Hunting unregulated | Data deficient (DD) | High | + |
| Sperm whale | May-November | Deep waters, southern part | Unknown | Protected (1985) | Not Applicable (NA) | Probably low | |
| Northern bottlenose whale | May-November | Deep waters only, mainly southern part | Probably rare | Unregulated | Not applicable (NA) | Probably low | |

* No or limited data available for the assessment area, but species is abundant in neighbouring Norwegian and/or Icelandic waters.

### 4.7.1 Marine mammals, species treated in detail

Polar bear and walrus are the best studied species within the assessment area, and therefore their accounts are more detailed and comprehensive than those for the other species.

**Polar bear *Ursus maritimus***

*Distribution*: The distribution of polar bears in the East Greenland area based on observations made by sealers, various expeditions and subsistence hunters living in the area – and catch statistics – was summarised by Petersen (1945), Born (1983), Dietz *et al.* (1985), Born & Rosing-Asvid (1989), Born (1995) and Sandell *et al.* (2001). Furthermore, studies involving satellite telemetry during spring 1979 (Larsen *et al.* 1983) and 1993-1998 (Born *et al.* 1997, Wiig *et al.* 2003) provided detailed information on movement of individual polar bears and habitat selection (Durner *et al.* 2007, 2009). A study initiated in March 2007 involving the use of satellite transmitters aims to provide supplementary and updated information on distribution, movement and habitat use of polar bears in the KANUMAS East assessment area (Figure 23).

Generally, polar bears are relatively frequent and abundant in the entire assessment area, but the area used by polar bears is seasonally and annually variable and is to a large extent governed by fluctuations in the distribution and density of ice and prey. Polar bears prefer areas with relatively dense sea ice at the continental shelf (Born *et al.* 1997, Wiig *et al.* 2003, Durner *et al.* 2007, 2009). Polar bears in East Greenland occupy the 'region of convergent sea ice' or 'the convergent ecoregion' (Amstrup *et al.* 2007, Durner *et al.* 2007, 2009). This region encompasses the Northern Beaufort Sea, the Arctic Basin and the East Greenland subpopulations of polar bears (Aars *et al.* 2006, Durner *et al.* 2007, 2009). The Beaufort Gyre and the Transpolar Drift Stream transport-persistent and older ice result in in an 'accumulation' of older ice along the northern shores of the Canadian Arctic Archipelago and North Greenland as well as along the east coast of Greenland (Durner *et al.* 2007, 2009). This allows polar bears in these areas to occupy 'near-shore' ice throughout the year.

The distribution of polar bears in eastern Greenland is largely determined by the extent of the pack ice coverage along the different parts of the coast (Born 1995). During minimal ice conditions in summer and early autumn some bears occur on the remnants of land-fast ice or on land (Born & Wiig 1995). Others are able to navigate on the offshore pack ice (Born *et al.* 1997, Wiig *et al.* 2003, Born *et al.*, unpublished data) the extension of which differs from year to year (Divine & Dick 2006).

Historical and recent observations of polar bears and their tracks show that polar bears range along the entire coast of East Greenland and on the offshore pack ice in the Fram Strait and the Greenland Sea in the KANUMAS assessment Area (Larsen *et al.* 1983, Dietz *et al.* 1985). Observations recorded by whalers and expeditions (Dietz *et al.* 1985), and studies involving satellite telemetry (Born *et al.* 1997, Wiig *et al.* 2003, Born *et al.* unpublished data; Figures 23, 24) confirm that polar bears are widely distributed in the offshore pack ice in this are, also during summer when they prefer areas with dense ice and ice edges (Wiig *et al.* 2003, Born *et al.* unpublished data).

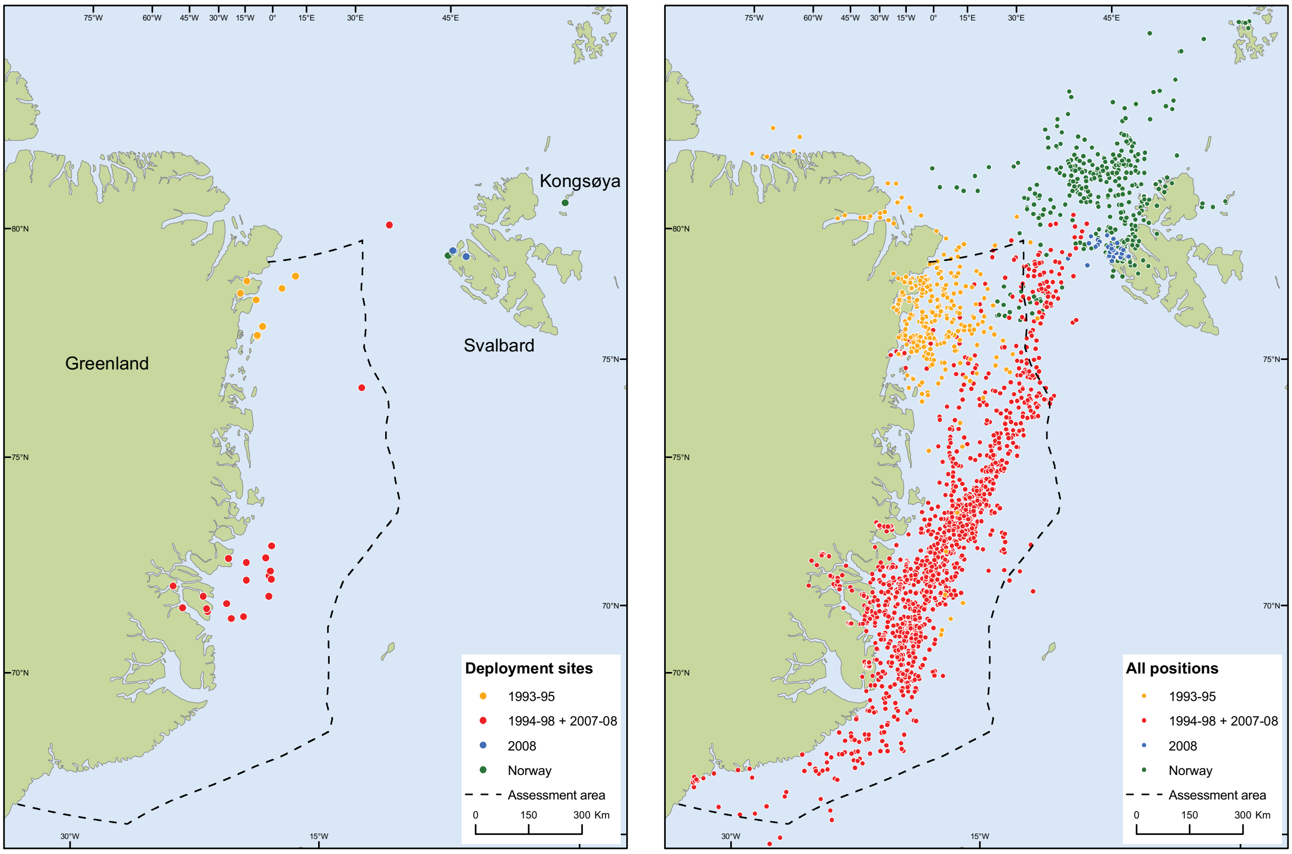


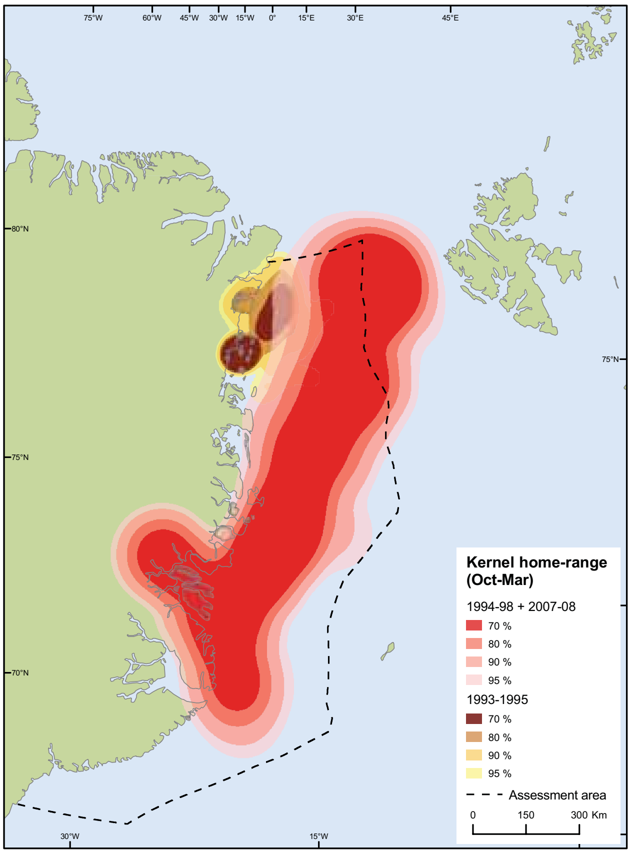

**Figure 23.** Map to the left: Locations where 35 polar bears have been instrumented with satellite transmitters that were used in this report to describe movement in the East Greenland and northwestern and northern Svalbard region during 1993-95, 1994-May 2008. Map to the right: Distribution of all locations in the East Greenland – North and Northwest Svalbard region during June 1993-May 2008 received from 35 polar bears instrumented with satellite transmitters. Source: Born *et al*. 1997, Wiig *et al*. 2003, Greenland Institute of Natural Resources, National Environmental Research Institute and Norwegian Polar Institute unpublished data.

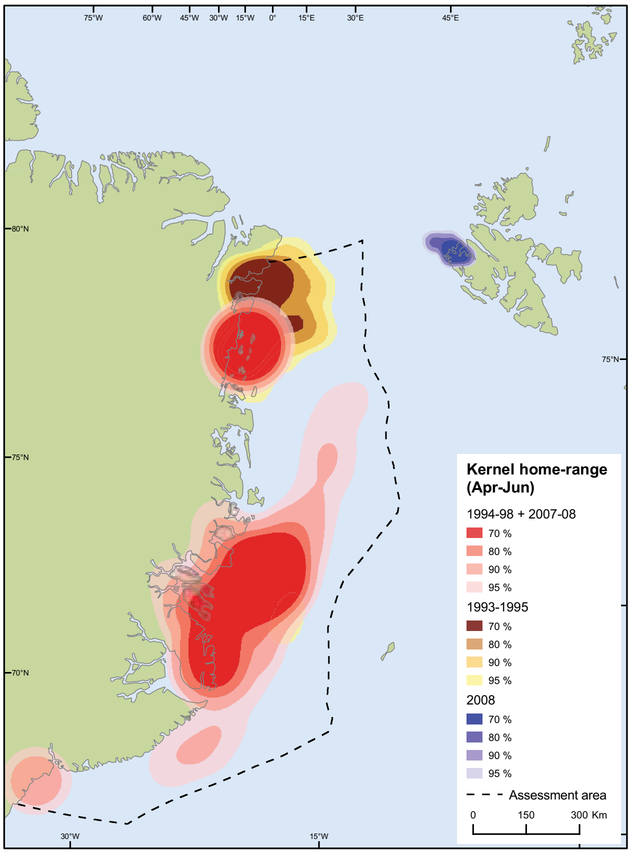
Recurrent polynyas at the entrance to Scoresby Sound, Kejser Franz Josef Fjord, Shannon, Dove Bay, Île de France and the Northeast Water are areas where polar bears frequently occur (Pedersen 1945, Born 1983, Dietz *et al.* 1985, Sandell *et al.* 2001). Polar bear predation on harp and hooded seals at their East Greenland aggregation sites along the ice edge has been reported (Dietz *et al.* 1985 and references therein) and satellite telemetry also confirms that polar bears are attracted to the whelping and moulting patches of these seals (Wiig *et al.* 2003).

Some polar bears are brought with the pack ice from East Greenland to Southwest Greenland as far north as Paamiut (approx. 62° N) in West Greenland (Vibe 1967, Born 1995).

*Population and movements*: The polar bears in East Greenland are thought to constitute a single subpopulation with only limited exchange with other subpopulations (Born 1995, Wiig 1995).

A genetic study revealed significant differences between polar bears from East and West Greenland (Paetkau *et al.* 1999). Limited – if any – exchange between the polar bear subpopulations in these two regions was also indicated by differences in concentrations of mercury in hair and internal organs (Born *et al.* 1991, Dietz *et al.* 2000, 2006) and studies of movements (Born *et al.* 1997, Taylor *et al.* 2001, Wiig *et al.* 2003).



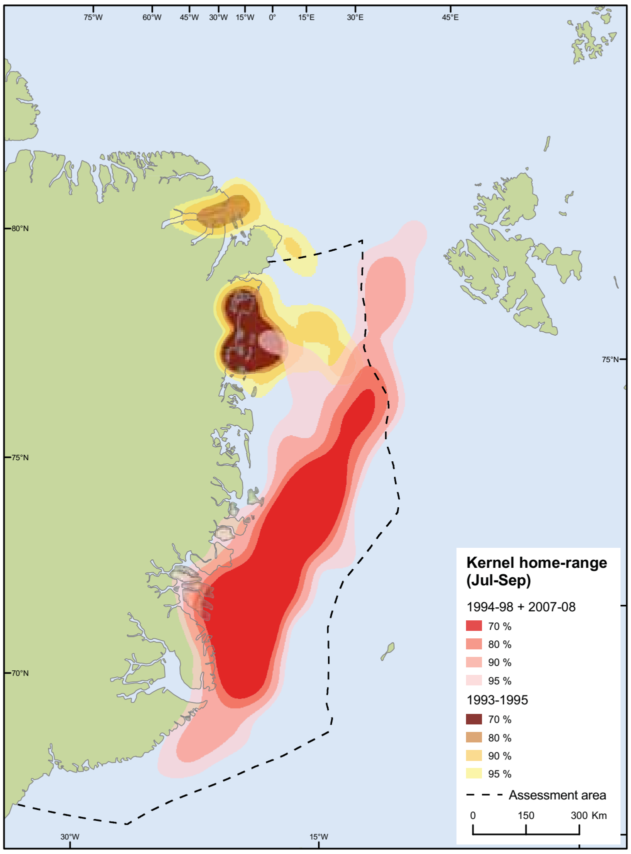




**Figure 24.** "Winter" (October-March) Kernel home-range contours of the East Greenland subpopulation of polar bears based on satellite telemetry tracking of a total of 28 polar bears (18 females, 10 males) during June 1993 – May 2008. "Spring" (April-June) Kernel home-range contours of the East Greenland subpopulation of polar bears based on satellite telemetry tracking of a total of 31 polar bears (21 females, 10 males) during June 1993 – May 2008. "Summer" or "open-water season" (July-September) Kernel home-range contours of the East Greenland subpopulation of polar bears based on satellite telemetry tracking of a total of 28 polar bears (18 females, 10 males) during June 1993 – May 2008. Deployed in Greenland: Brown-yellow – 1993-1995, N = 7 bears; red –1994-1998 and March 2007- May 2008, N = 21 polar bears; blue – deployed at NE Svalbard April 2008, N = 3. The definition of season relevant to polar bear ecology follows Born *et al*. (1997) and Wiig *et al*. (2003). For deployment sites and tracking periods see Fig. 1. Sources: Born *et al*. 1997, Wiig *et al*. 2003, Greenland Institute of Natural Resources, National Environmental Research Institute and Norwegian Polar Institute unpublished data). Polar bears exploit vast areas of the fast ice and pack ice in eastern Greenland for the majority of the year. Furthermore, an unknown proportion of polar bears from Svalbard (green) make use of the pack ice in the KANUMAS Assessment Area in the Fram Strait.

However, there was only minimal genetic difference between East Greenland and the neighbouring Barents Sea (i.e. Svalbard-Franz Josef Land) subpopulation to the east (Paetkau *et al.* 1999). Interestingly, polar bears from East Greenland were grouped with the Chukchi Sea, the Southern and Northern Beaufort Sea and the Barents Sea subpopulations indicating that the East Greenland subpopulation is not genetically isolated from these other subpopulations (Paetkau *et al.* 1999).

Movement of individual polar bears has confirmed that some individuals may migrate from other areas of the Arctic to East Greenland. Three polar bears that were marked on the pack ice north of Northeast Greenland, Svalbard and Franz Josef Land north of 82° N before 1982 were later shot in East and Southwest Greenland (Born 1995 and references therein, Wiig 1995). In the early 1990s, two polar bears instrumented with satellite radios in the Southern and Northern Beaufort Sea, respectively, visited Northeast Greenland (Durner & Amstrup 1995, Durner *et al.* 2007, 2009). During the same period two polar bears that had been marked on Baffin Island (Canada) and in the northern Beaufort Sea, respectively, were shot in East Greenland (Born 1995). This indicates that some polar bears mainly from the active ice in the rim of the Polar Basin migrate to East Greenland, presumably reflecting the main movement of the drift ice in the Polar Basin and East Greenland. However, given the fact that over the years several hundred polar bears have been tagged in the Southern and Northern Beaufort Sea (e.g. Stirling 2002, Regehr *et al.* 2006 and references therein), the migration of bears from these areas to East Greenland appears to be negligible.

Movement of conventionally marked bears and satellite telemetry indicate that there is limited exchange between the East Greenland and Barents Sea subpopulations (Born 1995, Born *et al.* 1997, Wiig 1995, Born *et al.* unpublished data, Figure 23, 24).

During 1966–1993, only 2 of 389 (0.5 %) bears conventionally marked at Svalbard had been caught in the East and Southwest Greenland (Wiig 1995) despite an annual catch of about 90 polar bears there during this period (Born unpublished data). After 1993 and until present a total of 1,076 polar bears (including juveniles) have been tagged in the Svalbard archipelago (Aars unpublished data), to our knowledge with no subsequent recoveries in East and Southwest Greenland.

Movement of polar bears that were instrumented with satellite-transmitters in East Greenland (N = 9; Born *et al.* 1997, Wiig *et al.* 2003) and at southern Svalbard, Franz Josef Land and the Kara Sea (N = 105; Wiig 1995, Mauritzen *et al.* 2002) before 2000 did not show any overlap in habitat use. An exception was a polar bear that made an excursion from Kongsøya in the eastern part of the Svalbard archipelago towards Northeast Greenland at 82°–83° N and approx. 20° W in 2000 (Wiig *et al.* 2000, Mauritzen *et al.* 2002, Born *et al.* unpublished data; Figure 23, 24).

However, in the mid-1990s satellite telemetry indicated that there might be some overlap in distribution in the Fram Strait and East Greenland Sea by East Greenland and Svalbard polar bears. A total of 21 satellite radios were deployed in March 2007 and 2008 in East Greenland. Additionally, three satellite radios were deployed in April 2008 in the Svalbard area (preliminary data shown in Figure 23). The majority of satellite radios deployed in Svalbard by the Norwegian Polar Institute since 1988 have been deployed in the southeastern parts of the archipelago (Wiig 1995, Aars *et al.* unpublished data). Only one out of 220 polar bears instrumented in this area made an excursion west where it came as close as approx. 100 km of the Nordostrundingen in Northeast Greenland (Aars *et al.* unpublished data). However, in the present context it is noteworthy that three out of 16 (approx. 19 %) polar bears that were instrumented in northern and northwestern Svalbard in 2006 and 2007 made migrations north of Svalbard and towards Northeast Greenland and in one case into the Fram Strait (i.e. the KANUMAS assessment area), thereby overlapping with the range of the East Greenland polar bears (Aars *et al.* unpublished data, Figure 23, 24). A polar bear tagged in central East Greenland during March 2007 came as close as 100 km from the north eastern corner of Svalbard. This indicates that in recent years there has been some overlap between the ranges of East Greenland and Svalbard polar bears. This indicates that a certain and yet undetermined proportion of the Barents Sea subpopulation of polar bears may potentially be affected by oil activities in East Greenland.

Existence of separate subpopulations in these regions was further supported by the finding of significant differences in prevalence of various cranial traits in East Greenland and Svalbard-Franz Josef Land polar bears (Henrichsen & Sjøvold 1986, Henrichsen 1988, Sonne *et al.* 2007, Bechshøft *et al.* 2008a, b, c).

*Movements and habitat use*: There are indications that polar bears may occur in ‘local’ groups in East Greenland. During tagging studies conducted during 1973–1975 a small group of polar bears showed a high degree of fidelity during spring to the coastal areas between approx. 72° and approx. 73° N (Vibe 1976a, b, Born & Rosing-Asvid 1989). Two bears that were tagged in this area in 1994 were killed by Greenlandic hunters in the same area in 1996 and 1999, respectively (Born & Wiig 1995, Sandell *et al.* 2001).

Long-term site tenacity to regions in East Greenland was also indicated in a study of heavy metals. Polar bears that were shot in the coastal areas north of 72° N (1983–1990) had significantly different loads of mercury and cadmium than polar bear shot further south (Dietz *et al.* 2000).

Polar bears typically show fidelity to den and spring feeding areas (Ramsay & Stirling 1990, Wiig 1995). Two adult females that were tracked during 1994–1998 (Wiig *et al.* 2003) showed an affinity during the open-water period to the coastal areas where they had been instrumented (72º and 73º N). However, these bears spent most of their time roaming the offshore pack ice. Therefore, it is likely that the females studied during spring in 1973–1975 (Vibe 1976a, b, Born and Rosing-Asvid 1989) also had large home ranges but returned annually to the same denning and spring feeding areas. Indications of the existence of ‘local groups’ in East Greenland are therefore not unequivocal. A tendency of seasonal site tenacity was also found during satellite tracking of bears between 78° and 81° N in East Greenland (Born *et al.* 1997).

The tendency that some polar bears can be found in the same area during the same season in consecutive years while exploiting much larger areas during their annual cycle has also been reported from other parts of the Arctic where polar bears inhabit areas with dynamic pack ice (Wiig 1995, Amstrup *et al.* 2000, Mauritzen *et al.* 2002).

According to coastal observations made by hunters living in East Greenland there is a general ‘passive’ transport of polar bears south with the drifting ice and an ‘active’ movement north along the coast (Dietz *et al.* 1985, Sandell *et al.* 2001). However, satellite telemetry studies have shown that polar bears are able to move south and north in the pack ice irrespective of the general southward movement of the ice floes in the East Greenland Current (Larsen *et al.* 1983, Born *et al.* 1997, Wiig *et al.* 2003, Born *et al.* unpublished data). Wiig *et al.* (2003) suggested that the distribution of polar bears in East Greenland pack ice likely reflects behavioural rather than physical processes, similar to the case of the polar bears in the Barents Sea (Mauritzen *et al.* 2003). The highest rates of movement occurred from April to September. A higher rate of movement in summer than in winter potentially relates to the slower southward ice drift of the East Greenland Current in summer than in winter or it may reflect increased feeding activity during the summer (Born *et al.* 1997, Wiig *et al.* 2003).

Generally, polar bears inhabiting active and highly fluctuating offshore ice make use of considerable areas of sea-ice covered habitat during the year. They have larger home ranges than bears inhabiting land-fast ice (Ferguson *et al.* 1999, Amstrup *et al.* 2000, Mauritzen *et al.* 2002). Satellite-telemetry during 1993–1998 has indicated that the home range of polar bears exploiting the offshore pack ice for most of the year are on average are approximatley five times larger than those of polar bears that prefer coastal habitat (mean: approx. 50,000 $km^2$) (Born *et al.* 1997, Wiig *et al.* 2003).

*Size of the East Greenland subpopulation*: The habitat used by polar bears basically encompasses all fast ice and offshore pack ice along the entire East Greenland coast. There have been no population inventories covering this vast area and the size of the East Greenland subpopulation is not known (e.g. Aars *et al.* 2006).

A mark-recapture study conducted in the fjords and along the coast between Kong Oscars Fjord and Dove Bugt in 1973–1975 (Vibe 1976a,b) resulted in an estimate of approx. 180 polar bears in the coastal areas between approx. 72° and approx. 77° N (Born & Rosing-Asvid 1989).

Given the estimates of the proportion of adult females found in a sample of the catch in the Scoresby Sound area and a catch of approx. 70 / year during 1993–2005 (i.e. after introduction of a new catch recording system and before the introduction of quotas in 2006) in East and Southwest Greenland combined, a minimum subpopulation of approx. 2000 individuals would be have been needed to have sustained this take. However, the actual number of animals in the exploited subpopulation is not known (Aars *et al.* 2006).

*Critical habitats – denning*: Female polar bears move to coastal areas in autumn where they dig a burrow in a snowdrift (a maternity den) and here give birth to their cubs in late winter. No studies have been conducted to specifically identify or locate areas with maternity dens in East Greenland. However, miscellaneous observations of maternity dens and family groups with 0-year-old cubs indicate that maternity dens may occur along the entire East Greenland coast with an apparent tendency of higher densities north of approx. 68° N (Pedersen 1945, Born 1983, Dietz *et al.* 1985, Born & Rosing-Asvid 1989, Glahder 1995, Born *et al.* 1997, Sandell *et al.* 2001, Wiig *et al.* 2003), where ice and weather conditions are generally more stable than further south (Vibe 1967). The data indicate that the following areas are regularly used for denning: Kangerlussuaq, the Blosseville Coast, the inner parts of the Scoresby Sound fjord complex, the areas between Kong Oscars Fjord and Kejser Franz Joseph Fjord, Shannon, Dove Bay, the areas between Île de France and Ingolf Fjord, and the coast at the Northeast Water.

Amstrup & Gardner (1994) suggested that polar bears that exploit the drifting pack ice until just before den entry have a less predictable choice of denning location that bears living on stable ice. This was also indicated in Wiig *et al.* (2003) where a female in different years entered maternity dens that were situated more than 500 km apart on the East Greenland coast. It is likely that some polar bears exploiting the dynamic pack ice in the East Greenland Current may choose highly alternating sites for maternity denning and that their choice depends on the extension and density of the pack ice before den entry in that particular year.

Larsen *et al.* (1983) noted that approx. 90 % of the tracks that were observed during the FRAM I expedition at approx. 83° N off Northeast Greenland were of females with small cubs. Based on the distance of such tracks from the coast and with the resemblance to the ice situation off the northern coast of Alaska where polar bears use maternity dens in offshore pack ice, Amstrup & DeMaster (1988) suggested that maternity dens may also be found on the multi-year pack ice in Northeast Greenland. However, this has not yet been confirmed during studies involving tracking of adult female polar bears (Born *et al.* 1997, Wiig *et al.* 2003, Born *et al.* unpublished data).

The catch: Polar bears are caught by subsistence hunters living in the former municipalities of Scoresbysund and Tasiilaq in East Greenland (e.g. Sandell *et al.* 2001). In addition, an average of approx. 7 bears / year (range: 0–16 / year) are taken by hunters living in Southwest Greenland and these bears have their origin in the East Greenland population (Born 2007).

In East Greenland, the majority of the catch activity takes place within approx.100 km of the permanently populated areas and generally not far from the coast (Glahder 1995, Born 1983, Sandell *et al.* 2001). However, in some cases hunters from the community at the entrance to Scoresby Sound make sled trips on the fast ice in the fjords and along the coast to hunt polar bears as far north as the Dove Bay (approx. 77° N) (Born 1983, Sandell *et al.* 2001). Apparently, it was common to make such trips in the 1970s and 1980s, but hunting activity in the areas north of Scoresby Sound decreased during the 1990s (Sandell *et al.* 2001).

In Greenland, quotas for the polar bear hunt were introduced 1 January 2006 (Lønstrup 2006). The annual quota for the East Greenland subpopulation for the period 2007–2009 is 54 (30 in Scoresbysund, 20 in Tasiilaq and 4 in Southwest Greenland; Anononymous 2006). Prior to 2006 the catch fluctuated. During 1993–2005 the catch from the East Greenland subpopulation averaged approx. 60 polar bears per year (range: 46–84; Born 2007). However, at the beginning of the 20$^{th}$ century catches were much larger, averaging more than 100 bears per year (Vibe 1967, Sandell *et al.* 2001, Rosing-Asvid 2006). Since the early 1900s the catch of polar bears from the East Greenland subpopulation has decreased significantly (Sandell *et al.* 2001). It cannot be precluded that this tendency reflects an overall decrease in the exploited population.

*Conservation status*: Using 10 of the scenarios by the Intergovernmental Panel of Climate Change (IPCC) of projected decrease of sea ice and resource selection functions (RSF) based on data from satellite telemetry on polar bear habitat preferences, Durner *et al.* (2007, 2009) forecasted that optimal polar bear habitat in East Greenland will decrease substantially during the next 50–100 years. The decrease will be most pronounced during spring and summer. A decrease in sea ice in the southern range of the polar bears will imply that areas with optimal polar bear sea-ice habitat in Northeast and North Greenland will become more important. This prognosis is the main reason for listing the polar bear as 'Vulnerable' (VU) on the both the global and the Greenland Red List.

*Sensitivity*: While moving on pack ice the polar bears enter the water to swim (Aars *et al.* 2007), thereby increasing their risk of becoming fouled in the case of an oil spill. At Svalbard, four polar bears that were monitored for between 12 and 24 months with satellite-linked dive recorders spent an average of 0.9 to 13.1 % of their time per year in water. The maximum duration of swimming events ranged between 4.3 and 10.7 h, and dives reached 11.3 m depth (Aars *et al.* 2007). Polar bears are very sensitive to oiling as they depend on the insolative properties of their fur and because they may ingest toxic oil as part of their natural grooming behaviour (Øritsland *et al.* 1981, Geraci & St Aubin 1990). Therefore polar bears that get into contact with oil are likely to succumb (Isaksen *et al.* 1998).

Female polar bears in dens seem to be rather tolerant to disturbance, e.g. because the snow provides acoustic insulation. They will occasionally relocate if disturbed and will do so most frequently early in the denning season. There are examples of activities taking place rather close (500 m) to denning female bears without abandonment of the den (Linell *et al.* 2000). But there seem to be large variation in the individual thresholds among female bears with regard to leaving a den (Linell *et al.* 2000). Female brown bear with cups which have been forced to leave their den showed elevated cub mortality (Linell *et al.* 2000).

It is currently not possible to determine the fraction of the total number of polar bears in the East Greenland subpopulation that may be affected by oil exploration and potential exploitation because of lack of knowledge of the number of bears in this subpopulation.

### Walrus *Odobenus rosmarus*

The distribution of Atlantic walrus in the East Greenland area (Figure 25) based on observations made by sealers, various expeditions and subsistence hunters living in the area – and catch statistics – was summarised by Born (1983), Dietz *et al.* (1985), Born (1990, 2005), Born *et al.* (1995), Born (2005) and Aastrup *et al.* (2005). The following review of distribution and abundance is based mainly on these sources. In addition, several studies involving satellite telemetry have provided information on movements, occurrence and activity of walruses in Northeast Greenland during 1989–2001 (Born & Knutsen 1992, 1997, Born & Acquarone 2007, Born *et al.* 2003, 2005, Acquarone *et al.* 2006). The status of the walrus subpopulation in East Greenland was assessed by the North Atlantic Marine Mammal Commission in 1995 and 2005.

The following life history traits are relevant to evaluation of the potential effects on walruses from oil-related activities. Walruses are gregarious year

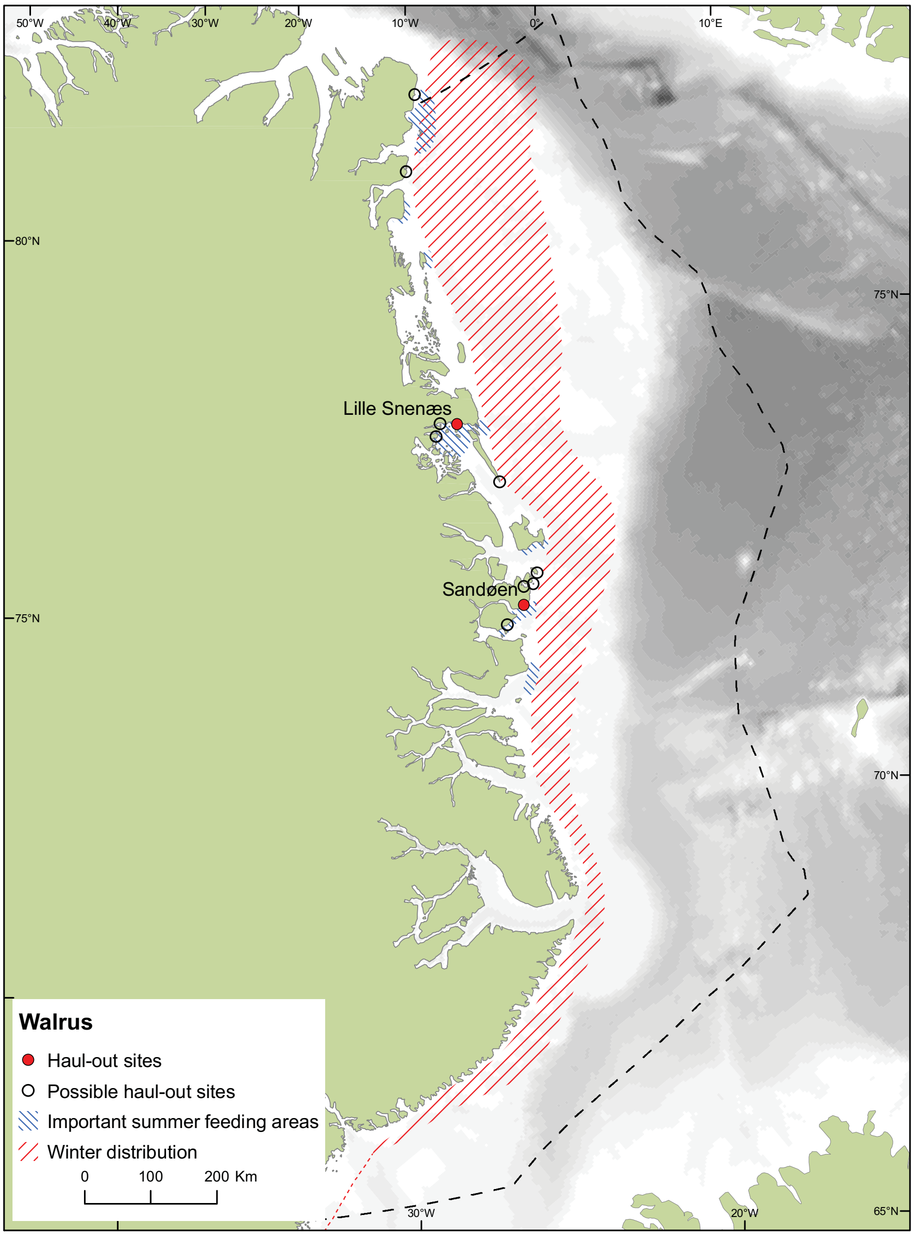



**Figure 25.** General distribution of walrus in the assessment area. Terrestrial haul-outs, both those regularly used and some which apparently are less frequently used are shown.

round (Fay 1982, 1985). They are benthic feeders that usually forage where water depths are less than approx. 100 m (Vibe 1950, Fay 1982, Born *et al.* 2003), although they occasionally make dives to at least 200–250 m depth, both inshore and offshore (Born *et al.* 2005, Acquarone *et al.* 2006). They use terrestrial haul-outs (‘*uglit*’, singular ‘*ugli*’) in the vicinity of shallow areas with suitable food and winter in waters with not too dense ice and predictable access to food (Born *et al.* 1995 and references therein). In East Greenland such habitat is mainly found north of approx. 73° N (Born *et al.* 1997). During the mating season (January–April; Born 2001, 2003 and references therein) male walruses engage in ritualized visual and acoustical display under water (Fay *et al.* 1984, Sjare & Stirling 1996, Sjare *et al.* 2003).

*Distribution*: In East Greenland walruses are mainly distributed north of the entrance to Kangersuttuaq / Scoresby Sound (approx. 70° N) (Born *et al.* 1997).

In several areas walruses are segregated by age and sex class for most of the year (Fay 1982, Born *et al.* 1995). This is also the case in East Greenland where there is a tendency that most adult females with young stay year round in the areas north of approx. 79° N whereas adult males make southward migrations along the coast to their traditionally used *uglit* (Born *et al.* 1997).

The few historical observations of walruses along the coast of southeastern Greenland, between the Tasiilaq area (Ammassalik) and the entrance to Scoresby Sound, are concentrated around the fjord of Kangerlussuaq and at the shallow banks along the northern parts of the Blosseville Coast, just south of the entrance to Scoresby Sound (Born *et al.* 1995 and references therein). A few walruses are occasionally caught in the Tasiilaq area. The seasonal distribution of catches indicates that walrus stragglers can occur in southeastern Greenland at all seasons with the possible exception of December (Born *et al.* 1997; Figure 26); however, catch records (1993–2006) show a peak in June–September (Born *et al.* 1997 and Figure 26). This seasonal pattern may represent a combination of increased boating activity during summer and a movement of walruses south along the coast from their northern wintering areas on the east coast.

When the town of Ittoqqortoormiit/Scoresbysund was founded in 1924/25 at the entrance to Scoresby Sound, walruses were apparently common there. They also hauled out on land in this area during summer and wintered in the polynya at the entrance to this fjord system. After only a couple of years of intensive hunting by the Inuit and foreign sealers walruses became scarce in the Scoresby Sound area, and only old males were observed occasionally during summer. It is probable that a resident group of walruses had been exterminated (Born *et al.* 1995, 1997).

Nowadays, single walruses or groups of 2–3 animals of both sexes and all age groups (except newborn) may occur at the entrance to Scoresby Sound

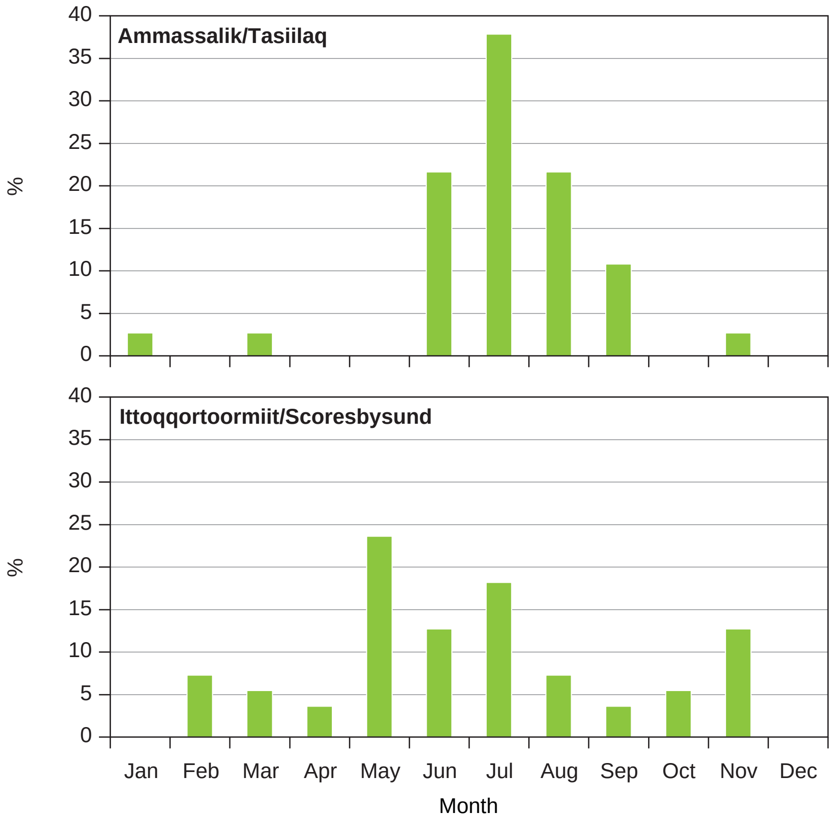



**Figure 26.** Seasonal distribution of the catch of walruses in the Tasiilaq area (above) (N=37) 1993–2006. The years 1994 and 2000 in which 60 and 99 walruses were reported to have been landed are not included as they clearly represent an artefact (Born 2005); Scoresbysund area (below) (N=55) 1993–2006. The years 1994, 1995 and 1999 in which 27, 46 and 26 walruses were reported to have been landed are not included either as the figures in these years are considered to be implausibly high (Born 2005). Source: Department of Fishery, Hunting and Agriculture, Nuuk).

in all seasons (Born 1983, Born *et al.* 1997) with a peak during May–July as reflected in the seasonal distribution of the catch (Figure 26). Similar to the situation further south this seasonal distribution of the catch may reflect both an increased hunting activity during spring and early summer, and an increased occurrence of walruses.

According to inhabitants living at the entrance to Scoresby Sound, the number of walruses frequenting this area have increased in recent years. The people ascribed this increase to the fact that walruses have been protected since the 1950s in the areas north of Scoresby Sound (Born 1983).

Observations of walruses between Scoresby Sound and the southern coast of Clavering Island (approx. 74° N) are few, presumably because there is little or no suitable walrus habitat in this area. The waters are relatively deep, both in the fjords and along the outer coasts (Born *et al.* 1997).

At the end of the 19th century until some point during the first half of the 20th century, walruses were common and used several *uglit* in the Clavering Island-Hochstetter Bay area, where sizeable concentrations were occasionally seen. Nowadays, small groups of walruses are observed along the coast between Clavering Island and the northern coast of Dove Bay (approx. 77° N). In these areas, regularly used *uglit* are found on Sandøen at the entrance to Young Sund and Lille Snenæs on the northern coast of Dove Bay, although some individuals have been observed while hauled out on land in other locations (Born *et al.* 1997, Born & Acquarone 2001, Gilg *et al.* 2003, Aastrup *et al.* 2005).

Several observations of walruses have been reported at Cape Borlase Warren, Cape Wynn, Sabine Island, Hvalros Island and Lille Pendulum Island at the promontory of Wollaston Forland. They also occur in the Kuhn Island area and along the south coast of Shannon Island. In these areas there can be open water during winter, and a polynya is present along the eastern coast of Wollaston Forland and southern coast of Shannon Island (Born *et al.* 1997).

Walruses are common in the Dove Bay area where they haul out on land regularly at Lille Snenæs (Born *et al.* 1997) and in recent years they have also been observed on land at Hvalrosodden (Born & Acquarone 2001) and at Port Arthur (Gilg *et al.* 2003). Apparently only males use these haul-outs (*Ibid.*).

North of Dove Bay walruses have been observed at several locations along the coast between Skærfjorden (approx. 77° 30' N) and Kilen (approx. 81° 14' N). Apparently they prefer the coastal areas between Dijmpha Sound (approx. 80° N) and Kilen where the water is shallow. A total of approx. 108 mainly adult female, young and newborn walruses were observed close to the coast between Kilen and Henrik Krøyer Holme on 3 June 1993 (Born *et al.* 1997). This is the highest concentration of walruses recorded in East Greenland in modern times. During a survey of the same area on 25 July 1993, 93 walruses were seen, of which 17 were recorded as small calves (Tahon & Vens 1994). During an aerial survey conducted by NERI in June 2008, 88 walruses, including at least 15 calves, were seen in open water at Kilen (NERI unpublished).

Although the majority of walrus observations have been made close to the coast, miscellaneous observations made during 1863–1992 indicate that walruses can also occur several hundred kilometres offshore during spring and summer (i.e. April–August; half of the observations recorded were from July–August) (Dietz *et al.* 1984, Born *et al.* 1997). Satellite telemetry has revealed that some individuals make foraging excursions more than 150 km offshore from their *uglit* in East Greenland (Born & Acquarone 2007, Born, unpublished data).

*Important and critical areas – terrestrial haul-outs/uglit*: The traditionally used *uglit* are an important element in the life history of walruses and walruses show great site tenacity to their *uglit*. In East Greenland it has been shown that some individually recognizable or tagged individuals have returned each summer to both the Sandø and Lille Snenæs *uglit* for many years (Born *et al.* 1997, Gilg *et al.* 2003, Born & Acquarone 2007). Although, a connection between groups of walruses using the different *uglit* has been observed (Born *et al.* 1997, Born unpublished data) individual walruses usually use the same *uglt*, from which they make foraging excursions during the summer (e.g. Born *et al.* 1997, Born & Knutsen 1997).

There are two very important *uglit* in the assessment area: Sandøen at the entrance of Young Sund and Lille Snenæs in Dove Bugt. Extensive studies have been carried out in recent years at both sites.

Sandøen is used regularly by a group of up to at least 81 different individuals (Born & Acquarone 2007). Apparently, the number of walruses using this *ugli* has increased since the early 1980s (Born *et al.* 1997). Although adult females with young occasionally have been observed at Sandøen, the group using this *ugli* primarily consists of adult males (Born *et al.* 1997, Born & Acquarone 2007).

The Lille Snenæs *ugli* is used each year by at least 50 adult males (Born & Knutsen 1992, 1997). The number of walruses hauling out on Lille Snenæs has increased significantly since the early 1950s, likely reflecting an overall increase in the East Greenland subpopulation of walruses (Born *et al.* 1997). In recent years walruses have also hauled out at the nearby sites Hvalrosodden (Born & Acquarone 2001) and Port Arthur (Gilg *et al.* 2003), also reflecting an increase in the population and an expansion of its range.

Other sites where walruses have also been observed on land include Cape Alf Trolle (southern tip of the island of Store Koldewey), and farther north in the Dijmphna Sound and Hanseraq Fiord areas at the coast of the Northeast Water (Dietz *et al.* 1985, Born *et al.* 1997).

There seems to be no regularly used *uglit* south of the entrance to Scoresby Sound.

Due to hunting, several *uglit* in the Scoresby Sound, Young Sound and Kuhn Island areas were abandoned at the beginning of the 20th century (Born *et al.* 1997).

*Important and critical areas – wintering areas*: The generally sedentary nature of walruses during winter and the inherent gregariousness of females appear to have been important factors influencing the evolution of the species' social behaviour and mating system (Sjare & Stirling 1996). Therefore wintering areas are important to the life history and survival of walrus subpopulations.

Various sources (Dietz *et al.*1985, Born *et al.* 1995, 1997) indicate that walruses winter in the following areas in East Greenland: the entrance to Scoresby Sound, the Gael Hamkes Bay area at Kap Borlase Warren along Wollaston Forland and Sabine Island, at Shannon Island, and the southern tip of Store Koldewey Island as well as farther north off Amdrup Land in the Eskimonæs and Antarctic Bay area. In these areas there are recurring polynyas with shallow water. Tracking of walruses instrumented with satellite-linked radios revealed that they can occur in the pack ice up to about 200 km offshore during winter, between approx. 78° N and 81° N (Born & Knutsen 1992, Born *et al.* 1997). The presence of polynyas at Île de France and at Hold with Hope (Born *et al.* 1997 and references therein) suggests that walruses may also winter there. It is likely that walruses also winter at other places along the coast in the shear zone between land-fast ice and the moving pack ice.

*Delineation of populations*: Genetic studies indicate that the walruses in East Greenland constitute a separate subpopulation which has only limited exchange with neighbouring subpopulations in West Greenland and at Svalbard-Franz Josef Land (Cronin *et al.* 1994, Andersen *et al.* 1998, Born *et al.* 2001, Andersen *et al.* in prep.). Satellite telemetry has supported the notion that walruses in East Greenland and at Svalbard-Franz Josef Land belong to two separate subpopulations as there has been no overlap in the ranges of the walruses that have been tracked in these two areas (Born & Knutsen 1992, Born *et al.* 2005, Born & Acquarone 2007, Wiig *et al.*1996, Freitas *et al.* in prep.).

Furthermore, genetic analyses (Andersen *et al.* 1998, Born *et al.* 2001, Andersen *et al.* in prep.) and photo-identification of individuals (Born *et al.* 1997) indicate that walruses that occur in Scoresby Sound, Young Sund, Dove Bugt and in Northeast Water polynya belong to one and the same population.

However, sporadic observations of walruses between eastern Greenland and Svalbard suggest that occasionally some individuals swim all the way across the Greenland Sea and Fram Strait (Dietz *et al.* 1985). The existence of such a connection was proven by the observation at Svalbard in 1992 of a walrus that had been tagged in eastern Greenland (77° N) in 1989 (Born & Gjertz 1993).

*Movements*: Seasonal movements along the coast have been demonstrated. Adult male walruses that were instrumented during summer at Lille Snenæs moved offshore during the period of formation of land-fast ice sometime in October. They subsequently moved north about 200–300 km offshore to winter in the Northeast Water area (Born & Knutsen 1992, Born *et al.* 2005), where apparently many (most?) of the adult female walruses occur year round (Born *et al.* 1997). The mating season in walruses is in winter with an apparent peak in January–April (Born 2001, 2003 and references therein). The movement north of adult male walruses and their wintering in the Northeast Water area indicate that this polynya is an important wintering and mating area.

The southward migration has not been documented. However, during July walruses return to their haul-outs in Dove Bay and Young Sound. The reappearance in Dove Bay in subsequent summers of individuals that were tracked during their fall migration shows a high degree of cyclic annual movement pattern and site tenacity (Born *et al.* 1997, Born *et al.* 2005).

*Size of the East Greenland subpopulation*: The number of walruses in the East Greenland subpopulation is not known and its status in relation to its pristine state is uncertain (NAMMCO 2005). However, based on various observations some estimates of population size have been presented. Andersen (1984) recorded a total of about 329 walruses between Nordostrundingen and Scoresby Sound. About 240 of these were observed between Kilen and Norske Øer. Based on aerial reconnaissance in June 1993, Born *et al.* (1994) tentatively concluded that not more than approximately 200 walruses were present between Eskimonæs (74° N) and Nordostrundingen (81° 30' N). This crude estimate is similar to that of Andersen (1984). Each of the two summering areas for males, Dove Bay and Young Sound (see above), has 50+ walruses during the open-water season, primarily adult males (Born & Knutsen 1992, Born & Acquarone 2007).

Based on these observations, a rough estimate of 500 to 1,000 animals in the eastern Greenland subpopulation was tentatively suggested by Born *et al.* (1995, 1997), who believed that the estimate of 1,000 including compensatory adjustments for animals missed during surveys was closer to the real order of magnitude than the estimate of 500. A relatively large proportion of this population is distributed north of approximately 79° N during much of the year.

Based on the population estimate of 1,000, the catch record and a net population increment of 2–5 % / year, Born *et al.* (1997) estimated that the East Greenland subpopulation numbered 1,500–1,900 animals in 1889 (i.e. before the initiation of intense catches by foreign sealers). Using a Baesian framework, Witting & Born (2005) estimated that the 'pristine' East Greenland subpopulation numbered approx. 1,600 animals in 1889.

*The catch*: Due to a general scarcity of walruses in southeastern Greenland, the catch in this region has always been very small (Dietz *et al.* 1984, Born *et al.* 1995, 1997). Since the 1980s the reported catch of walruses south of Scoresby Sound has averaged 3–4 per year (Born *et al.* 1995, Department of Fishery, Hunting and Agriculture, DFFL, Nuuk, unpublished data).

In the Scoresby Sound area walruses are taken at the entrance to the fjord complex (Born 1983, Sandell & Sandell 1991). They can be caught in all seasons with a peak in May–August (Born *et al.* 1997 and Figure 26). Although a few subadults and adult females are occasionally killed in the Scoresby Sound area, the catch consists mainly of adult males (Born *et al.* 1997). This likely reflects the southward migration along the coast of adult males during spring and summer and the fact that adult male walruses usually are less wary than females and young (Born 2005).

During 1993–2006 (1994, 1995 and 1999 not included due to implausibly high numbers reported), an average annual catch of 5.0 walruses (SD=3.4, range: 1–11 walruses, n=10 years) has been reported from this area (DFFL unpublished data) with no apparent trend (F=0.346, p=0.571, df:9 / 1).

Between 1889 and the 1950s foreign sealers and hunters and trappers killed a substantial number of walruses in Northeast Greenland, leading to decimation of the population (Born *et al.* 1997).

*Conservation status*: Today walruses are totally protected within the National Park in North and Northeast Greenland. In 1951 (i.e. before establishment of the national park in 1974), they became protected north of 74°

24´ N and since then the East Greenland subpopulation seems to have increased (Born *et al.* 1997, NAMMCO 2005).

To the south of the national park walruses are taken by hunters from Scoresby Sund and Tasiilaq (see previous section). These animals derive from the population further north. This hunt takes almost exclusively adult males and seems to be sustainable. The population has a favourable conservation status and is listed as 'Near Threatened' (NT) on the Greenland Red List, mainly due to the small numbers of individuals.

*Sensitivity*: Due to the highly localised distribution of the walruses within the assessment area, a large proportion of the population may be affected by a single and long-lasting incident – an oil spill or disturbance from permanent infrastructure or construction.

It is well known that walruses, particularly when hauled out on land, are sensitive to disturbance, including sailing, traffic on land, and flying (Born *et al.* 1995 and references therein). This was for example documented by Born & Knutsen (1990) who, based on fieldwork in the assessment area, concluded that air traffic should not go closer than 5 km to walrus haulouts in order to minimise disturbance.

An environmental impact assessment of sailing along the Northern Sea Route (the Northeast Passage) concluded that the walrus populations could be negatively impacted by disturbance from traffic and by oil spills (Wiig *et al.* 1996).

The effect of oil spills on walruses has not been studied in the field. However, Wiig *et al.* (1996) speculated that if walruses do not avoid oil on the water, they may suffer if their habitats are affected by oil and that they, like other marine mammals, can be harmed by both short-term and long-term exposure. Wiig *et al.* (1996) also pointed out that walrus feeding areas could be impacted, resulting in the ingestion of toxic bivalves or in the reduction of available food supply. This latter effect could be critical for walruses wintering in limited open-water areas. The high level of gregariousness may also make walruses especially sensitive to oil spills – many individuals will be affected by oil spills hitting an assemblage and oil may be transferred between individuals.

The most important walrus areas in the assessment area are the *uglit* (Sandøen, Lille Snenæs) and their surrounding waters, the summer concentration areas (coasts of Hovgaard Ø, Amdrup Land, Kilen) and winter concentration areas (shallow parts of the Northeast Water and the Wollaston Forland polynya).

### 4.7.2 Seals

Four species of seals occur in the assessment area. Two resident species, the ringed seal (*Phoca hispida*) and the bearded seal (*Erignathus barbatus*), and two which perform extensive seasonal migrations, the hooded seal (*Cystophora cristata*) and the harp seal (*Phoca groenlandica*).

The effects of oil on seals were reviewed by St. Aubin (1990). Seals are vulnerable to oil spills because oil can damage the fur, produce skin irritation and seriously affect the eyes as well as the mucous membranes that surround the eyes and line the oral cavity, respiratory surfaces, and anal and urogenital orifices. In addition, oil can poison seals through ingestion or inhalation. Finally, oil spills can have a disruptive effect by interfering with normal behaviour patterns.

Effects of oil on seals have the greatest impacts on the pups (St. Aubin 1990 and references therein). Pups are sessile during the weaning period and can therefore not move away from oil spills. They are protected against the cold by a thick coat of woolly hair (lanugo hair) and oil will have a strong negative effect on the insulating properties of this fur. The mother seals recognize their pups by smell and a changed odour caused by oil might therefore affect the mother's ability to recognize its pup.

Although the sensory abilities of seals should allow them to detect oil spills though sight and smell, seals have been observed swimming in the midst of oil slicks, suggesting that they may not be aware of the danger posed by oil (St. Aubin 1990).

**Hooded seal *Cystophora cristata***

This is a large migratory seal which, like the harp seal, assembles in whelping and moulting areas on the ice. Whelping takes place late March-early April and hooded seals nurse their pups for only a few days.

*Distribution*: The Greenland Sea population of hooded seals whelp and moult in the same area as the harp seals (Figure 27). This means that the position of the whelping grounds is highly variable between years, depending on the distribution of the drift ice; although the whelping seals are usually found within the assessment area. The hooded seals are, however, more scattered on the ice than the harp seals. Moreover, the moulting period for hooded seals – June-early July – is later than that for the harp seals. The ice edge will then usually be closer to the Greenland coast, and therefore the moulting area will have a more westerly position than the whelping areas.

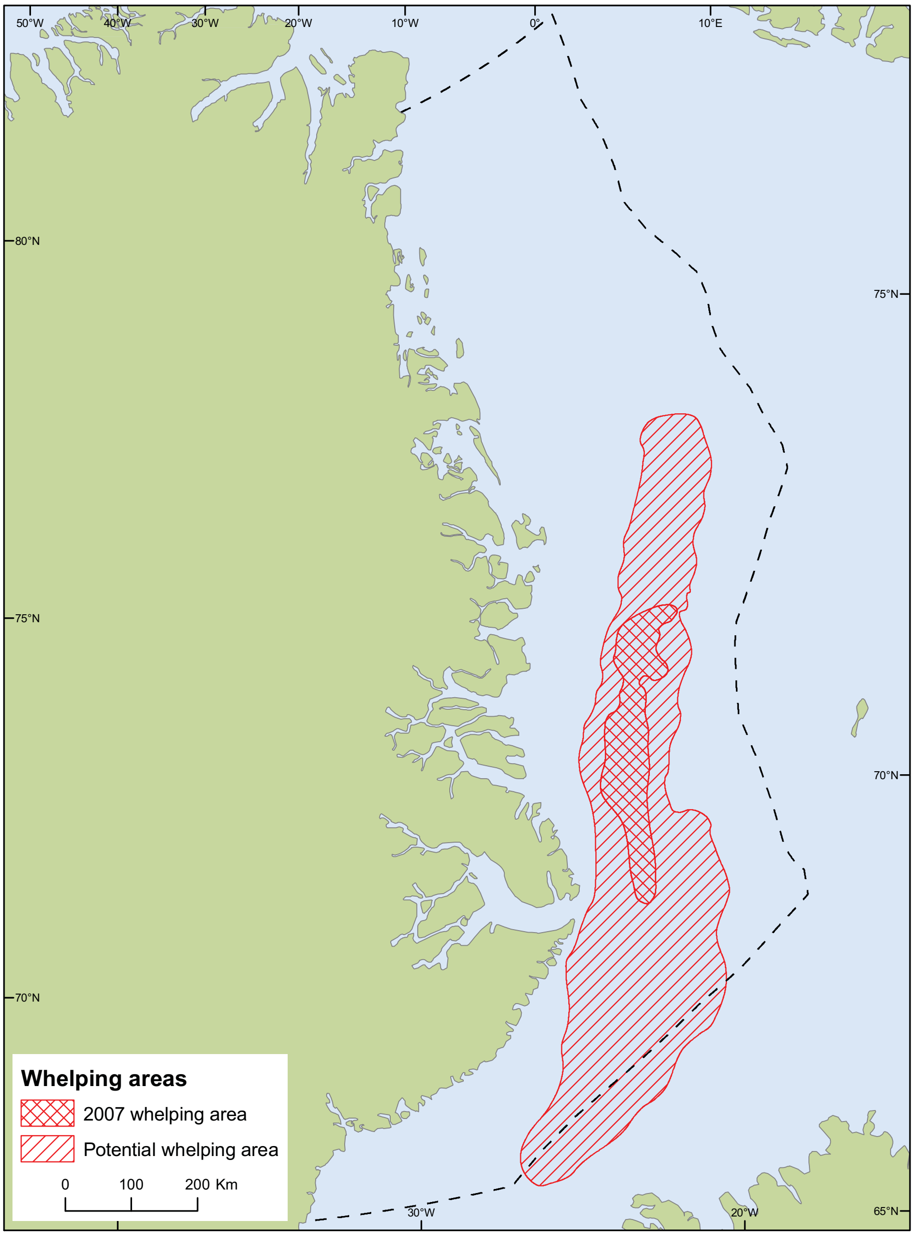
Outside the whelping and moulting season, the hooded seals disperse in the open waters and the drift ice in the North Atlantic and are generally most numerous in the eastern parts of the drift ice belt of the assessment area (Figure 28, 29).

*Biology*: Hooded seals are deep divers regularly feeding below 500 m depths. Adult seals mainly eat large fish and squids, while young eat mainly capelin and polar cod (Haug *et al.* 2004).

*Population*: The whelping hooded seals were surveyed in 2005 by Norwegian researchers, and the result was approx. 70,000 adult seals, which produced approx. 15,200 pups (Øigård *et al.* 2008). A new survey in 2007 resulted in an estimate of 15,370 pups (Øigård *et al.* 2008).

*The catch*: The hooded seal population in the Greenland Sea was strongly reduced by Norwegian sealers in the years following the Second World War. Quotas have regulated the sealing since the 1980s and the harp seals have doubled in numbers since then, whereas the hooded seals have failed to recover. Commercial catches of hooded seals have therefore been stopped, whereas subsistence hunting by Greenlanders is allowed to continue. The hunt from Scoresbysund takes only 10-20 seals / year.

**Figure 27.** The potential and the 2007 whelping area for harp and hooded seals in the Greenland Sea. The potential area is where the whelping has been recorded in recent decades. Source: Øigård *et al*. (2008).




*Conservation status*: The population has an unfavourable conservation status (see above under ‘Catch’). The hooded seal is listed as of ‘Least Concern’ (LC) on the Greenland Red List.

Reduction in the amount and distribution of sea ice induced by climate change will probably reduce the available whelping habitats for the hooded seals and negatively impact the population.

*Critical and important habitats*: The whelping and moulting grounds where high densities may occur in spring and early summer are the most critical habitats for hooded seals and during this period they are sensitive to both disturbance and oil spills.

### Harp seal *Phoca groenlandica*

Harp seals perform long seasonal migrations between whelping and moulting grounds in the drift ice and summer feeding areas in more or less ice-free waters.

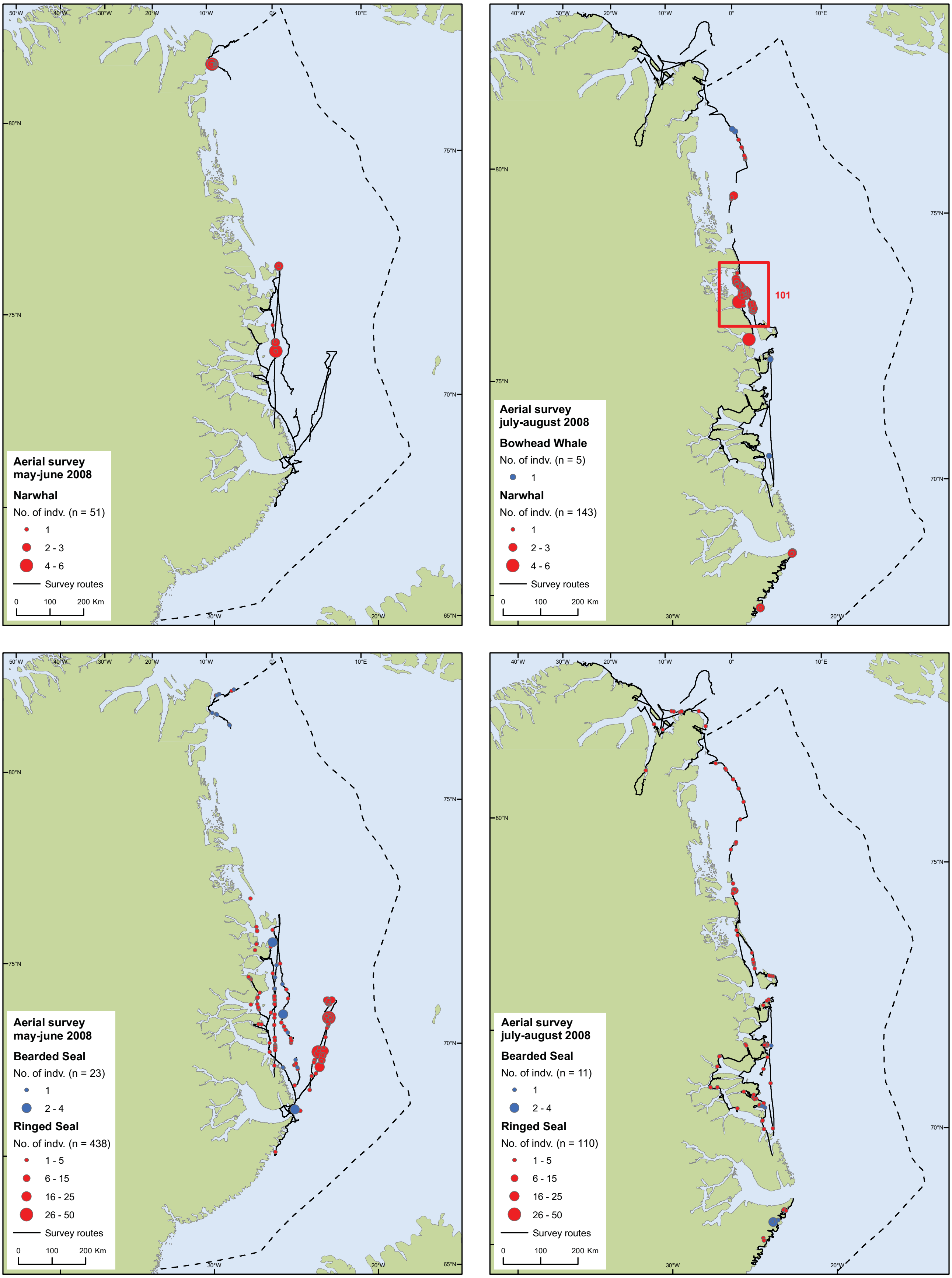



**Figure 28A.** Observations of marine mammals during the NERI aerial surveys in May/June and July/August 2008. Total numbers of narwhals recorded inside the frames area are given with red numbers. Total numbers of walruses are given for the framed areas with blue numbers.

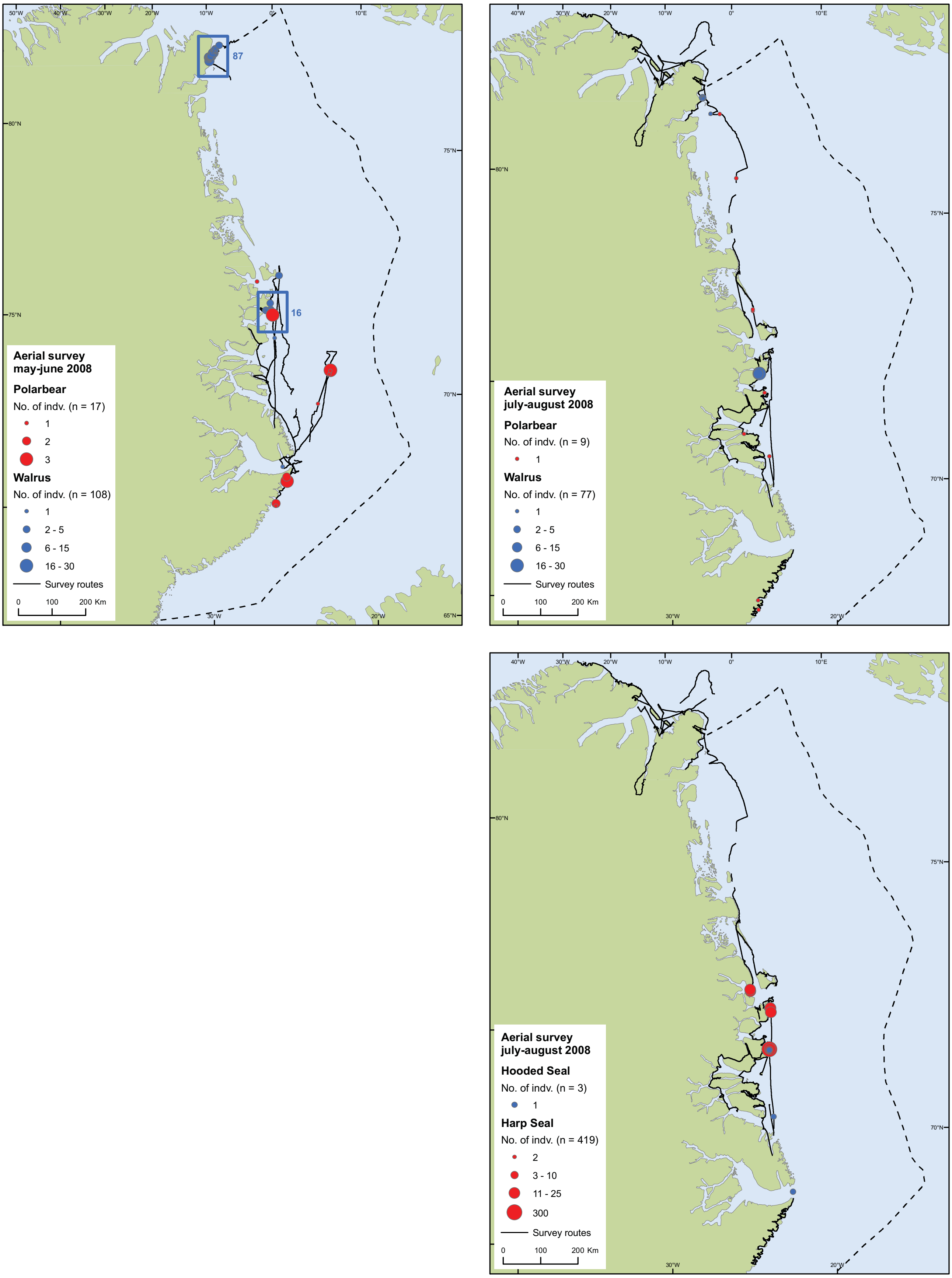



**Figure 28B.** Observations of marine mammals during the NERI aerial surveys in May/June and July/August 2008. Total numbers of narwhals recorded inside the frames area are given with red numbers. Total numbers of walruses are given for the framed areas with blue numbers.

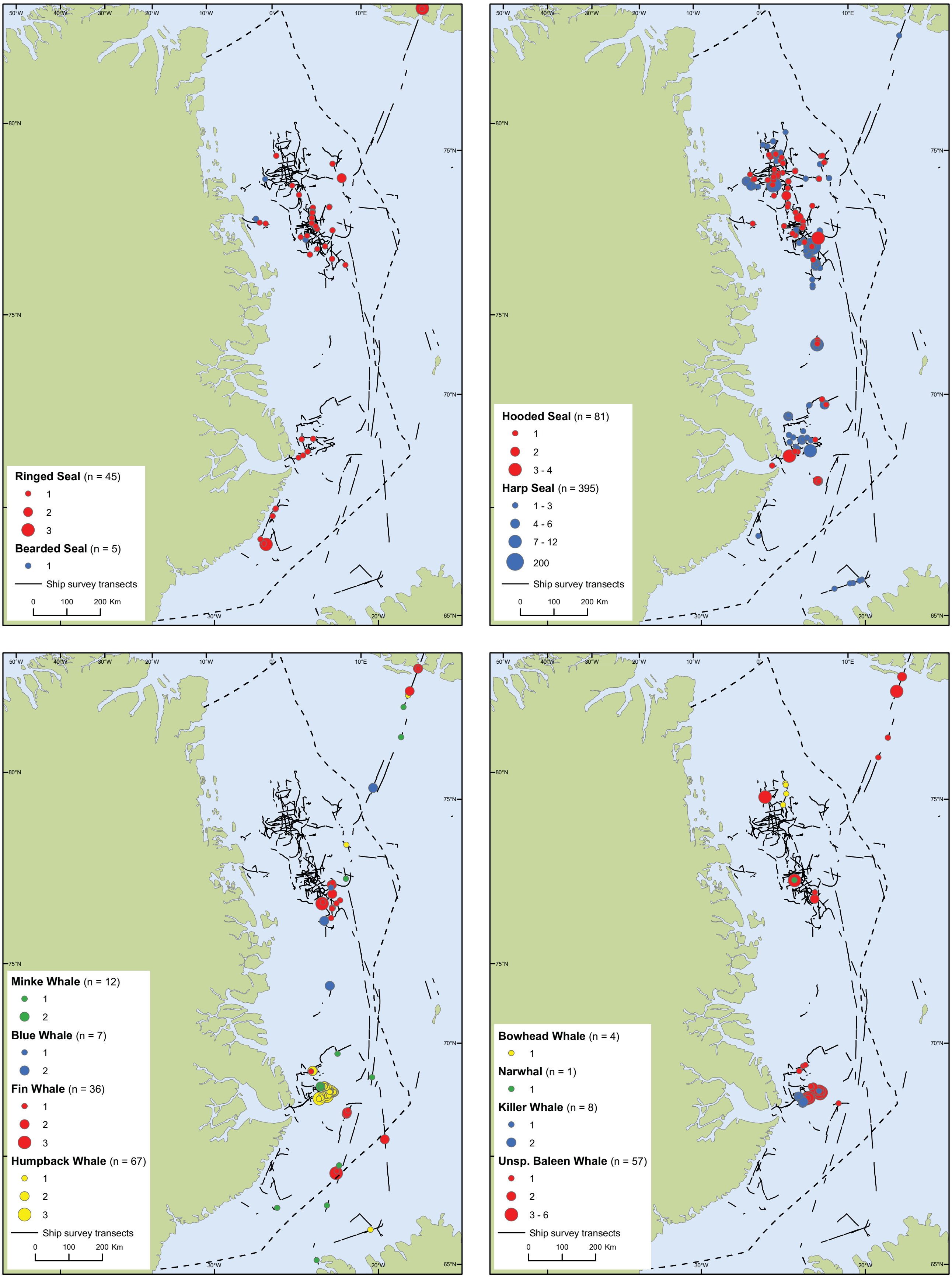



**Figure 29.** Marine mammal observations during the four seabird surveys in 1994, 1995, 2005 and 2006. All observations are given as dots.

Harp seals assemble in large concentrations, and whelp and nurse their pups on drift ice in March–April (the lactation period is 10–12 days).

*Distribution*: The Greenland Sea harp seal population has whelping grounds within the assessment area (Figure 27). After leaving the pups, adult and juvenile seals concentrate again in late April to moult on the ice. In the late 19th and early 20th centuries the whelping grounds were usually located between 70° and 75° N and 10° W and 5° E. The moulting areas were located somewhat further north, between 75°and 76°30´ N and 10° W and 0° (Sergeant 1991). In recent years whelping grounds have also been found within these boundaries (Figure 27).

Outside the whelping and moulting period harp seals disperse in the open-water areas (Figures 28, 29) in northern parts of the northeast Atlantic, including much of the assessment area.

*Biology*: During the winter the main prey of harp seals in the assessment area is capelin (*Mallotus villosus*), krill and amphipods (*Parathemisto* spp.), and during summer amphipods and polar cod (Haug *et al.* 2004).

*Catch*: Norwegian sealing vessels operate within the assessment area in the whelping season. The quota has in recent years been 15,000 pups, but only a minor part of this TAC (Total Available Catch) has been taken (ICES 2005).

For the Greenlanders, the harp seal is not as important as hunting quarry as the ringed seal. Along the coasts near the towns of Scoresbysund and Tasiilaq the annual harvest is approx. 1,000 seals / yr.

*Conservation status*: The population has a favourable conservation status as it has increased considerably since the 1980s (ICES 2005). The estimated population size in 2005 was about 600,000–700,000 seals producing about 100,000 pups a year (Øigård *et al.* 2008). The harp seal is listed as of 'Least Concern' (LC) on the Greenland and the global Red Lists.

Reduction in the amount and distribution of sea ice induced by climate change will probably reduce the available whelping habitats for the harp seals and negatively impact the population.

*Critical and important habitats*: Whelping and moulting grounds on the drift ice where dense concentrations of harp seals occur in spring are sensitive to both disturbance and oil spills (Figure 27).

### Bearded seal *Erignathus barbatus*

The bearded seal is a large seal, associated with sea ice, and considered as resident in the assessment area. However, a pup has been tracked from Svalbard to the coastal areas in the assessment area (Gjertz *et al.* 2000), indicating that the population within the assessment area is not isolated. Bearded seals avoid the very thick multi-year ice and are usually found in dynamic drift ice where cracks and leads give access to open waters. Bearded seals are able to maintain breathing holes where the ice stays relatively thin.

*Distribution*: Bearded seals occur throughout the assessment area where suitable habitat is available, but they are not common and as numerous as the ringed seals (Figure 28). No particularly important areas for the species are known within the assessment area.

*Biology*: Bearded seals feed on fish, but a significant part of the diet consists of benthic invertebrates found in waters down to 100 m depth (Burns 1981, Gjertz *et al.* 2000).

Birth takes place in April–May on drifting ice or near ice edges with access to open water and the lactation period is thought to be 12–18 days long (Burns 1981).

*The catch*: Catch statistics show that bearded seals are taken in the Scoresby Sund polynya throughout the year. The annual catch in the assessment area is approx. 40 seal / year, peaking in summer.

*Conservation status*: The population has a favourable conservation status, and the uniform and widespread distribution of bearded seals is believed to be good protection against overexploitation (Anon. 1998). The bearded seal is listed as 'Data Deficient' on the Greenland Red List.

*Sensitivity*: Bearded seals vocalise very often, especially during the breeding season in spring (Burns 1981); they may therefore be vulnerable to acoustic disturbance (noise) (Wiig *et al.* 1996). Their feeding habits also make them vulnerable to oil-polluted benthos. However, the dispersed distribution makes bearded seal populations less vulnerable to disturbance and oil spills than the more gregarious species.

### Ringed seal *Phoca hispida*

This is a small seal adapted to life in ice-covered waters. It can maintain breathing holes in thick winter ice and gives birth in lairs made in snowdrifts associated with its breathing holes. The pups are born in late March and April and lactation lasts about 7 weeks (Hammill *et al.* 1991).

*Distribution*: Ringed seal is common and widespread in the assessment area, both in the fjords and in the drift ice off the coast (Figure 28). The main breeding habitat is considered to be coastal fast ice and consolidated drift ice.

Ringed seals have only been surveyed systematically in the southern part of the assessment area, where resting seals on fast ice were counted from aircraft in June. Densities in Scoresby Sound and Kong Oscars Fjord were estimated in the range 1.04 to 2.00 seal / $km^2$ (Born *et al.* 1998). This density range can probably be applied to most of the fjord systems in the assessment area.

*Biology*: No feeding studies have been carried out on ringed seals in the assessment area, but small fish like arctic cod (*Boreogadus saida*) or polar cod (*Arctogadus glacialis*) and amphipods (*Themisto* ssp.) are likely to be among their main prey in this area. Polar bear is an important natural predator.

*The catch*: The annual catch of ringed seals in the assessment area (by the inhabitants of Scoresbysund) is approx. 2,500 seals. However, many of the more than 10,000 seals caught annually in Southeast and in Southwest

Greenland are likely to be juvenile seals originating from the assessment area. The sale of ringed seal skins is very important for local hunters and the meat is of high importance in the household economy. The overall catch from this population has been relatively stable for many years and is therefore considered to be sustainable.

*Conservation status*: The population has a favourable conservation status, and is listed as of 'Least Concern' (LC) on the Greenland Red List. However, reduction in the ice, primarily in summer, may have a negative effect.

*Critical and important habitats*: Breeding ringed seal depend on stable sea ice when they establish territories, whelp and nurse the pups. This stationary behaviour makes them vulnerable to disturbance and particularly to activities which disrupt the stable ice. But ringed seals do not form whelping congregations as do harp and hooded seals; therefore the population is less sensitive to localised disturbance.

### 4.7.3 Baleen whales

Baleen whales occurring in the assessment area include bowhead whales and five species of rorquals (the family Balaenopteridae): blue whale, fin whale, minke whale, sei whale and humpback whale.

Bowhead whales are associated with sea ice and probably use the assessment area year round.

Rorquals are all believed to migrate between southerly calving and mating grounds during winter and northern feeding grounds during summer. Their summer distribution includes parts of the North Atlantic, including the seas around Greenland. There is very little information about these species in the assessment area (Table 2).

Seismic surveys from 1996, 1997, 2006 and 2007 revealed substantial numbers of rorquals in the KANUMAS East area (Figure 29).

These species migrate long distances to take advantage of summer peaks of productivity in northern waters. Climate change will likely impact these migratory species in terms of distribution changes due to geographic shifts in the locations of frontal and upwelling areas that concentrate their food. Such large-scale oceanographic changes are likely to affect most marine mammals, but they are currently very difficult to predict (Kovacs & Lydersen 2008). In the assessment area, new habitats for these migratory whales may open if the ice-edge retreats during the summer months, as most models predict, and the area may become more important than at present for these species.

Baleen whales whales produce distinctive low frequency calls that can be detected over tens of kilometres (Širović *et al.* 2007) and which overlap with the noise from seismic hydrophones (Figure 30).

**Bowhead whale *Balaena mysticetus***
The bowhead whale occurs regularly in the assessment area, but numbers are very small, perhaps only a few tens. However the number of sightings have been increasing since the mid-1980 (Gilg & Born 2005) and four

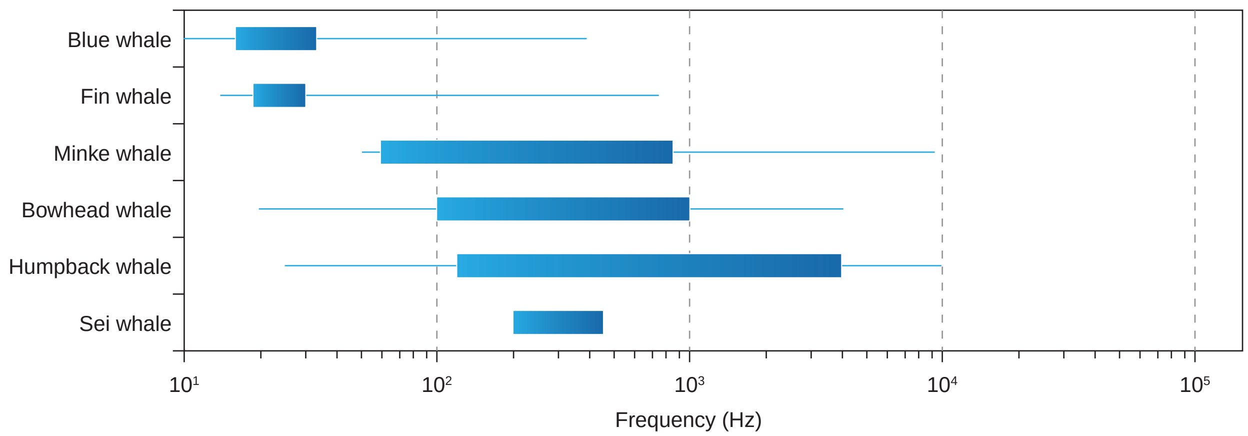



**Figure 30.** Known frequency ranges used by the baleen whales present in the KANUMAS east area. The thick bar shows the range of the most common types of vocalisations, while the thinner line shows recorded extremes of frequency. Adapted from Mellinger *et al*. 2007.

animals were seen on a seismic survey in 2006 and further five during the NERI 2008 survey in July and August 2008 (Figures 28, 29).

*Distribution*: The bowhead whales occurring in the assessment area are believed to belong to the Spitsbergen Stock, which occurs in the marginal ice zone between Franz Josef Land and East Greenland.

In East Greenland they have in recent years been recorded between the Blosseville Coast and the North East Water (Gilg & Born 2005), usually along ice edges or in the marginal ice zone.

*Important and critical areas*: It is not possible to point out important and / or critical areas within the assessment area, due to the few and very dispersed observations in recent years. However during the whaling of the 1800s, a 'south fnishing ground' or 'southern whaling ground' was situated in the marginal ice zone off East Greenland between 72° and 75° N (Ross 1993), at least indicating an area where whales were more available than in other East Greenland waters.

*Conservation status*: Bowhead whales have a high conservation value due to the extreme rarity of the species. This particular stock of bowheads was almost exterminated by two centuries of whaling (from 1611), and only a few individuals remain, usually estimated at a few tens (Gilg & Born 2005). Recent sightings indicate that this could be somewhat underestimated. Bowhead whale is considered as 'Critically Endangered' (CR) both on the national Red List (the Spitsbergen stock separately) and the global Red List.

*Sensitivity*: Bowheads are sensitive to disturbance (noise), and may avoid areas with drilling and seismic surveys. Local populations may be displaced or reduced by increased traffic and oil activities (Wiig *et al.* 1996). Bowhead whale sensitivity to oil spills is unknown, but it has been speculated that bowheads are especially vulnerable to fouling of their baleen, due to their skim feeding habits (Lowry 1993).

### Minke Whale *Balaenoptera acutorostrata*

Minke whales are the smallest rorquals in the northern hemisphere, with average lengths in the North Atlantic of 8–9 m and average weights of 8 tonnes. Because of their relatively small size, their inconspicuous blow, their extremely fast movements and the fact that they are usually solitary animals, minke whales are often difficult to survey.

Minke whales feed on a large variety of prey, including small herding fish and krill, and migrate seasonally from boreal, Arctic and sub-Arctic waters in summer to warmer waters in winter. Summer feeding grounds extend from northern Europe and North America, including Iceland and Greenland, into the ice edge. Winter breeding grounds are unknown, but may include tropical waters off the Caribbean and West Africa. Some individuals remain at high latitudes during winter.

*Distribution*: The occurrence of minke whales in the assessment area is unknown. At least a few were seen during the seismic survey in 2006 and as far north as 75° N; all on the east side of the drift ice. Furthermore minke whales have been observed by GINR researchers (unpublished) working with other species at the ice edge within the assessment area during spring, and one was observed in the Northeast Water in May 1993 (Kapel & Berg 1994).

*Conservation*: The population occurring in the assessment area has a favourable conservation status. Both the global Red List (IUCN 2008) and the Greenland Red List categorise the minke whale as of 'Least Concern' (LC).

*Stocks*: For management purposes, the International Whaling Commission (IWC) recognizes four different stocks of minke whales in the North Atlantic (Figure 31). These management regions were established based on studies of catch statistics, biological characteristics and tagging. Newer molecular studies tend to confirm the established subdivisions (Andersen *et al.* 2003, Born *et al.* 2007).

The assessment area overlaps with two of the minke whale stocks from the North Atlantic: the Central Stock and the North Eastern Stock. Since the mid-1980s Norway, Iceland and the Faroe Islands have carried out several surveys in the ice-free waters of the Northeast Atlantic. These surveys do not tend to cover waters in the proximity of the ice edge and the assessment area is consequently very poorly surveyed.

There is no single estimate for the number of minke whales in the Central Stock. However, the Scientific Committee of the IWC agreed in 2008 (IWC 2008a) that the best estimates available for the three sub-areas of the central stock were 24,900 (CV 0.45), 10,700 (CV 0.229) and 23,600 (CV 0.26).

Based on a series of Norwegian surveys from 1996 to 2001, Skaug *et al.* (2004) estimated 107,205 minke whales (CV = 0.14) in the whole Northeast Stock. The authors also concluded that there are large annual variations in the number of minke whales migrating to the different areas within their range, indicating that minke whales do not present a strong site fidelity to specific feeding grounds. This year-to-year variation in regional minke whale abundance is probably related to changes in abundance and distribution of possible prey species.

*The catch*: There is a quota of 13 minke whales per year for East Greenland. However only two whales were reported caught in 2007. The whales are usually caught in the former municipality of Tasiilaq, just south of the assessment area, but occasionally some are taken in the entrance of Scoresby Sund.

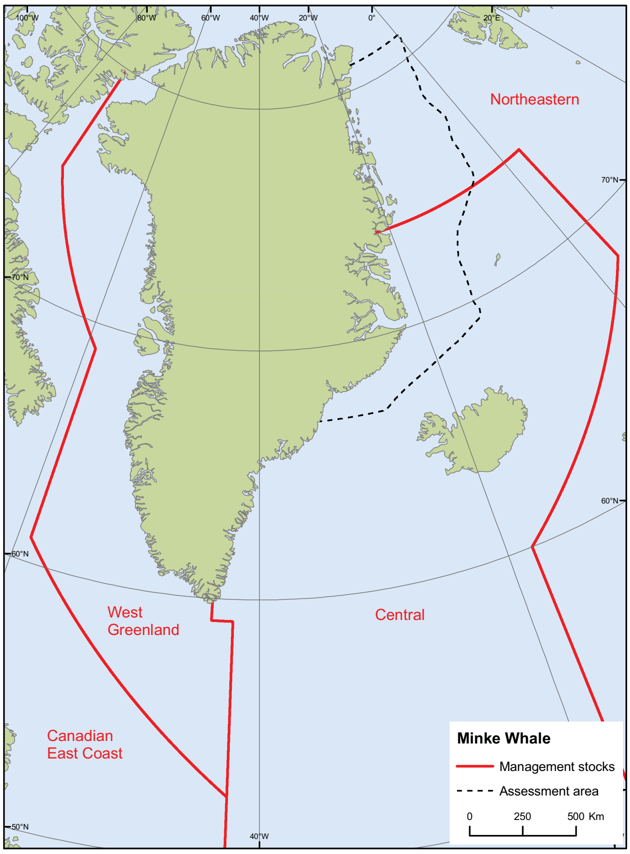



**Figure 31.** The four management stocks of minke whales in the North Atlantic. Two of them overlap the assessment area, but only whales from the central stock are frequent within the assessment area.

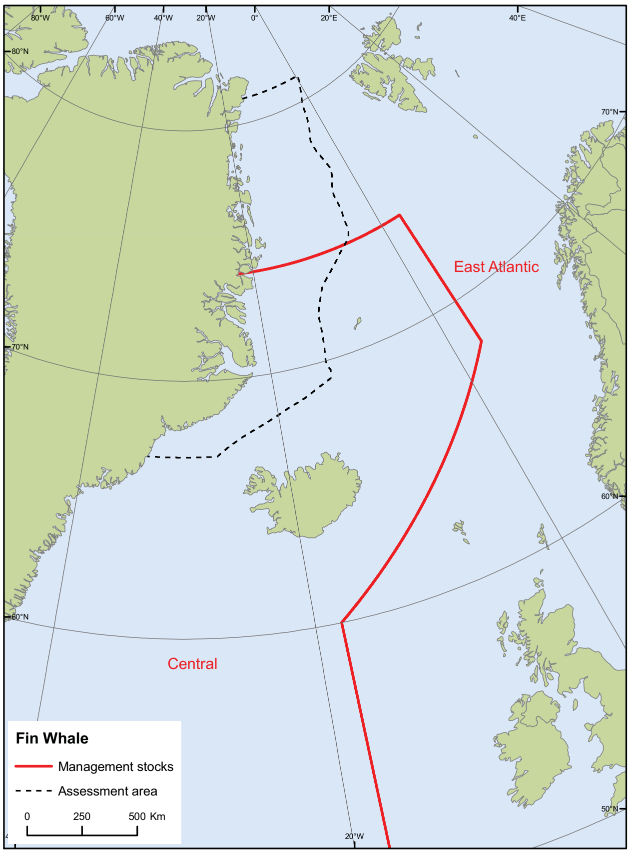



**Figure 32.** The delimitation of the two fin whale stocks in the North East Atlantic: Central and East Atlantic.

*Sensitivity*: Minke whales in high and low latitudes have been recorded producing a variety of vocalisations, using frequencies that vary from a few kHz down to 60 Hz (Shannon & Barlow 2005). Underwater sound related to oil exploration and extraction can reduce the range at which whales can detect their sounds by masking (*cf*. the description for fin whale).

### Sei whale *Baleanoptera borealis*

Sei whales are on average 14 m long and weigh 20–25 tonnes. They are very similar in appearance to fin whales, and usually a close look by an experienced observer is needed to tell these two species apart. Sei whales feed on small fish, krill, squid and copepods. Their distribution is worldwide, from subtropical or tropical waters to high latitudes of the sub-Arctic or sub-Antarctic. It is assumed that most populations move seasonally between high latitudes in summer to tropical waters in winter (IWC 2008b).

*Distribution*: The distribution of sei whales is poorly understood. They occur in apparently unpredictable patterns and can be seen in an area regularly for several years, after which they may largely disappear. Although they occur in polar areas, sei whales seem to be more restricted to mid-latitude temperate zones than other rorquals (Jefferson *et al.* 2008).

A ship survey in Southeast and West Greenland encountered sei whales frequently in the same areas as fin whales (Heide-Jørgensen *et al.* 2007). The survey was made in September 2005, and the resulting estimate was

729 sei whales (95 % CI 226–2358) in Southeast Greenland (to the south of the assessment area). This is an underestimation of the actual numbers of sei whales in East Greenland because the survey did not cover all the potential habitat of sei whales and because animals underwater at the time of the survey and animals missed by observers were not accounted for.

Sei whales in East Greenland belong to a large, oceanic population of the mid-Atlantic that does not have pronounced site fidelity. It is not known to what extent sei whales use the assessment area, but they probably occur within the same areas as fin whales.

*Conservation*: The population occurring in the assessment area probably has an unfavourable conservation status as commercial whaling in the 20th century depleted sei whale populations. After protection in the 1970s and 1980s, this species has been subject to relatively little research and the extent to which stocks have recovered is uncertain. Sei whales are classified as 'Endangered' (EN) in the global Red List (IUCN 2008) and as 'Data Deficient' (DD) on the Greenland Red List.

*Sensitivity*: See the description for fin whales

**Blue whale *Balaenoptera musculus***

The blue whale is the largest animal in the world, with an average length of 25–26 m and average weight of 100-120 tonnes, females being larger than males.

They are globally distributed from the equator to polar waters, moving to high latitudes for feeding during summer and to low latitudes for feeding during winter. Their main prey is krill (*Euphausia* spp.).

*Distribution*: Blue whales occur frequently in the waters between Iceland and Greenland (south of the assessment area, and blue whales were also observed much further north in the assessment area during the seismic surveys in 2006 (Figure 29). No important areas are known for blue whales within the assessment area. But a recent unconfirmed observation of a large concentration of blue whales east of Scoresby Sund indicates that such a site may be found east of the drift ice.

Winter calving grounds for the blue whales occurring in East Greenland are unknown. Their most important feeding grounds in the North Atlantic are in eastern North America (St. Lawrence Bay, Newfoundland, Labrador) and the Greenland Sea / Denmark Strait area, including waters from northern and western Iceland and the waters of the assessment area (east of the drift ice).

Despite the major importance of East Greenland waters for blue whales, research of this species in the assessment area is non-existent.

*Conservation*: The population occurring in the assessment area has an unfavourable conservation status, because it was heavily exploited by commercial whaling during the first half of the 20th century. The population shows some signs of recovery since global protection was applied in 1966, but population size remains at a very low level (IUCN 2008). There are roughly approximately 1,500 blue whales in North Atlantic waters. Blue whales are categorised as 'Data Deficient' (DD) on the Greenland Red List.

In the IUCN Red List, blue whales are classified as globally 'Endangered' (EN), and 'Vulnerable' (VU) in the North Atlantic (IUCN 2008).

*Sensitivity*: Blue whales produce distinctive calls with low frequency and high intensity that can be detected over hundreds of kilometres (Širović *et al.* 2007). Due to their low densities and their potential ability to communicate acoustically over very large distances, blue whales may be especially sensitive to acoustic pollution. Low frequency sounds may effectively mask blue whale calls, thus interfering with their social activities and / or navigation.

**Fin whale *Balaenoptera physalus***

Fin whales are probably the most common and widespread of the rorquals within the assessment area. They are found worldwide from temperate to polar waters but are less common in the tropics.

Fin whales favour prey items as krill (*Euphausia* spp.) and small herding fish, such as herring (*Clupea harengus*) and capelin (*Mallotus villosus*). During summer they feed at high latitudes and are believed to migrate south to unknown breeding grounds during the winter. However, satellite tracking (Mikkelsen *et al.* 2008) and passive acoustic monitoring (GINR & University of Washington, unpublished data) indicate that at least several individuals remain at high latitudes year round.

*Distribution*: Fin whales occur in the assessment area mainly off the east side of the drift ice and mainly in the summer and autumn (Figure 29). There is however no information on their occurrence or biology there.

*Stocks and population size*: For management purposes, the IWC (International Whaling Commission) and the NAMMCO (North Atlantic Marine Mammal Commission) recognize two major fin whale stocks in the Northeast Atlantic: the Central North Atlantic and the Eastern North Atlantic (Figure 32).The ranges of these two stocks overlap with the assessment area. They may, however, form a single population comprised of individuals that move over very large areas. Current genetic research is trying to determine which of these two scenarios is true (Pampoulie *et al.* 2008).

A workshop of leading experts agreed in 2006 that for general purposes the best estimate of current abundance in the Central North Atlantic (including the Faroes) was 25,800 (CV=0.125) for the year 2001. The best estimate for the Eastern North Atlantic was 4,100 (CV=0.210) from a 1996–2001 survey series (NAMMCO-IWC 2006)

Since 1985, Iceland, the Faroe Islands and Norway have carried out a number of surveys for cetaceans in the North East Atlantic. These surveys indicate that the population in the Central North Atlantic increased from the 1980s to 2001 and had stabilised by 2007 (Pike *et al.* 2008).

The survey of 2007 was an international coordinated effort by Canada, Greenland, Iceland, the Faroe Islands, Norway and Russia. The survey area included a small southern portion of the assessment area, east of Scoresby Sound, where several fin whales were observed. That they also occur further north is evident from the 2006 seismic survey (Figure 29).

*Conservation*: Fin whales globally have an unfavourable conservation status and are categorised as 'Endangered' (EN) on the global Red List (IUCN 2008). The reason for the global Red List category was an estimated worldwide reduction to below 50 % of the population size 60–75 years before the assessment, mainly due to whaling in the southern hemisphere (IUCN 2008). However in the North Atlantic fin whales are abundant and the population here has a favourable conservation status, listed as of 'Least Concern' (LC) on the Greenland Red List.

*The catch*: Fin whales are not hunted in the assessment area.

*Sensitivity*: Oil activities that can potentially impact whales include seismic exploration, exploratory drilling, ship, helicopter and aircraft noise, discharges into the water, dredging, marine construction and exploitation drilling.

Rorquals, including fin whales, produce low frequency calls, many of which are species-specific and can be detected over tens to hundreds of kilometres (Mellinger *et al.* 2007). Due to their potential ability to communicate acoustically over very large distances, rorquals may be sensitive to acoustic pollution from sources such as seismic airguns, drilling, offshore construction, aircraft and supply vessels.

### Humpback whale *Megaptera novaeanglia*

Humpback whales are on average 12–14 m long and weigh 25–30 tonnes. They feed on a variety of small schooling fish and krill. Humpbacks are widely distributed and occur seasonally in all oceans from the Arctic to the Antarctic. Humpbacks migrate between mid- and high-latitude summer feeding grounds and tropical or subtropical winter breeding and calving grounds. Known calving grounds for humpbacks from the North Atlantic are in the Caribbean and around the Cape Verde islands.

*Distribution*: There are no in-depth studies of ecology, distribution or abundance of humpback whales in East Greenland, and the importance of the assessment area for this species is not known. A ship-based survey from 2005 off East Greenland, south of the assessment area, detected humpback whales in potential association with capelin (*Mallotus villosus*) aggregations (Heide-Jørgensen *et al.* 2007). The seismic surveys in the assessment area, particularly the 2006 survey, encountered many humpback whales, mainly to the east of the Scoresby Sund entrance, but even as far north as 75° N.

Humpback whales in the North Atlantic show high levels of site fidelity with occasional long-distance movements across four main feeding aggregations (Figure 33) in the Gulf of Maine, eastern Canada, West Greenland and the eastern North Atlantic (Stevik *et al.* 2006). Distances between re-sightings of individually recognizable whales suggest that humpback whales from the Eastern Feeding Aggregation move over very large distances between feeding grounds, such as from Iceland to Norway (Stevik *et al.* 2006).

In the future, reduction in summer sea ice due to global warming coupled with a potential range expansion of humpback whales in the Eastern Feeding Aggregation due to increasing population size may result in an increased use of the assessment area by humpback whales. The observations in 2006 may be the first sign of such a development.

**Figure 33.** The four main feeding aggregations of humpback whales in the North Atlantic: Gulf of Maine, Eastern Canada, West Greenland and Eastern North Atlantic. Question marks indicate that the Eastern North Atlantic aggregation area may overlap the assessment area to higher degree than shown.


*Conservation*: The population occurring in the assessment area has a favourable conservation status as it is abundant and increasing. The number of humpback whales around Iceland has been documented to increase at a rate as high as 11 % per year (Sigurjonsson & Gunnlaugsson 1990).

Whaling has seriously depleted all humpback whale stocks, and humpback whales were protected on a worldwide basis in the 1980s. Globally humpback whales are red-listed as of 'Least Concern' (VU) (IUCN 2008) and in Greenland also as of 'Least Concern' (LC).

*Sensitivity*: Humpback whales are well known for the long and complex songs produced by males in the breeding grounds (recent review of humpback whale song in Parsons *et al.* 2008). Most knowledge about the sound produced by humpback whales in their feeding grounds comes from a few studies in the North Pacific (D'Vincent *et al.* 1985, Thompson *et al.* 1986) and the Gulf of Maine (Stimpert *et al.* 2007), where social feeding calls, as well as click-like sounds have been described. Humpback whale sounds are low- to mid-frequency, usually 30 Hz to 8 kHz, although up to 24 kHz may be reached. Peak frequencies tend to be around 315 Hz and 630 Hz (Parsons *et al.* 2008).

Off Newfoundland, Ketten *et al.* (1993, in Gordon *et al.* 2004) found damage consistent with blast injury in the ears of humpback whales trapped in fishing gear after blasting operations in the area. Two of the humpback whales with damaged ears had been observed by scientists shortly before in an area where blasting was occurring (Lien *et al.* 1993). The blasting did not provoke obvious changes in behaviour among the whales, even though it may have caused severe injury, suggesting that whales may not be aware of the danger posed by loud sound.

Off Australia, humpback whales have been observed to change course and speed consistently in order to avoid close encounters with operating seismic arrays (McCauley *et al.* 2000).

### 4.7.4 Toothed whales

Five species of toothed whale are common in the northern North Atlantic and their distributions overlap with the assessment area: killer whale, pilot whale, white-beaked dolphin, bottlenose whale and sperm whale. The distribution of these species is not restricted to the Arctic. All are found in boreal waters, and sperm and killer whales occur in all oceans. Moreover, they all avoid densely ice-covered waters, so their use of the assessment area is restricted to the ice-free months. With the expected reduction in sea-ice cover due to climate change, they may become more frequent and stay for longer times in the assessment area.

Besides the five widely spread species of toothed whales mentioned above, there is one exclusively Arctic toothed whale found in the assessment area: the narwhal. The narwhal is a North Atlantic Arctic species presumably found in the assessment area year round. There is a second Arctic toothed whale, the white whale, which has a nearly circumpolar distribution that includes all Arctic waters except for East Greenland. Thus, the white whale is only a very rare visitor to the assessment area.

All toothed whales produce clicks for echolocation[1] and communication. In addition, killer whales produce pulsed calls comprising clicks in very rapid succession, and white-beaked dolphins, pilot whales and killer whales produce whistle-like sounds. Pulsed calls serve several purposes, including long-range communication and transmission of information about kinship and group cohesion. Whistles are important during short-range social contact. Figure 34 shows the frequency ranges of echolocation clicks, calls and whistles produced by toothed whales in the KANUMAS area.

Masking by anthropogenic sounds, including noise from ships as well as oil exploration and development activities, can reduce the active space of sounds produced by toothed whales. Whales can also be displaced from noisy areas, and extremely loud sounds may physically damage their hearing organs (review in Nowacek *et al.* 2007). In addition, there may be indirect effects of underwater noise associated with altered prey availability (Gordon *et al.* 2004).

The effect of oil spills on toothed whales has been well described by Matkin *et al.* (2008), who monitored the demographics and group composition of killer whales from Prince Williams Sound 5 years prior to and 16 years after the 1989 Exxon Valdes oil spill. Killer whale groups in the proximity of the spill were unable to avoid the oil and suffered losses of up to 41 % in the year following the spill. Sixteen years later the groups had either not recovered at all or recovered at rates lower than the groups not affected by the oil.

---

1 Echolocation is the ability of finding (i.e. locating) objects by listening to the reflections (echoes) of echolocation clicks.

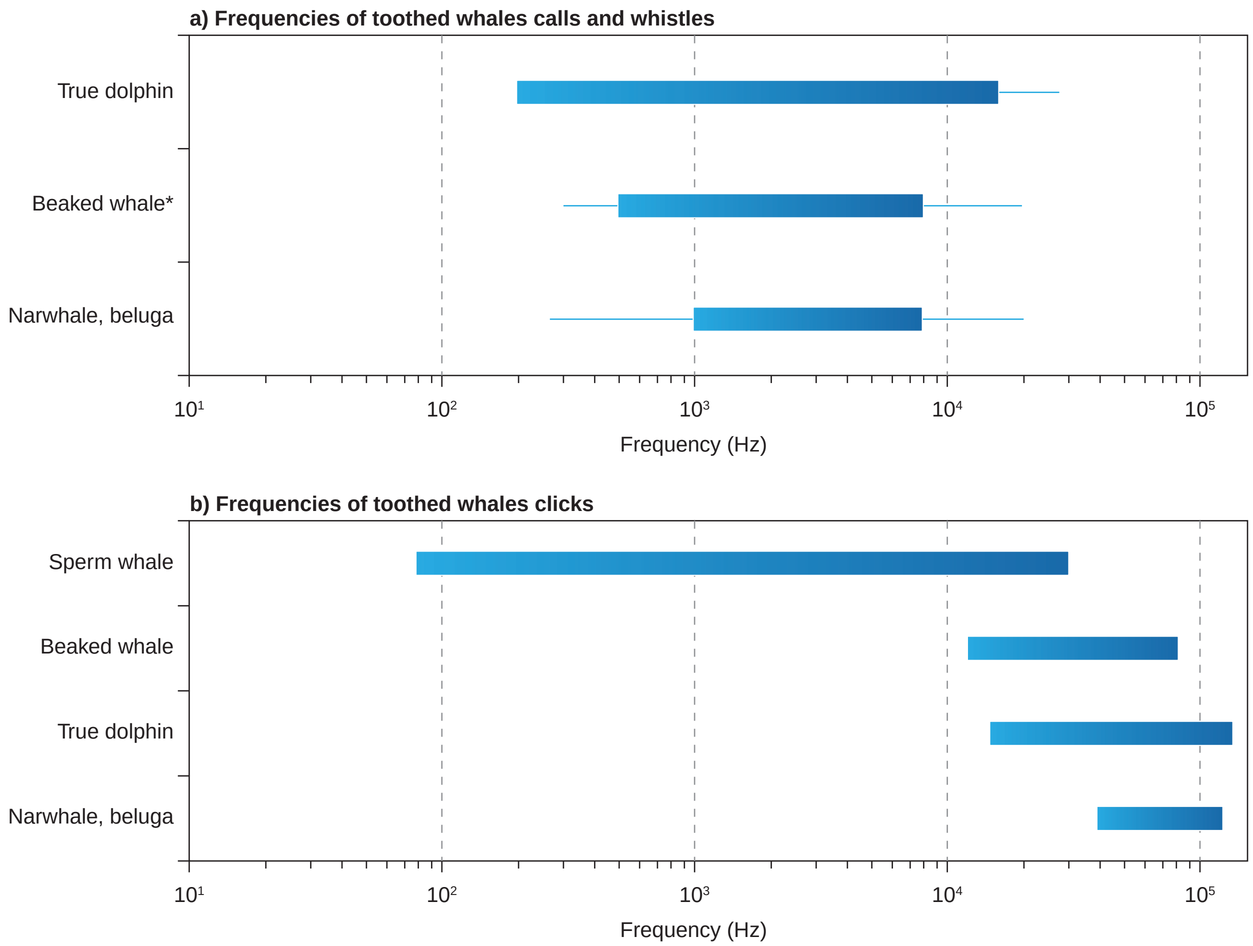



**Figure 34.** Known frequency ranges of pulsed calls and whistles (**a**) and echolocation clicks (**b**) made by toothed whales in the KA-NUMAS area. True dolphins (family Delphininae) include killer whale, pilot whale and white-beaked dolphin. Beaked whales (family Ziiphidae) include bottlenose whale. Narwhal and white whale are also included. Figure modified from Mellinger *et al.* 2007.

**Long-finned pilot whale *Globicephala melas***

*Distribution*: The long-finned pilot whale occurs in temperate and subpolar zones and, according to most literature, ranges in the North Atlantic from Disko Bay in the southern Baffin Bay and Ungava Bay in Davis Strait, 68° N in eastern Greenland across Iceland and the Faroes to mid-Norway, and south to North Carolina, the Azores, Madeira, and Mauritania (e.g. Jefferson *et al.* 2008). Greenlandic catch statistics (Greenland Home Rule, unpublished data) show that pilot whales may occur as far north as Scoresbysund on the east coast in late summer and early autumn from July to October. They however apparently avoid ice-covered waters and will only come close to the coast in years with very little ice (Heide-Jørgensen & Bunch 1991).

*Biology*: Long-finned pilot whales are very social and generally found in groups of 20–100 individuals. In the western North Atlantic they concentrate in areas over the continental slope in winter and spring, and move over the shelf in summer and autumn (Jefferson *et al.* 2008).

Diet consists primarily of squid, but also small to medium-sized fishes are taken, such as cod and herring.

*The catch*: Pilot whales are occasionally caught by hunters from Tasiilaq and Scoresbysund, and the annual catches range between 0 and 19.

*Population*: The pilot whales occurring in the assessment area (and the rest of Greenland) are likely to represent vagrants from a single North Atlantic population of which the size unknown, except that it is large.

In 1993, the population in the northeast Atlantic was estimated at 778,000 whales (Buckland *et al.* 1993).

*Conservation*: Long-finned pilot whale is listed as of 'Least Concern' (LC) according to both the IUCN (2008) Red List and the Greenland Red List.

*Sensitivity*: Pilot whales are probably as sensitive as other toothed whales to noise, disturbance, and oil spills.

### White-beaked dolphin *Lagenorhynchus albirostris*

White-beaked dolphins inhabit the North Atlantic Ocean in the cold temperate zone to subpolar waters. In the Northeast Atlantic they reach into the Arctic waters in the Barents Sea, around Spitsbergen and to East Greenland at approx. 74º N. They are the most common dolphin off south-eastern Greenland, in Denmark Strait and the seas around Iceland (Reeves *et al.* 1999, Kinze *et al.* 1997).

Up to 100,000 white-beaked dolphins inhabit the north-eastern Atlantic including the Barents Sea, the eastern part of the Norwegian Sea and the North Sea north of 56° N (Øien 1996, in IUCN 2008).

White-beaked dolphins' primary habitat is in waters less than 200 m deep, especially along the edges of continental shelves. But they may also occur in deeper waters.

White-beaked dolphins feed mainly on a variety of small schooling fishes like herring, capelin, lesser sandeel and cod, but may also eat squid and crustaceans (Jefferson *et al.* 2008).

The species has been very little studied and very little is known about its biology and ecology. White-beaked dolphins are most often found in groups of 5–10, but are commonly found in larger groups and occasionally in their hundreds (Rasmussen 1999). When feeding, the dolphins are often associated with other species of whales. Young are mainly observed from June to August and migration patterns are unknown.

White-beaked dolphin is not a target of commercial fisheries, but occasionally drowns as by-catch in fishing gear. The rate of fisheries by-catch is however low compared with other dolphin and porpoise species, and incidental catches are not thought to be high enough to represent a severe threat for white-beaked dolphins (IUCN 2008).

*The catch*: In Greenland, white-beaked dolphins are caught for subsistence. There are no catch statistics for this species prior to October 2005. From East Greenland, catches of white-beaked dolphins were reported from Tasiilaq, south of the assessment area in October 2005 (three dolphins), August 2006, September 2006 and September 2007 (one dolphin in each month). Catch statistics after September 2007 are still incomplete.

*Conservation*: The IUCN (2008) status of the white-beaked dolphin is of 'Least concern' (LC). On the Greenland Red List, the white-beaked dolphin is listed as 'Data Deficient' (DD).

### Killer whale *Orcinus orca*

Killer whales are top predators that occur in all oceans, but tend to concentrate in colder regions with high productivity. They feed on prey items that vary in size from herring to adult blue whales. Different killer whale populations tend to specialise and feed on locally abundant prey species. Across populations the movements and behaviour of the prey influence killer whale behaviour, movements and social organisation. As a result of these sipecialisations, there are different ecotypes of killer whales, each ecotype formed by one or more killer whale populations that share an ecological niche. Examples of such ecotypes include killer whales that feed seasonally on sea lion and elephant seal pups in Patagonia (Lopez and Lopez 1985), herring in Norway and Iceland (Simon *et al.* 2007), sharks in New Zealand (Visser 2005) and tuna fish in the Gibraltar Strait (Guinet *et al.* 2007). In some cases, up to three different ecotypes are known to overlap in one area, such as in the Northeast Pacific where the ecotypes called 'residents', 'transients' and 'offshores' feed on salmon, marine mammals and sharks, respectively (Ford & Ellis 2006, Baird & Dill 1995, Herman *et al.* 2005). Moreover, in Antarctica, three ecotypes feed on toothfish, seals or large whales, respectively (Pitman & Ensor 2003). Sympatric ecotypes (i.e. with overlapping ranges) seldom interact and do not interbreed.

Killer whales are typically found in groups of 3–30 animals, but group size may vary from one to more than 100 animals. Large groups are temporary associations of smaller, more stable groups with long-term associations and limited dispersal (review in Baird 2000).

Killer whale populations tend to be small, often numbering in the hundreds rather than thousands (e.g. Big *et al.* 1990, Similä & Ugarte 1997, Ford & Ellis 2000, Visser 2001). Based on genetic analyses of killer whales from several locations in the North Pacific, Hoelzel *et al.* (2007) suggested that killer whale populations in the North Pacific had small effective sizes and that there was ongoing low-level genetic exchange between populations.

*Distribution*: There is very little information about killer whales in East Greenland. Norwegian small-type whalers caught 136 killer whales south of the KANUMAS East area between 1959 and 1972 (Øien 1998). Norwegian catches of killer whales in Greenland stopped when the market for meat from toothed whales for pets and fur animals was much reduced.

Heide-Jørgensen (1988) reviewed published and unpublished information available on killer whales in Greenland and carried out a questionnaire-based investigation of sightings of killer whales. Observations occurred in almost all areas of Greenland, with exception of the assessment area north of Scoresby Sund, where survey effort was low. But killer whales seem to be absent in the coastal areas. Killer whales were reported off the pack-ice belt in East Greenland and on rare occasions during ice-free summers in Scoresby Sound.

*Stocks*: An estimated 10–15,000 killer whales occur in the Northeast Atlantic, but high concentrations are found only seasonally in Iceland and Norway (Øien 2000). An unknown proportion of Icelandic killer whales and the majority of Norwegian killer whales belong to a Scandinavian ecotype of herring-eating killer whale (Simon *et al.* 2007). These herring-eating killer whales form at least two separate populations that migrate following major herring stocks: the Icelandic summer-spawning herring and the Norwegian spring-spawning herring (Sigurjónsson & Leatherwood 1988, Similä *et al.* 1997).

After a collapse in the 1960s, the Icelandic summer-spawning herring stock increased in following decades, while rise in sea temperature has affected the distribution of the stock, which expanded in a westerly direction during the period 1996–2006 (ICES 2007). This expansion brings the northwest edge of the range of the Icelandic summer-spawning herring to overlap with the KANUMAS East area, increasing the likelihood of finding herring-eating killer whales in this area. Killer whales following the Norwegian spring-spawning herring may also occur within the eastern edge of assessment area during summer. Killer whales that feed on marine mammals have been observed in Tasiilaq, south of the assessment area. These killer whales tend to have large home ranges, and those from southwest Greenland probably occur also in the assessment area.

*Conservation*: Killer whales are listed as 'Data Deficient' (DD), both globally (IUCN 2008) and nationally.

*The catch*: Killer whales are hunted in Greenland, partly for human subsistence and partly to feed dogs, but also because they are considered as a pest (competitors to hunters). Between 1996 and 2006, killer whales were taken on two occasions off Tasiilaq, in East Greenland south of the assessment area. There are no reports of killer whale caught in the assessment area.

**Narwhal *Monodon monoceros***

Narwhals are High Arctic mammals that feed primarily on Greenland halibut and occasionally on other species of Arctic fish, shrimp and squid. Narwhals undertake regular migration between shallower summer grounds in fjords, where they apparently do not feed, and wintering grounds in deep and densely ice-covered waters, where they feed (Figure 35). They are gregarious, occurring usually in groups comprising a few to more than 100 individuals.

*Distribution*: Narwhals occur throughout the assessment area. In winter primarily in the wide drift ice belt off the coast, and in summer along the coast and in the fjords (Figure 35) (Dietz *et al.* 1994).

Figures 28 and 29 show the observations from the seismic surveys and the NERI aerial survey in 2008.

*Population*: Only two systematic surveys have been carried out in the assessment area. In 1983 and 1984 narwhal abundance was estimated in Scoresby Sund and adjacent waters to be 300 and 102, respectively, based on aerial censuses (Larsen *et al.* 1994). A new aerial survey in the areas available to hunters in East Greenland has been carried out in August 2008, and telemetry studies are planned for 2009. Data from the survey from 2008 was being analysed at the time of this assessment was being written.


**Figure 35.** The general distribution of narwhal.

The narwhals in East Greenland are, like the whales in Baffin Bay, probably divided in several subpopulations separated in their summer grounds. Current research by GINR aims at investigating the population structure and abundance of narwhals in East Greenland.

*The catch*: Narwhals are important quarry for the hunters in both Scoresbysund and Tasiilaq, because narwhal skin ('mattaq') and male tusks can be traded at considerable prices. The Scoresbysund hunters catch narwhals in the large Scoresby Sund fjord complex and along the northern part of the Blosseville Coast. Hunters from Tasiilaq travel to Kangerlussuaq and the southern Blosseville Coast (Glahder 1995). Catch statistics show an increasing catch in the assessment area, from19 animals / year as an annual average in the period 1997–2003 to between 30 and 93 animals / year from 2004-2006. However, the catch statistics for East Greenland most likely underestimate the real catch.

*Conservation status*: The narwhal population in the assessment area probably has a favourable conservation status, as they are fully protected within the National Park of North and Northeast Greenland. However to the south of the National Park the hunt is unregulated, and many are taken by hunters from both Scoresby Sund and Tasiilaq (see above). Whether this catch is sustainable is not known.

The Scoresby Sund area seems to have been more important for summering narwhals prior to establishment of the town of Scoresbysund around 1925 (Dietz *et al.* 1994). However there is no information on population trends from East Greenland and the population is listed as 'Data Deficient' (DD) on the Greenland Red List.

*Critical and important habitats*: There is very little information to elucidate this issue in the assessment area. In spring narwhals congregate along the fast-ice edges waiting for the fjords to be available, as seen along the southern ice edge in the Northeast Water Polynya in May 2008 (Figure 28). Large numbers have also been reported from some fjords, particularly Kangerlussuaq in the southernmost part of the assessment area (Glahder 1995).

*Sensitivity*: Narwhals are generally believed to be sensitive to noise from seismic surveys, and drilling, increased traffic and oil activities may cause displacement from critical habitats and reduction in the population. A preliminary impact assessment of seismic surveys in West Greenland waters propose specific narwhal areas no-go areas when narwhals are present (Mosbech *et al.* 2000).

**Sperm whale *Physeter macrocephalus***

With males reaching lengths of 18 m and weights of 50 tonnes, sperm whales are the largest toothed whale, and the third largest animal, after blue and fin whales. On average, male sperm whales are 15 m long and weigh 45 tonnes, while females are 11 m long and weigh 20 tonnes. As in the case of bottlenose whales, sperm whales are found in deep waters, often seaward of the continental shelf and near submarine canyons. As a species, sperm whales are found in all oceans, from the ice edges to the equator. Females and calves remain in tropical and sub-tropical waters year round, while males segregate to high latitudes at the onset of puberty, aged between 4 and 15 years (Best 1979, Mendes *et al.* 2006). The larger males, in their late twenties or older migrate occasionally to lower latitudes in search of mating opportunities. When in lower latitudes, males move between different groups of females and their offspring, sometimes engaging in physical combat with other males (Whitehead and Weilgart 2000).

Sperm whales forage on a wide variety of deep-sea cephalopods and fish. Prey size ranges from a few centimetres to 3-metre long sharks and even giant squids that weigh up to 400 kg (reviews in Rice 1989 and Whitehead 2003). Sperm whales in the Northeast Atlantic feed heavily on the deep water squid, *Gonatus fabricii* (Santos *et al.* 1999), favouring mature squid with mantle length of approx. 19 to 26 cm (Simon *et al.* 2003). Male sperm whales off northern Norway tagged with multi-sensor instruments feed both at shallow depths of about 117 m and at the sea bottom at depths down to 1860 m, showing that male sperm whales have flexible feeding habits (Teloni *et al.* 2008). In some areas, sperm whales take fish from longline fisheries (e.g. Roche & Guinet 2007) or approach trawlers in search of discarded fish (e.g. Karpouzli & Leaper 2003).

Stomach samples from sperm whales caught between Iceland and Greenland were dominated by fish, squid being a secondary food item (Roe 1969, Martin & Clarke 1986). The most important fish species in the diet was lumpfish (*C. lumpus*), but redfish (*Sebastes marinus*), anglerfish (*Lophius piscatorius*), Atlantic cod (*Gadus morhua*) and blue whiting (*Micromesistius poutassou*) were also common.

*Distribution*: Based on ship surveys in July 2001, the estimated number of sperm whales between East Greenland and the Faroe Islands was 11,185 (CV 0.34, Gunnlaugsson *et al.* 2002). There was thick sea ice in East Greenland at the time of that survey, and thus coverage of the assessment area was very poor. Most of the sightings of sperm whales were in the Denmark Strait close to the southern part of the assessment area, or south, east and northeast of Iceland. There were no sperm whales seen in the proximity of the assessment area north of approx. 68° N.

The International Whaling Commission considers that all sperm whales in the North Atlantic belong to a single stock (Donovan 1991). This assumption is supported by genetic analyses (Lyrholm and Gyllensten 1998).

*Sensitivity*: The echolocation clicks of sperm whales have a source energy flux density of up to 193 dB re 1 µPa2s. These clicks are the loudest sound known to be produced by any animal (Møhl *et al.* 2003), and therefore sperm whales may be more tolerant to loud noises than other whales.

During a controlled exposure experiment in the Gulf of Mexico, sperm whale horizontal movements were not noticeably affected by a seismic survey, but foraging effort seemed to diminish when airguns were operating (Jochens *et al.* 2008). The results of this study may not be representative for other parts of the world because these particular sperm whales lived in an area with heavy shipping traffic and a long history of oil activity; therefore the whales may have habituated to anthropogenic noise.

*Conservation*: Sperm whales were the target of commercial whaling for over two centuries. By the second half of the 20th century sperm whales were still numerous, but several populations were depleted. Commercial whaling of sperm whales stopped with the moratorium on whaling at the end of the 1980s. Nowadays, sperm whales are not caught anywhere in the North Atlantic. On the Greenland Red List, sperm whales are listed as 'Not Applicable' (NA) and globally as 'Vulnerable' (VU) (IUCN 2008).

*Critical and important habitats*: Sperm whales are often found feeding in deep, underwater canyons and on the deep side of steep continental slopes.

**Northern bottlenose whale *Hyperoodon ampullatus***

Next to the sperm whale, the northern bottlenose whale is the largest toothed whale in the North Atlantic, with adult females measuring up to 9 m in length and males up to 11 m. They are found in deep waters, often seaward of the continental shelf and near submarine canyons, from the ice edges south to approximately 30° N. They have a fission-fusion social system (i.e. live in groups that join and split), with group sizes from about 4 to 20 animals. Groups may be segregated by age and sex and males may form long-term companionships with other males (Wimmer & Whitehead 2004).

The main prey of the bottlenose whale is squid (*Gonatus* spp.), but prey items also include fish (herring *Clupea harengus*, redfish *Sebastes* spp., etc.), and invertebrates, such as sea cucumbers, starfish and prawns (Hooker *et al.* 2001). Prey is often caught near the bottom at depths greater than 800 m (Hooker & Baird 1999). Bottlenose whales are known to take Greenland halibut from long-line fisheries.

Northern bottlenose whales have only been studied in detail in an area surrounding the Gully, an underwater Canyon off Nova Scotia, at the southern end of the species' range. Based on boat surveys, photo-identification and molecular analyses, it has been established that these northern bottlenose whales live in a small population of about 150 animals that is rather stationary and isolated from other populations (Wimmer & Whitehead 2004, Whitehead and Wimmer 2005, Dalebout *et al.* 2006). It is not known whether northern bottlenose whales in other parts of their range also form relatively small, isolated and stationary populations.

*Conservation*: The Red List status of the northern bottlenose whale is 'Data Deficient' (DD) on the global list, and 'Not applicable' (NA) on the Greenland list.

*Distribution*: Northern bottlenose whales are the most frequently observed cetaceans around the Jan Mayen Ridge (Gunnlaugsson & Sigurjónsson 1990), just east of the assessment area. Within the area, they can be observed during summer in deep waters east of the East Greenland Current, especially associated with abrupt changes in the bottom topography, such as underwater mounts or canyons.

Northern bottlenose whales were the target of Norwegian whaling during two periods. The first period was from 1882 to the 1920s, when somewhere in the region of 60,000 northern bottlenose whales were taken. Approximately 5,800 whales were taken during the second period, from 1930 to 1973 (NAMMCO 1995). Norwegian catches were spread over much of the Northeast Atlantic, including the Greenland Sea and the Denmark Strait and, after 1959 some bottlenose whales were taken in West Greenland and eastern Canada (Figure 37). Norwegians stopped hunting bottlenose whales because the market for whale oil and meat for pets and farmed mink was no longer profitable.

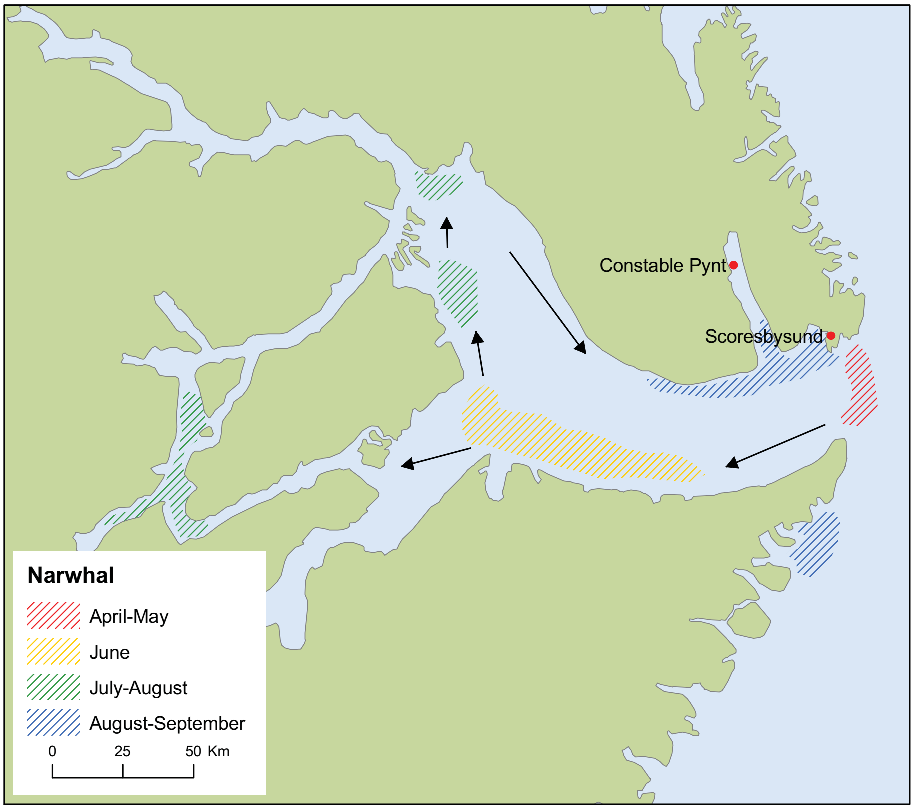
Scottish sealers and whalers took approximately 1,961 bottlenose whales from 1856 to 1970, including catches in both the Davis Strait and the Greenland Sea (Thompson 1928, in NAMMCO 1995). The majority of these catches (1,787) were from the period 1877–1892.

Before the studies from the Gully were published, a group of specialists assumed that bottlenose whales from the Northeast Atlantic (i.e. east of Kap Farvel) could be considered as a single population that migrated across several areas and numbered about 40,000 whales (NAMMCO 1995). It was assumed that northern bottlenose whales migrate because whaling catches peaked in different months at separate whaling grounds.

**Important and critical habitats for marine mammals**

The marine mammals of the assessment area are dependent on open waters: seals and whales for breathing, polar bears for feeding. Therefore recurrent and predictive open waters among otherwise ice-covered areas

Figure 36. Annual narwhal movements in the Scoresby Sund complex, based on local information (Aastrup *et al*. 2005).




will be critical to the ice-dependent marine mammals in the assessment area. At the ice edge, the polynyas and the lead zones are such critical areas. Particularly the Northeast Water is extremely important to walruses, narwhals, bowhead whales, polar bears and probably also to ringed and bearded seals. The many smaller polynya along the coast are also important, at least to walruses and polar bears, and probably also to ringed and bearded seals. The other large polynya at the entrance to Scoresby Sund is of similar importance to marine mammals, and represents the reason why the town of Scoresbysund was founded here. The outer ice edge (also less well defined) to the Greenland Sea is habitat for bowhead whales, narwhals (mainly in winter) and also for polar bears and walrus. It is, however, not possible to designate specific important areas along this ice edge, due to lack of knowledge and due to the highly dynamic features of this part of the ice.

Polar bear denning areas are widespread along the coast, and it is not possible to point out specific important coastline for this very sensitive habitat. There seems to be a tendency for higher densities of maternity dens north of approx. 68° N, and known regular denning areas include Kangerlussuaq, the Blosseville Coast, the inner parts of the Scoresby Sound fjord complex, the areas between Kong Oscars Fjord and Kejser Franz Joseph Fjord, Shannon, Dove Bay, the areas between Île de France and Ingolf Fjord and the coast at the Northeast Water.

Polar bear is also dependent on ice cover, preferring relatively dense sea ice at the continental shelf where there are high concentrations of ringed seals.

Well-defined edges of the shore fast-ice are frequent in the polynyas and other parts of the assessment area. Along these there are often open waters and here narwhals and other Arctic marine mammals may congregate in

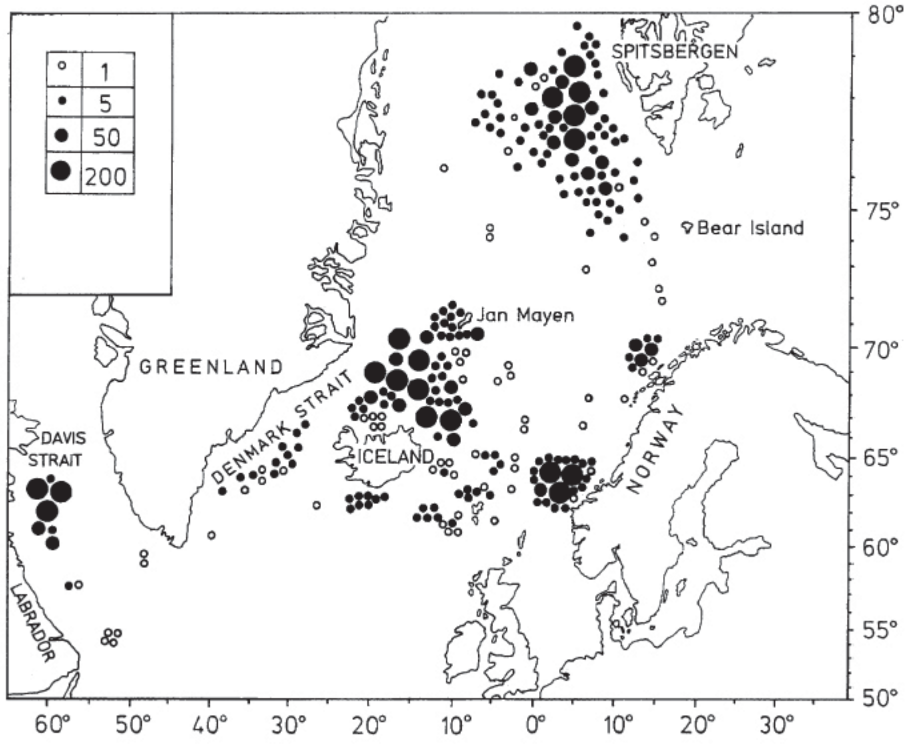



**Figure 37.** Localities of northern bottlenose whales caught by Norwegian Whalers in the period 1938–1972 (modified from Benjaminsen and Christensen 1979, in Bjørke 2001).

spring. There is however no knowledge available on the pattern of occurrence at such sites, and it is most likely highly variable and not predictive on a fine scale.

Walruses are dependent on shallow feeding grounds with high densities of bivalves. They also need access to air for breathing and to suitable haul-out sites on ice or land. During winter, polynyas are extremely critical to the walrus population in the assessment area. Two important sites for walrus during summer and autumn in the assessment area are the zones surrounding Young Sund and Dove Bugt.

Critical habitats on the ice are evident for the two seal species whelping and moulting in dense aggregations: the harp seal and the hooded seal. These areas are located on the drift ice in the eastern part of the assessment area and are highly dynamic in their position due to the variation and movements of the drift ice.

Narwhals spend the summer months in coastal waters, and many of the fjords on the Blosseville Coast, some the inner parts of Scoresby Sund, the large fjords of Kong Oscar and Kejser Frantz Josef, as well as Young Sound, Dove Bay and the Northeast Water are known to be important.

## 4.8 Summary of VECs from KANUMAS East assessment area

The VEC (Valued Ecosystem Component) concept is explained in section 9.1.2. It must be underlined that designation of VECs will always be constrained by availability of the data. In the present assessment area, data on wildlife and other ecosystem components are limited, and more species, e.g. blue whale and killer whale, may in fact be VECs. New data will probably clarify the status.

**Primary productivity**
Due to lack of data it is not possible to point out particularly important, recurrent areas for primary productivity, except for a general designation of polynyas and ice edges.

**Zooplankton**
It is not possible to designate specific important areas for zooplankton. The key species *Calanus hyperboreus* and *Parathemisto libellula* are definitely VECs.

**Ice flora and fauna**
Due to lack of data it is not possible to point out particularly important, recurrent areas for sympagic flora and fauna.

**Benthos**
There are many areas with high densities of benthos, and those in shallow waters are often important feeding grounds for walrus and eiders. Such areas have only been studied locally (Young Sound and adjacent waters) and no other areas can be pointed out based on the available knowledge. It will be possible to pinpoint some of these areas using the data from satellite-tracked walruses.

**Fish**
VECs among the fish include the Greenland halibut (the only species utilised on a commercial basis), polar cod (ecological key species) and Arctic cod. The fishing grounds for Greenland halibut and the rivers utilised by Arctic char are important VECs. However, it is not possible to designate important areas for polar cod or other fish species due to lack of data.

**Birds**
Northern fulmar breeding colonies are found at a few sites in the assessment area. Here concentrations occur, but offshore occurrence of the species is highly dispersed and high densities are rare. The conservation status of the breeding population is probably favourable.

Common eider is the most numerous coastal seabird in the assessment area and it is an important predator on shallow benthic communities. It occurs in breeding concentrations from May and in moulting concentrations from late June. The most important breeding colony is found at the military outpost Daneborg and the most important moulting areas seem to be the fjords to the south of Scoresby Sund. The conservation status of the population is probably favourable, in contrast to the declining population in West Greenland. Due to the latter, the species is red-listed in Greenland.

King eider is another coastal seabird, but it occurs in lower numbers than the common eider. In spring, concentrations are more localised and moulting concentrations have so far only been located in a single fjord south of the Scoresby Sund entrance. Most important spring concentrations were found in the coastal areas of the NEW polynya.

Kittiwake breeding colonies are found scattered along the coast, particularly at sites with early ice break-up or polynyas. The breeding population in the assessment area has apparently a favourable conservation status in contrast to the declining population in West Greenland. Offshore concentrations have occasionally been reported from polynyas. Largest breeding colonies are found at the polynyas at Scoresby Sund and NEW.

Sabines gull concentrations are found at the breeding colonies scattered along the coast. It is red-listed due to a small population.

Ivory Gull is a species with a particularly high conservation value, and it is red-listed. It occurs in migration concentrations on the drift ice, in breeding colonies and in feeding concentrations during summer. The most important area for ivory gull is the NEW polynya and the lead system along the coast northwest of NEW.

Ross's gull is another very rare and red-listed species only breeding at one site in the assessment area in NEW. Concentrations of non-breeders occur in summer in the MIZ, particularly in NEW.

Arctic tern concentrations are mainly found at the breeding colonies along the coasts. Migration concentrations have not been described.

Thick-billed murre (the breeding population) has an unfavourable conservation status in the assessment area, and the Greenland population is red-listed. Concentrations occur in summer at the breeding colonies (only at the Scoresby Sund polynya) and at feeding grounds. Large numbers of extra-limital birds move through the assessment area in autumn, and probably also in spring when they occur mainly in the MIZ.

Little auk is the most numerous seabird in the area with very large breeding concentrations in the Scoresby Sund entrance. The conservation status of this breeding population is probably favourable. The entire breeding population from Svalbard (millions of birds) also move through the assessment area during spring and summer.

**Marine mammals**

Bowhead whales have a high conservation value due to their rarity. They occur throughout the assessment area with no known concentration areas and there is no knowledge on specifically important areas to date; although a former, important whaling area, the 'south fishing ground' was situated off the Greenland coast between 72° and 75° N (Ross 1993).

Narwhal is an important VEC. There is a general conservation concern for the species, a significant part of the global population occur in the assessment area and it is a resource for the communities living in East Greenland. Several fjords of the assessment area are important summer grounds for narwhals, there is however no specific knowledge on which are the most important, and therefore it is difficult to designate particularly important sites.

Blue whales are globally endangered. Populations show some signs of recovery in the North Atlantic and Southern Ocean, but remain at very low levels. The Denmark Strait, at the south of the assessment area, is one of two areas of the North Atlantic where blue whales are regularly seen. Recent observations indicate that blue whales are seasonally present further north, through a large part of the assessment area. Due to the scarcity of published information, it is not possible to indicate specific summer feeding grounds.

Harp seal whelping patches on the drift ice of the assessment area are very important concentration sites in March–April. Outside the whelping season no particularly important sites are known.

Hooded seal whelping is more dispersed than that of harp seals, but more or less within the same area of the drift ice and also in March–April. Outside whelping season no particularly important sites are known.

Ringed seal is an ecological key species of the assessment area. Densities vary from area to area, but no particularly important sites are known. It is an important resource for the inhabitants of the town of Scoresbysund.

The walrus population of the assessment area is probably more or less isolated, and has a high conservation value. It is moreover a resource for the people living in the town of Scoresbysund. The conservation status of the population is favourable as it shows sign of improvement, and the hunt takes only males at the margin of the range. There are several important concentrations areas in the assessment area: terrestrial haul-outs and spring / winter concentrations areas in some polynyas.

A significant part of the global polar bear population occurs within the assessment area and the species is of international and high national conservation value. Polar bears are globally and nationally red-listed due to an expected population decline caused by climate change. Polar bears are important quarry for hunters of the assessment area. Particularly important areas of concentration include ice edges, polynyas, areas with high densities of ringed seals and coasts offering denning possibilities. However, concentrations rarely occur and then not at predictable areas and times.

**Other ecological features**

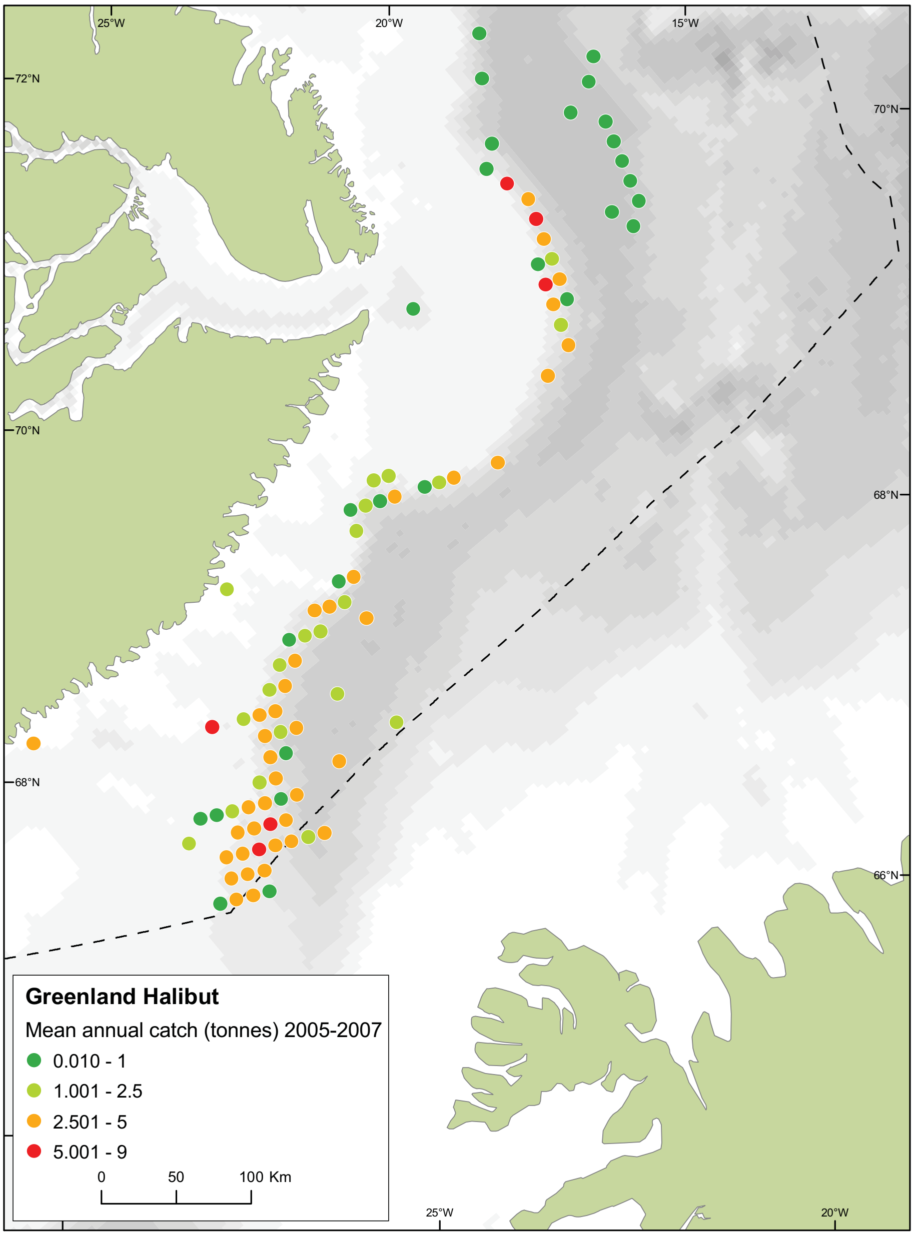
Key habitats which are VECs in the assessment area include recurrent ice edges, polynyas (often in combination), recurrent lead zones and the MIZ. Besides these, many small islands are important as breeding grounds for seabirds.

# 5 Natural resource use

## 5.1 Commercial fisheries

Very little commercial fishery takes place in the assessment area. However, a Greenland halibut fishery was developed in 2005 in the area between 67° and 71° 30’ N on the continental slope at water depth between 500–1000 m. The total fishery in the area amounted to about 1,200 tons in 2005. Catches decreased to about 250 tons in 2006 but increased again to 700 tons in 2007. Within the assessment area only 204 tons on average were taken annually in 2005–2007 (Figure 38). This fishery is conducted from large trawlers, and no commercial fishing has been conducted from the only settlement within the assessment area (Scoresbysund).

**Figure 38.** Distribution of Greenland halibut fishery within the assessment areas. Catches are given as annual average over the years 2005–2007.



## 5.2 Subsistence hunting and fisheries

In 2006 the human population in the assessment area numbered 529 inhabitants, all living in the town of Scoresbysund (Ittoqqortormiit) and the adjacent settlements (more or less abandoned today). In 2004 23 occupational hunters and 125 leisure hunters were registered (Statistics of Greenland 2008, Aastrup *et al.* 2005). Also hunters from Tasiilaq utilise the southernmost part of the assessment area. They move to the Kangerlussuaq area mainly for hunting narwhal and polar bear (Glahder 1995).

### 5.2.1 Hunting

The hunt in the Scoresbysund area takes place in the entire fjord system and along the outer coasts of Liverpool Land and Blosseville Coast. Transportation is mainly by means of dog sledge or snow scooter, and in the open-water season also dinghy or small boat. Previously hunters went by dog sledge far north into the National Park to hunt polar bears in early spring, but this activity has apparently ceased in recent years (Aastrup *et al.* 2005).

The most important quarry from the marine environment is ringed seals, harp seals, narwhals and polar bears. Many other species are taken, including walrus, the other seal species and seabirds.

The most important hunting areas are the ice edge of the polynya (winter, spring) and the coasts to the east and northeast of the town (Kap Tobin). During summer, narwhals are caught in the inner parts of the Scoresby Sound fjord complex and southwards into the fjords around Turner Ø.

In the period 1972–1980 approx. 4,000 ringed seal skins were traded annually in Scoresbysund. However, the number of seals caught may have declined, since the hunting statistics (introduced in 1993) only recorded about 2,000 ringed seals in 1996. In 2007, 1,525 ringed seals were reported to the hunting statistics in Scoresbysund and 9,622 in Tasiilaq. Most of the seals caught by hunters from Tasiilaq were taken south of the assessment area.

The annual polar bear catch in entire East Greenland (incl. the area outside the assessment area) comprised approx. 60 animals in the period 1999–2003 (Born & Sonne 2005). Since 1996, the hunt of polar bears in East Greenland has been limited by a quota of 30 bears per year to Scoresbysund and 20 to Tasiilaq. All the bears from Scoresbysund and some of the bears from Tasiilaq are caught within the assessment area. The quota was increased by 5 animals for each of the two towns in August 2008.

The reported narwhal catch for East Greenland in 2006 was 112 animals. Of these, 29 were taken by inhabitants of Scoresbysund in the assessment area, and part of the remaining 93 were taken by hunters of Tasiilaq in the southern part of the assessment area. The actual catches from Scoresbysund are probably higher than reported.

Hunters from Tasiilaq often stay at 'Skærgården' and make hunting trips into the Kangerlussuaq fjord or along the outer coast as far as Vedel Fjord at 28° W. In summer they travel by boat, hunting mainly narwhal and in spring, February–May, by dog sledge, hunting polar bear (Glahder 1995).

### 5.2.2 Fishery

No commercial fishery takes place out of Scoresbysund, and fishery activity for domestic use is rather limited. The most important species in this subsistence fishery is Arctic char, which is mainly caught along the coast of Hurry Inlet, at Sydkap inside the Scoresby Sund fjord and in some of the fjords of the Blosseville coast (Figure 14). Other species caught include spotted wolffish (*Anarchichas minor*), Greenland shark (used for dog food) (*Microcephalus somniosus*), Greenland halibut (*Reinhardtius hippoglossoides*), sculpin (*Myxocephalus scorpius*) and polar cod (*Boreogadus saida*) (Sandell & Sandell 1991, Petersen 1993)

## 5.3 Tourism

The tourist industry is one of three major sectors within the Greenland economy and is increasing significantly in importance in Greenland and indeed the KANUMAS East area itself. The National Strategy of Tourism 2008–2010 plans a 10 % increase per year in the number of cruise tourists alone (Erhvervsdirektoratet 2007), a trend wich is very apparent in Scoresbysund

The most important asset for the tourist industry is the unspoilt, authentic and pristine nature, which is particularly abundant in the KANUMAS East assessment area, e.g. in the National Park.

Two kinds of tourists visit the assessment area: tourists spending the night on land (hotels, camping, and other kinds of accommodation) and tourists from cruise ships. Tourists spending the night on land include those on scientific expeditions or those engaging in outdoor recreational activities, e.g. mountaineers.

The tourists staying on land all arrive through the airport at Constable Pynt, and operate usually from there or from Scoresbysund town, explaining why this type of tourism is concentrated in the southern part of the assessment area – mainly the Scoresby Sund Fjord and the southern part of the National Park.

Cruise ships may visit any ice-free coast during the summer, and they arrive either from Svalbard, moving southwards along the outer coast and in the fjord lands or they arrive from the south (Tasiilaq or Iceland) visiting mainly the town of Scoresbysund and the adjacent fjord land.

Both types of tourists have increased in numbers in the area in recent years. However, no statistics are available on the number of tourists and their regional distribution in Greenland. But hotel statistics show that only 5–10 % of the overall total of 250,000 'bed nights' in hotels in 2006 were spent in Northwest and East Greenland (= the former municipalities of Qaanaaq, Upernavik, Uummannaq, Scoresbysund and Tasiilaq) (Statistics of Greenland 2008).

Unspoilt wilderness, the trademark of Greenland tourism, is particularly available in Northeast Greenland, because of the very limited human population and the National Park of North and Northeast Greenland. Tourists expect unspoilt nature in the assessment area and when cruise ships

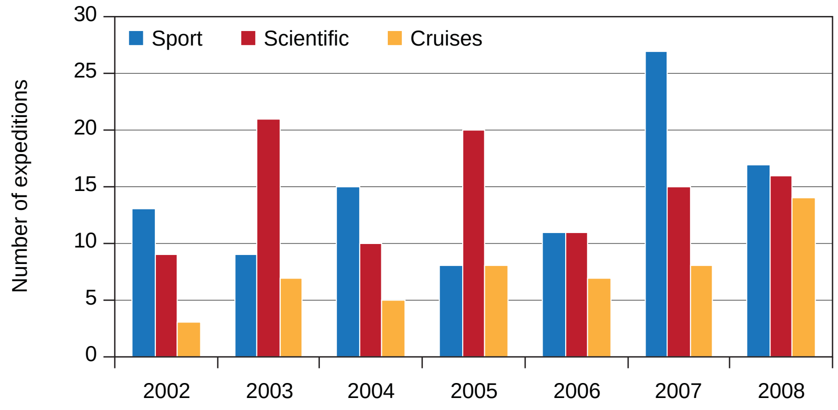



**Figure 39.** Number of expeditions in Northeast Greenland by year. Data provided by the Danish Polar Centre (DPC).

come across 'spoilt nature', such as for instance flensing sites with unused narwhal carcasses, the story hits the press with considerable impact.

**Expeditions**

The terrestrial and coastal parts of the assessment area are the destination of many types of expedition, both scientific and recreational: natural history, mountaineering, kayaking, etc. (Figure 39).

**Cruise ships**

Cruise ships spend the majority of time in the coastal zone and sightings of marine mammals and birds are major highlights alongside the scenic views and visits to the inhabited places. Figure 40 shows the number of cruise ships and passengers 1994–2007 calling at Scoresbysund. The number is increasing rapidly and according to the Danish Naval Authorities in Greenland, the number of visitors from cruise ships will increase (in Greenland overall) from 23,000 in 2006 to 55,000 in 2007.

With the expected increase in cruise tourism and with more open water in the summer time, cruise ship activity will most likely intensify in the assessment area, in terms both of number of ships and people, but also in terms of visiting more and more remotely situated sites.

### 5.3.1 Scoresbysund (Ittoqqortoormiit)

As the only town in the area, most tourists go through Scoresbysund. There is one locally based tour operator, Nanu Travel, and a couple of operators based in Iceland also organise activities. The annual temporal distribution of tourist activities is shown in Figure 41. Activities for tourists include:

*Dog sled trips* take place mainly in Liverpool Land in April / May when it is still cold but the sun has returned from the dark winter period. The local operator, Nanu Travel, arrange about 600 sled passenger days, normally one day per tourist.

*Kayaking* takes place in the open-water season (July–September), and a number of tourists go kayaking in Scoresby Sund and the fjords of the southern part of the National Park each year.

*Boat trips* are arranged mainly as transport to landing sites for hiking or kayaking in summertime.

*Hiking* takes place in summer in the Scoresby Sund fjord complex or in the southern part of the National Park.

*Trophy hunting* (muskox) takes place in spring and mainly in Jameson Land.

### 5.3.2 The National Park

The National Park receives a few independent visitors (expeditions) and some cruise ships. Because of the sea ice most areas are only accessible for a short time of year.

Much of the tourist activity within the assessment area takes place in the coastal zone, which potentially can be exposed to oil spills. As the most important asset of the tourist activity in the area is the unspoilt nature, an extensive oil spill has the potential to seriously impact the local tourist activity and industry.

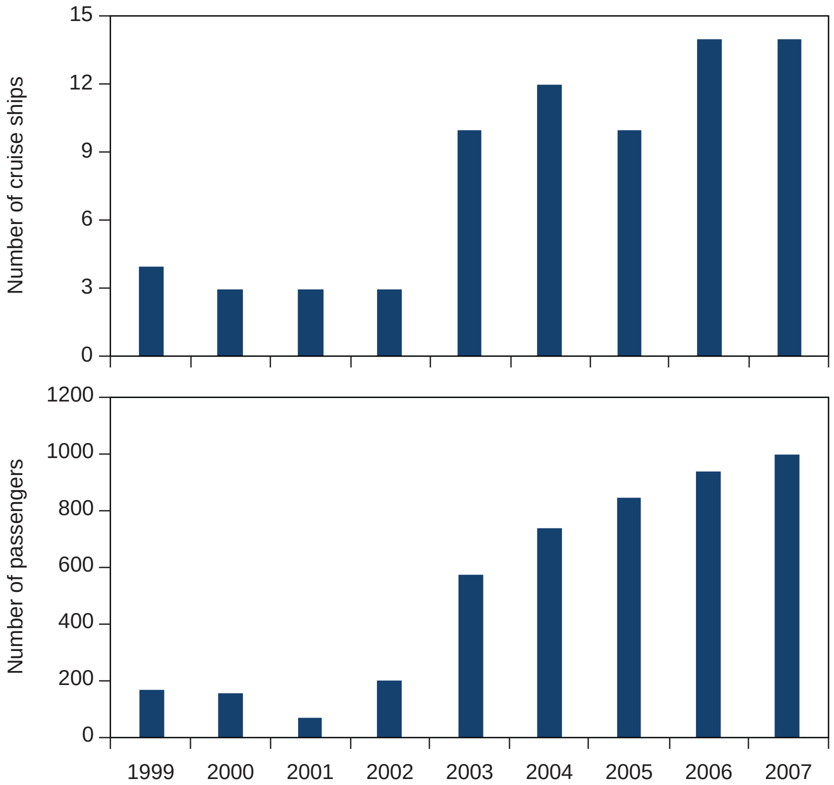



**Figure 40.** Development in number of cruise ships and number of passengers 1994–2007 in Scoresbysund (Greenland Tourism pers. comm.).

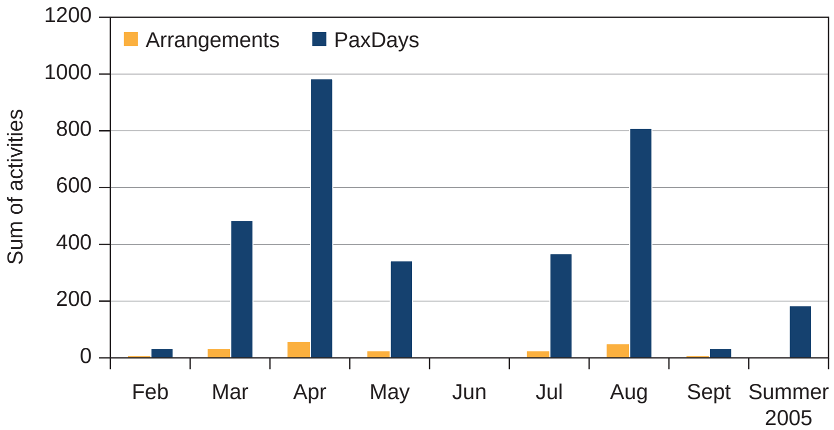



**Figure 41.** Sum of activities 2004– 2007 by Nanu Travel, Ittoqqortoormiit (pers. comm.).

# 6 Protected areas and threatened species

## 6.1 International nature protection conventions

According to the Convention on Wetlands (the Ramsar Convention), Greenland has designated eleven areas to be included in the Ramsar list of Wetlands of International Importance (Ramsar sites). These areas are to be conserved as wetlands and should be incorporated in the national conservation legislation; however, this has not yet been applied in Greenland. Three of the Ramsar sites are found within the assessment area (Figure 42). These are all designated due to the presence of geese in internationally important numbers, i.e. more than 1 % of the flyway population (Egevang & Boertmann 2001).

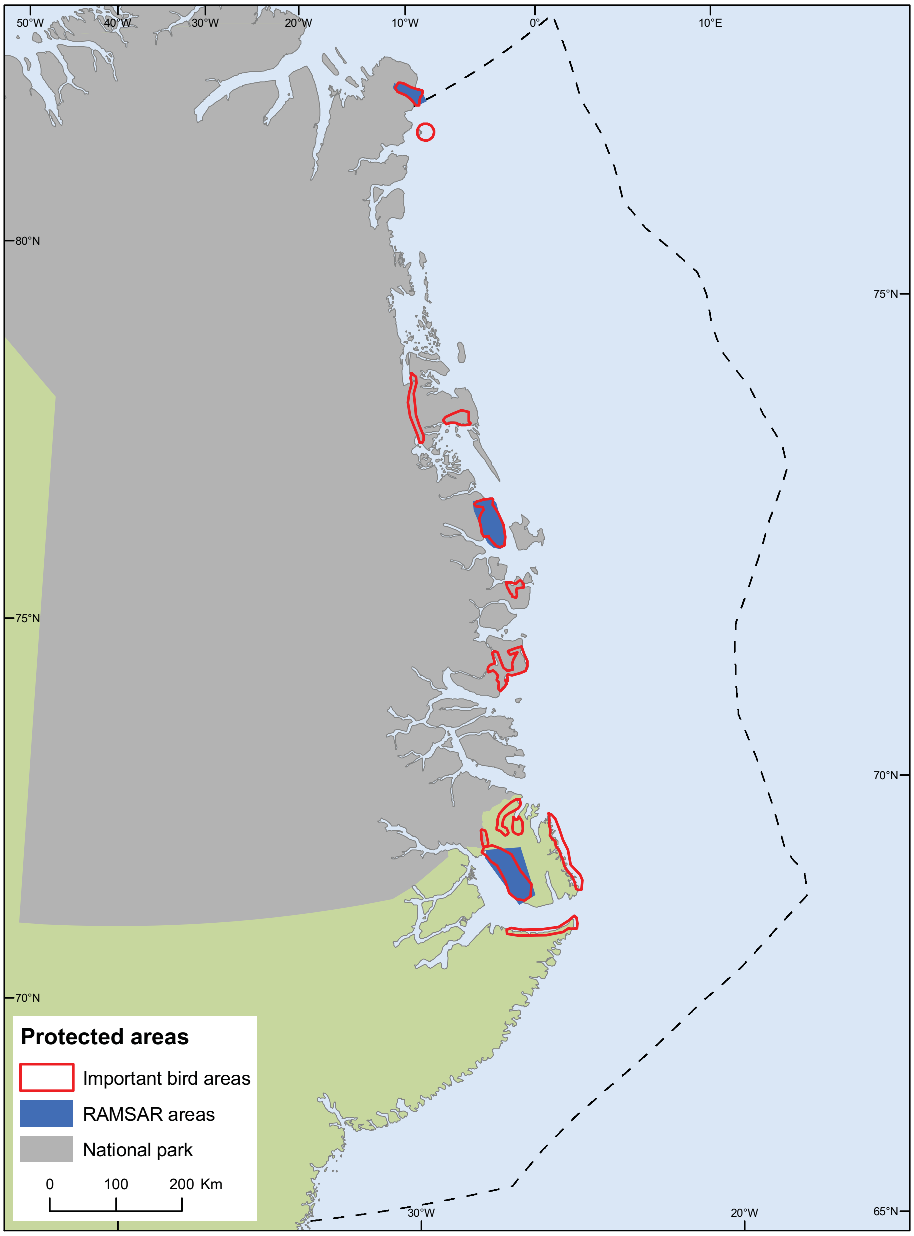



**Figure 42.** Areas protected according to the Greenland Nature Protection Law (Melville Bay reserve and Bird Protection areas), international conventions (Ramsar) and areas designated as Important Bird Areas (IBAs) by BirdLife International.

## 6.2 National nature protection legislation

The major part of the land and fjord areas adjacent to the KANUMAS area is designated as national park – The National Park of North and East Greenland (Figure 41), with strict protection of nature and environment. However, it is allowed to explore for petroleum and minerals within the national park (Boertmann 2005, Aastrup *et al.* 2005). Management of the park is under revision, and zoning in relation to the particular management designs is an option which is dicussed.

There are no specific sites protected according to the Bird Protection Order within the assessment area, but all seabird breeding colonies and their immediate surroundings are generally protected from disturbing activities (*cf.* the map showing all known seabird breeding colonies). According to the Mineral Extraction Law, a number of 'areas important to wildlife' are designated and, in these, mineral exploration activities are regulated in order to protect wildlife. There are several of these areas important to wildlife within the assessment area (Figure 43).

Recently the available knowledge (including local knowledge) on ecosystem components of the National Park and adjacent areas was reviewed (Aastrup *et al.* 2005). This was updated in 2009 (Aastrup & Boertmann in prep.). Important areas for wildlife were identified (Figure 44).

## 6.3 Threatened species

Greenland has red-listed (designated according to risk of extinction) four species of mammals and twelve species of birds (Table 3) occurring in the assessment area (Boertmann 2008).

A number of species have been categorised as 'Data Deficient' (DD) or 'Not Applicable' (NA) and they may become red-listed when additional information is available (Table 4).

National responsibility species occurring in the assessment area include one mammal and five birds (Table 4). However, also narwhal may be included here, but knowledge on numbers and the proportion in Greenland is unknown.

Globally threatened species occurring in the assessment area include some marine mammals:

| | |
|---|---|
| Polar bear | Vulnerable (VU) |
| Bowhead whale, Spitsbergen population | Critically Endangered (CR) |
| Fin whale | Endangered (EN) |
| Blue whale | Endangered (EN) |
| Sperm whale | Vulnerable (EN) |

Narwhal is considered as 'Data Deficient' (DD) on the global list (IUCN 2008), and might prove threatened or 'Near Threatened' (NT) when more information becomes available.

Within the assessment area there are some hot-spots containing threatened species (Figure 45), particularly the mouth of Scoresby Sund, the entrance to Dove Bugt and the islands of Henrik Krøyer Holme. These are all at polynyas.

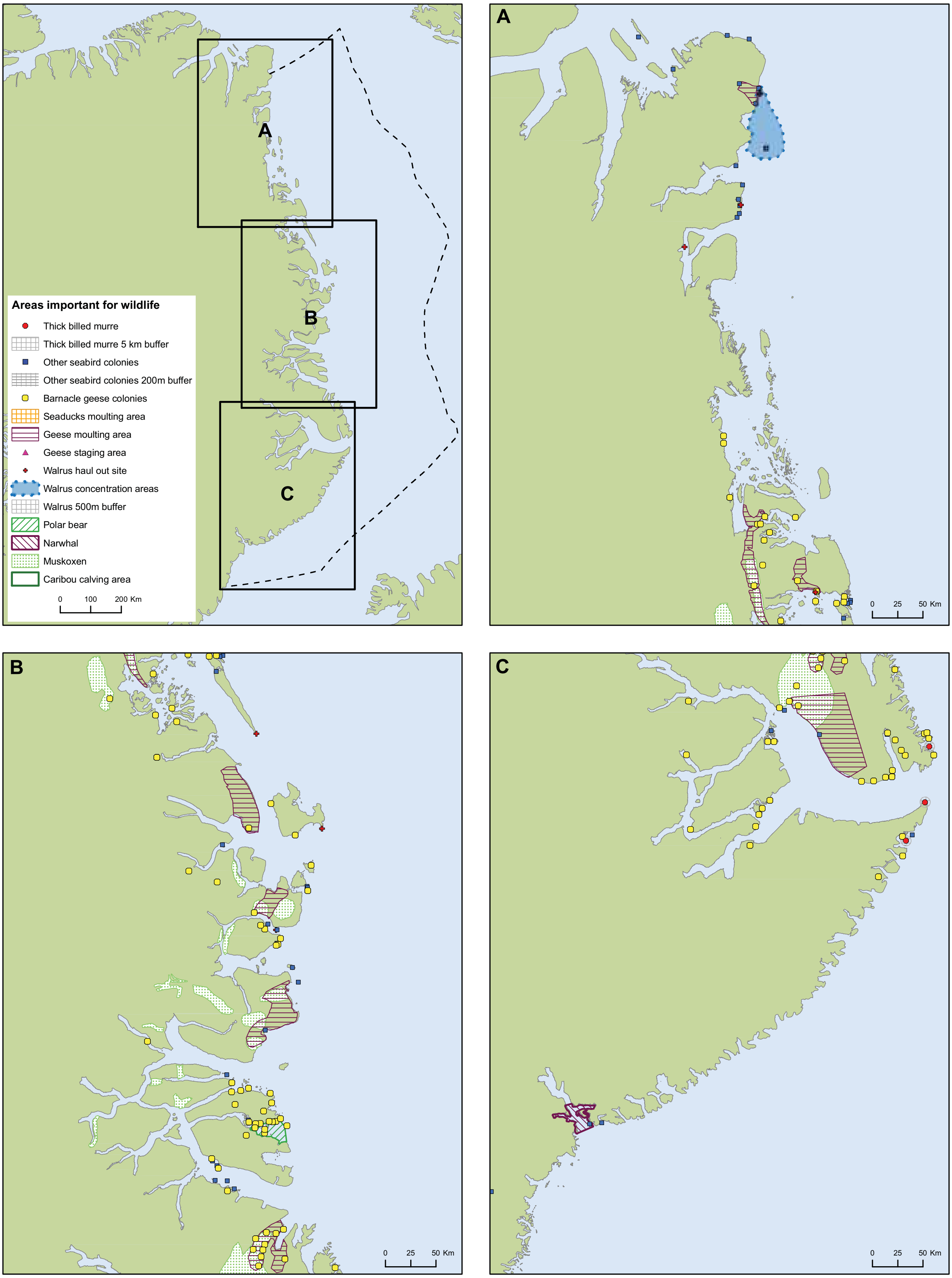



**Figure 43.** Areas designated as “important to wildlife” by Bureau of Minerals and Petroleum as a part of the field rules for prospecting and exploration activities.

**Table 3.** Red-listed species occurring in the assessment area of KANUMAS East.

| Species | Greenland Red List status |
|---|---|
| Wolf** | Vulnerable (VU) |
| Polar bear | Vulnerable (VU) |
| Walrus | Near Threatened (NT) |
| Bowhead whale | Critically endangered (CR) |
| Great northern diver | Near Threatened (NT) |
| Light-bellied brent goose | Near Threatened (NT) |
| Gyr falcon** | Near Threatened (NT) |
| European golden plover** | Near Threatened (NT) |
| Whimbrel** | Near Threatened (NT) |
| Sabines gull | Near Threatened (NT) |
| Ross's gull | Near Threatened (NT) |
| Black-legged kittiwake | Vulnerable (VU)* |
| Ivory gull | Vulnerable (VU) |
| Arctic tern | Near Threatened (NT)* |
| Thick-billed murre | Vulnerable (VU) |
| Atlantic puffin | Near Threatened (NT) |

*applies to the entire Greenland population, and red-listed because the population in West Greenland is de-creasing, a trend not apparent in East Greenland. ** are not associated with the marine environment.

**Table 4.** National responsibility species (more than 20 % of global population in Green-land)and species listed as 'Data Deficient' (DD) or 'Not applicable' (NA) occurring in the assessment area. Only species which may occur in marine habitats are included.

| National responsibility species | Species listed as 'Data Deficient' (DD) or 'Not Applicable' (NA) |
|---|---|
| Polar bear | Bearded seal |
| Pink-footed goose | Blue whale |
| Light-bellied brent goose | Killer whale |
| Barnacle goose | White-beaked dolphin |
| Knot | Narwhal (East Greenland population) |
| Black guillemot | Sperm whale |
| Little auk | Bottlenose whale |

## 6.4 NGO designated areas

The international bird protection organisation BirdLife International has designated a number of Important Bird Areas (IBAs) in Greenland (Heath & Evans 2000), and fourteen are within the assessment area (Figure 42). These areas are particularly important areas for birds and are areas which should be protected by national regulations. They are designated using a large set of criteria, for example that at least 1 % of a bird population should occur in the area. For further information see the IBA website (Link). Some of the IBAs are included in or protected by the national regu-lations e.g. within the National Park, but many are without protection or activity regulations.

Figure 44. Areas with major biological interests in and adjacent to the National Park of North and Northeast Greenland designated during a review of available information (Aastrup *et al*. 2005, Aastrup & Boertmann 2009).

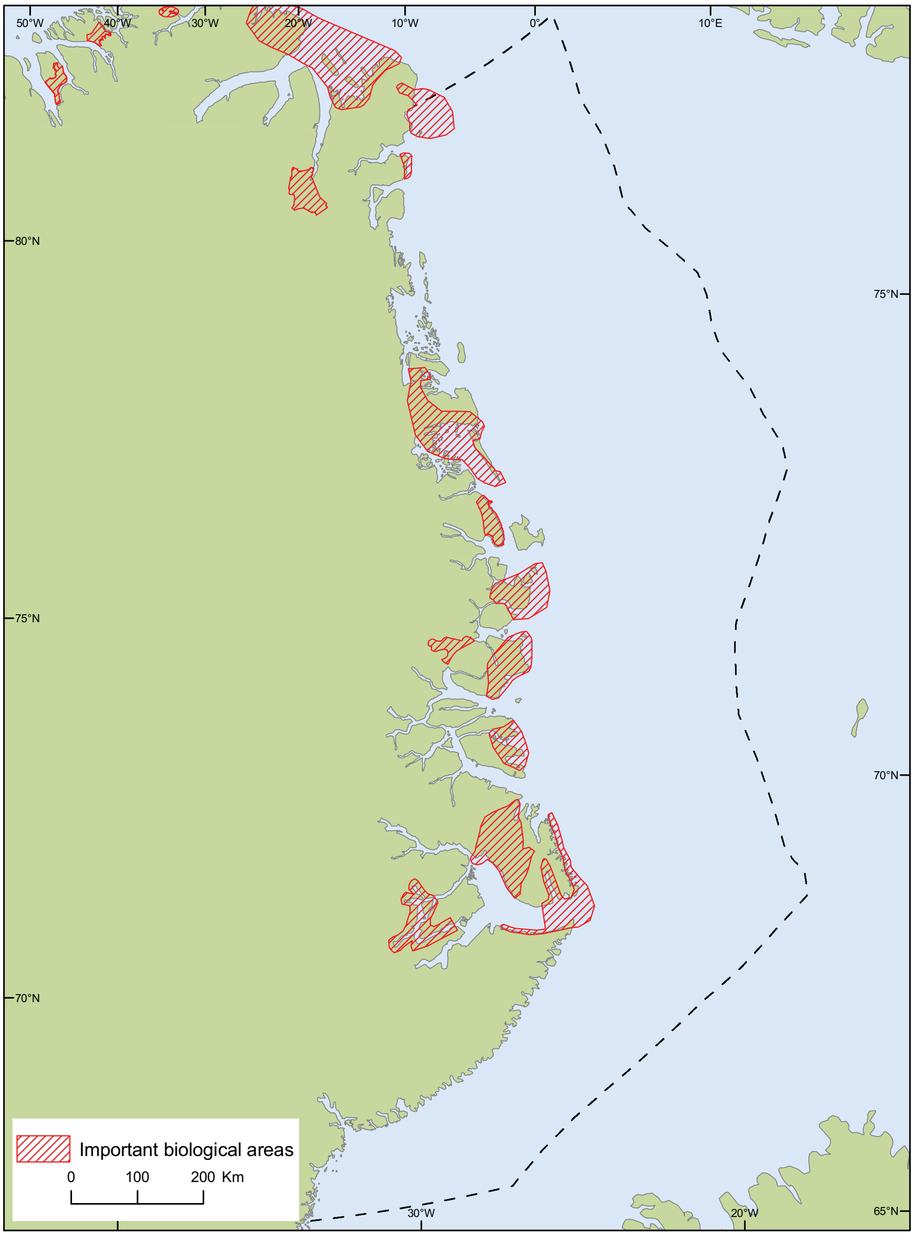
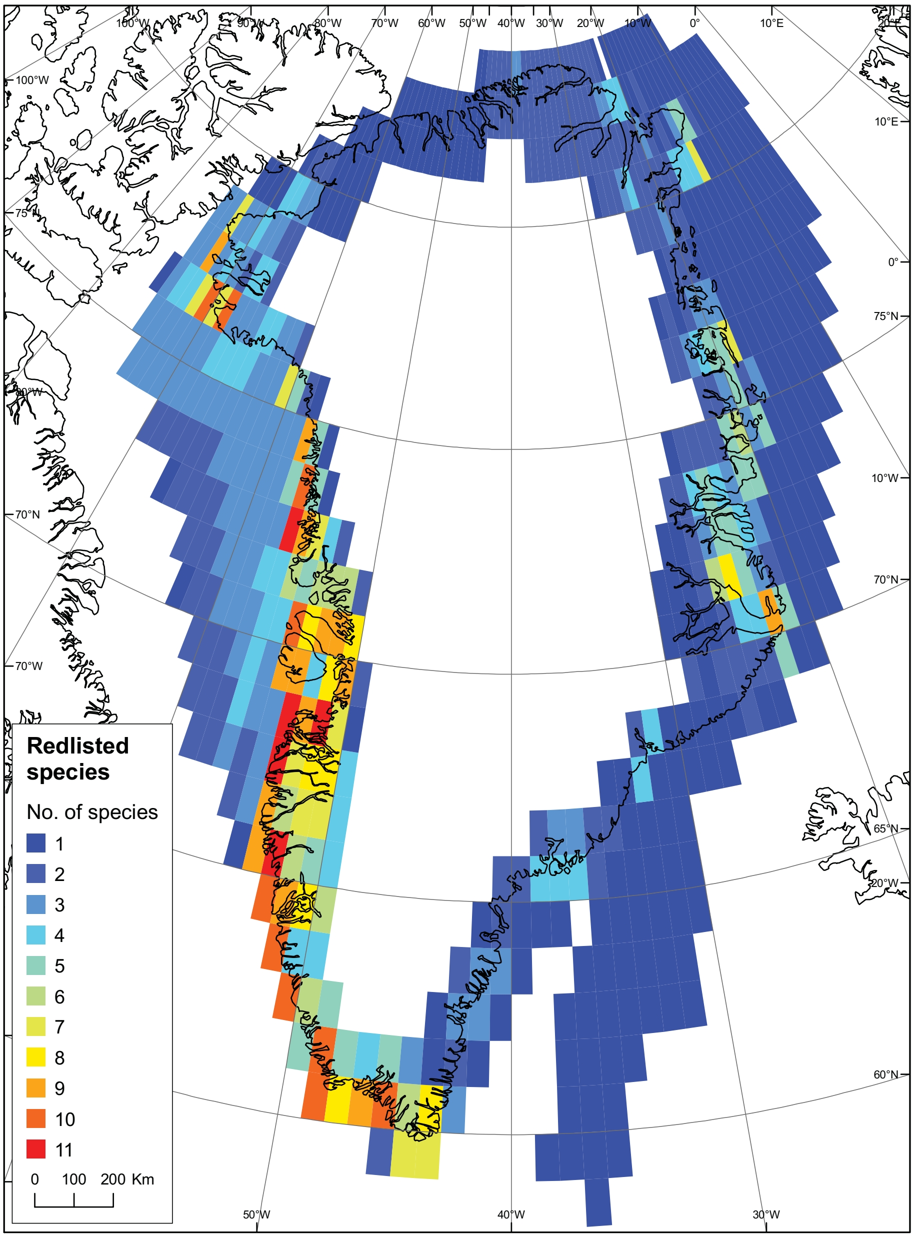


**Figure 45.** Distribution of Red Listed species in Greenland shown as number of species in 1°×1° squares.



# 7 Contaminants, background levels and effects

The occurrence of contaminants in the marine environment and their potential impacts on biota has been studied in Greenland over past years in various regions and for different purposes. An overview is given in the following sections, with focus on studies with relevance for the assessment area.

Baseline data on lead, cadmium, mercury and selenium levels in molluscs, crustaceans, fish, seabirds, seals, walruses, whales and polar bears have been compiled for different geographical regions, including West, Northwest and Central West Greenland (Dietz *et al.* 1996). Only data have been included for animals not affected by local pollution sources, i.e. former mine sites. The overall conclusion was that lead levels in marine organisms from Greenland were low, whereas cadmium, mercury and selenium levels were high, exceeding Danish food standard limits. No clear conclusions could be drawn in relation to geographical differences concerning lead, mercury and selenium concentrations. In general, cadmium levels were higher in biota from Northwest Greenland compared to southern areas.

At Maarmorilik (Uummannaq, the southernmost part of the assessment area) lead and zinc ore was mined from 1973 to 1990. The ore was primarily found in the mountain called ‘Black Angel’. Environmental studies have been conducted at the mine since 1972 by measuring lead and zinc in seawater, sediments and biota in the fjords at Maarmorilik (Larsen *et al.*, 2001, Johansen *et al.*, 2006). The last assessment in 2005 showed that pollution sources still exist 15 years after the mine closure in 1990. Lead and zinc levels in seawater and biota have decreased, in particular after the mine closed, and the area affected by pollution with lead and zinc has been reduced over the years. It is now primarily in the Affarlikassaa and Qaamarujuk Fjords where an impact can be seen. However, the metals in the sediments still affect the marine biota in the area. Faunal re-colonisation 15 years after closure was slow and the impacted areas were still dominated by opportunistic species (Josefson *et al.* 2008).

Pollution impacts on the marine environment on a local and regional level were studied at Thule Air Base in 2002 (Glahder *et al.* 2003). The study indicated several contaminant sources resulting in elevated concentrations of certain contaminants in the marine environment. Among those, PCBs appeared to be the most important one, since concentrations elevated 2–30 times were found. Concentrations of PCB in sculpin are comparable to levels found in specimens from coastal European areas. However, the study also showed that the impact is local and limited to an area of 5–10 kilometres from Thule Air Base.

**AMAP Monitoring Activities**

In 1991 the Arctic Monitoring and Assessment Programme (AMAP) was established to monitor identified pollution risks and their impacts on Arctic ecosystems. The Arctic is a region with almost no industry or agriculture. Most of the persistent organic pollutants (POPs) and a substantial part of the mercury (Hg) found in the environment are anthropogenic and have reached the Arctic as a result of long-range transport by air and water. In general, mercury has increased in the Arctic, with implications for the health of humans and wildlife. There is also some evidence that the Arctic is a 'sink' for global atmospheric Hg (Outridge *et al.* 2008).

As part of AMAP activities a biological time trend programme was set up in Greenland with focus on a suite of POPs, including PCBs, and different trace metals, i.e. cadmium (Cd), mercury (Hg), selenium (Se). Two regions were chosen, one being Qeqertarsuaq (Godhavn) on the west coast. Species included in the programme were the landlocked Arctic char, shorthorn sculpins (*Myoxocephalus scorpius)*, black guillemot (*Cepphus grylle*) and ringed seal (*Phoca hispida*). In addition contaminant levels in polar bears (*Ursus maritimus*) have been studied.

In the following an overview is given concerning the contaminant levels and temporal trends in the monitored species based on Riget (2006a, updated 2007) and follow-up publications.

## 7.1 Heavy metals

Heavy metal content was measured in the liver of shorthorn sculpins, ringed seals, and polar bears.

An increase, though not significant, in the mercury levels was found in shorthorn sculpins and ringed seals from 1999 to 2006. Cadmium, on the other hand showed a decreasing trend in shorthorn sculpins and ringed seals. Nevertheless, the cadmium concentrations found in shorthorn sculpins and ringed seals where highest when compared to biota from other Arctic regions (Riget *et al.* 2000, 2005). The patterns found appear mainly to be related to natural geological differences in mineral occurrence (Riget *et al.* 2005).

As summarised by Dietz (2008), marine mammal populations from Northwest Greenland and the Central Arctic show the highest concentrations of mercury. The highest cadmium concentrations were found in mammals from Central West Greenland and Northwest Greenland.

Temporal trends of mercury (Hg) in West Greenland gyrfalcons, peregrine falcons, and white-tailed eagles were determined over 150 years from 1851 to 2003. Hg was measured in the fifth primary feather. It was shown that Hg levels increase in the order gyrfalcon (lowest) < peregrine falcon (intermediate) < white-tailed eagle (highest). All species showed significant age-related accumulations. The comparisons of Hg 10-year medians for adult peregrine falcons and juvenile and adult white-tailed eagles indicated a continued increase during recent decades. However, low levels of Hg in a few recent collections among gyrfalcons and peregrines could indicate a change in the increasing trend (Dietz *et al.* 2006).

Temporal trends in mercury concentrations for the last two to three decades were also determined in different species from Northwest Greenland (NWG, 77°N) and central West Greenland (CWG, 69°N). For shorthorn sculpin from CWG and NWG and walrus from NWG no temporal trend was found. In ringed seals from NWG, an increase in mercury of 7.8 % per year was observed. In ringed seals from CWG no trend in mercury concentrations was found during the period 1994–2004 (Riget *et al.* 2007a).

Biomagnification of mercury and methyl mercury (MeHg) in the West Greenland marine ecosystem has been studied in fourteen species including invertebrates, fish (e.g. Greenland halibut) and seabirds (sampled between 62° and 69°30'N) and marine mammals (62° to 71°30'N). Biomagnification was clearly visible with a biomagnification factor similar to those found in other marine systems (Riget *et al.* 2007b).

## 7.2 Persistent Organic Pollutants (POPs)

The substances belonging to this group include polychlorinated biphenyls (PCBs), various organochlorine pesticides (DDTs, dieldrin, HCHs or toxaphene), brominated flame retardants (PBDE) or perfluorinated compounds (PFCs). All of them are known to be accumulated in organisms, preliminary in fat storage tissues. Furthermore, biomagnification towards the upper end of the food web has been documented for them all (Riget *et al.* 2004).

POP levels are generally lower in the Arctic environment than in more temperate regions; however, they could be of concern particularly for higher trophic predators such as polar bears (Dietz 2008).

Levels of certain POPs have also been measured in a range of marine fish collected in West Greenland and in the northern Baffin Bay (AMAP 2004). Concentrations were relatively consistent across species with the exception of the Greenland shark (*Somniosus microcephalus*) and Greenland halibut (*Reinhardtius hippoglossoides*), which displayed higher levels. The Greenland halibut is a large, benthic fish, which may account for the higher levels. PCBs were the predominant compounds in these two fish species, followed by DDTs and chlordanes, reflecting their generally higher trophic level (AMAP 2004). Concentrations of organic chlorines in Greenland sharks collected in the Davis Strait and Cumberland Sound region in 1997 and 1999 were in the range of other top Arctic marine predators, i.e. polar bear and glaucous gull (AMAP. 2004). Concentrations were 10–100 higher than those observed in Greenland halibut and 3–10 times than those in ringed seals, suggesting a very high trophic position.

As part of the monitoring programme, the concentrations of different POPs were measured in black guillemot eggs, ringed seal blubber and polar bear adipose tissue. The content of POPs increases with age; therefore ringed seals and polar bears were divided into two groups, juveniles and adult. If possible a distinction was also made between males and females.

PCB concentrations showed a decreasing trend for ringed seals; for guillemot eggs no clear trend was visible, but the time series only started in 1999. DDT levels have decreased significantly in all species monitored.

For HCB, a significant non-linear decrease was observed for ringed seal since 1994. Concentrations have clearly decreased, and particularly from 1994-1999. HCB levels in guillemot eggs showed a slight increase since 1999. In general, a similar trend as for PCBs was found.

The effects of biological and chemical factors on trophic transfer of organochlorines (OC) were measured in six zooplankton species, a benthic invertebrate (*Anonyx nugax*), Arctic cod, seabirds (six species), and ringed seals in the North Water Polynya. Strong positive relationships were found between organochlorine concentrations and trophic level providing clear evidence of their biomagnification in Arctic marine food webs (AMAP 2004).

## 7.3 Brominated flame retardants

Polybrominated diphenyl ethers (PBDEs) represent the most widely used flame retardants found as an additive in plastics, textiles or electronic equipment to prevent fires. PBDEs have similar physical and chemical properties as PCBs. PBDEs were analysed in blubber of ringed seals, partly retrospectively since the measurements were performed on the same samples used for the PCB analyses. BDE-47 was the only congener consistently found above the detection limit. It showed a significantly increasing trend of approx. 5 % annually (Vorkamp *et al.* 2008). However, these levels are about 10 times lower than those observed in ringed seals from East Greenland (Riget *et al.* 2006).

## 7.4 Perfluorinated compounds (PFCs)

Compounds belonging to this group, e.g. perfluorooctane sulfonate (PFOS), are used in a variety of consumer products and in industrial materials. They have been identified as global pollutants and are also known to bioaccumulate within marine food webs. Their levels were measured in the livers of ringed seals and polar bears (< 5 years), partly using archived samples.

In ringed seals an increasing trend of PFOS, PFDA and PFUnA has been observed since 1980 with an annual rate between 5.7 % and 12.1 %, which was significant only in the case of PFUnA. Generally, PFC levels were significantly lower in ringed seals from West Greenland compared to those from East Greenland (Bossi *et al.* 2005).

## 7.5 Tributyltin (TBT)

The antifouling agent, tributyltin (TBT) can be found in many coastal waters in both industrial and developing countries, with the highest levels in harbours and shipping lanes (Tanabe *et al.* 2000). In remote areas such as the Arctic environment, TBT has mainly been detected close to harbours and shipping lanes (Strand & Asmund 2003, AMAP 2004). The presence of TBT residues in harbour porpoises from Greenland shows that organotin compounds have also spread to the Arctic region even though the concentrations are rather low (Jacobsen & Asmund 2000, Strand *et al.* 2005).

Presence of TBT and triphenyltin (TPhT) was indicated in the area around Thule Airbase (TAB) in Northwest Greenland during a study performed in 2002 (Strand *et al.* 2006). Occurrence of imposex, a sensitive indicator for the presence of TBT, was found in the Arctic whelk *Buccinum fumarkianum* at several locations around TAB (Strand *et al.* 2006).

## 7.6 Polycyclic Aromatic Hydrocarbons (PAH)

Levels of oil hydrocarbons are generally low in the Arctic marine environment and often close to background concentrations, except in areas with anthropogenic impact such as harbours. Presently, the majority of petroleum hydrocarbons in the Arctic originate from natural sources such as seeps (AMAP 2007).

Over the years various studies on hydrocarbons, their patterns and sources have been performed mainly in Southwest Greenland (Mosbech *et al.* 2007b).

In 2004, Total Petroleum Hydrocarbons (TPC) and PAH levels were estimated in sea sediments from areas with indication of potential seeps including two sites in East Greenland, i.e. Young Sound and Greenland Sea (Mosbech *et al.* 2007b). Samples from the Greenland Sea showed considerably higher levels whereas those from Young Sound were in the background range. The comparison of the rations between petrogenic and pyrogenic PAHs revealed no significant petrogenic sources and no indication for a natural petroleum seep (Mosbech *et al.* 2007b).

From the studies performed so far in Greenland with regard to PAH levels on biota and sediment (including sediments from offshore areas, from municipal waste dumpsites and from sites with no known local pollution sources), levels of petroleum compounds in the Greenland environment appear to be relatively low.

## 7.7 Conclusions on contaminant levels

In general, AMAP activities have revealed that levels of organoclorines in Arctic biota are generally highest in the marine organisms belonging to the top trophic level (e.g. great skuas, glaucous gulls, great black-backed gulls, killer whales, pilot whales, Arctic fox, and polar bears). This is particularly true for biomagnification of PCBs and DDT. AMAP activities have also shown a decrease in the levels of some POPs (e.g. PCBs and DDT), as result of the introduction of bans and restrictions relating to their use in other parts of the world (AMAP 2004). At the same time, however, levels of new persistent pollutants, currently produced in large quantities, are increasing (AMAP 2004). These substances have also been detected in animals from Greenland. The brominated flame retardants, hexabromocyclododecane (HBCD) and tetrabromobisphenol A (TBBPA) are chemicals produced in high volumes. In recent years, their presence has been reported in sediment and biota from the marine environment (Frederiksen *et al.* 2007). Concentrations of HBCDs in animals from West Greenland are generally lower than in the same species and tissues from East Greenland. The same effect has previously been described for other halogenated compounds such as PBDEs (Vorkamp *et al.* 2007).

The short overview given, based on available data and information, documents that our present knowledge on contaminant levels in marine organisms from the KANUMAS East assessment area is still limited. Further studies are needed to fill the gaps in order better to understand the extent to which biota in the potential oil exploration area might be impacted by contaminants and to serve as baseline for a future monitoring and assessment.

There are also major gaps concerning the potential impact of oil-related pollution in species already affected by POPs or metals.

In this respect we also need to know if the present contaminant loads have any biological impact, involving sublethal health effects or impairment.

## 7.8 Biological effects

The research and monitoring activities described in the previous section clearly indicate the presence of different kinds of contaminants (e.g. POPs, heavy metals) in biota from Greenland. Regional differences in the contaminant levels have been found as well as differences between species, with highest concentrations apparent in top predators (e.g. polar bear, seals). However, contaminant levels are often still lower than in biota from more temperate regions, e.g. North Sea or Baltic Sea. The questions that arise relate to whether the levels found in the Arctic are sufficiently high to cause biological effects and what the threshold levels of impact might be.

Threshold levels have been estimated for various contaminants in a range of species, both under laboratory conditions and in the field in European waters. These studies have clearly indicated that organisms are affected by contaminants and that their physiological responses depend on the duration and extent of exposure. The effects revealed range from enzyme inhibition and changes in cellular processes, to immuno-suppression, neurotoxic and genotoxic effects up to reproduction impairment or histopathology alterations as endpoint of the pollutant impact. Differences in the response are notable among species and regions (Van der Oost *et al.* 2003, Lehtonen *et al.* 2006, Picado *et al.* 2007). Toxicity tests have also widely been used in temperate regions to relate environmental concentrations to biological effects, but very few tests have been published on polar species.

Presently, little is known about the sensitivity of Arctic species towards pollution impacts. This, in turn, makes it difficult to estimate if threshold values determined in other species are valid for comparison with the contaminant levels found in Arctic species.

Arctic species have very specific life strategies and population dynamics as a result of adaptation to the harsh environment. Moreover, their fat content and seasonal turnover differs compared to more temperate species (AMAP 2004). The lower temperatures in the Arctic are also likely to have an impact on the toxicity of contaminants.

Few data are available to determine whether polar species are more (or less) sensitive to pollutants than temperate species and hence whether the relationships between contaminant concentrations and impacts derived from temperate species can be applied to high latitudes.

### 7.8.1 Biological effects of contaminants in Arctic organisms

Recently, awareness that the pollution levels in Arctic organisms may cause sublethal biological effects has increased. Based on laboratory and field studies performed at Bear Island (Bjørnøya) and in Svalbard it has been demonstrated that the present levels of certain POPs found in polar bears and glaucous gulls have an influence on behavioural, biochemical, physiological and immunological parameters, affecting the health of these species (Gabrielsen 2007).

In Greenland pollution effects have been investigated mainly on polar bears since they are the species showing the highest levels of certain contaminants in the Arctic, e.g. the populations from East Greenland and Svalbard (Norway). Different studies on East Greenland polar bears performed over the past years have provided evidence that higher loads of PCBs, DDT and / or polybrominated diphenyl ethers are a cofactor in the development of renal lesions and contribute to liver histopathology. Furthermore, these substances are believed to reduce bone mineral density in polar bears (Kirkegaard *et al.* 2005, Sonne *et al.* 2004, 2005, 2006).

Polar bears from Greenland also show considerable amounts of mercury in their tissues. Mercury is a potent neurotoxic heavy metal. Its accumulation is associated with subtle neurological damage, as determined by measuring neurochemical biomarkers known to be disrupted by mercury. In a recent study it has been shown that East Greenland polar bears show decreased levels of NMDA receptors, which play a role in the neuronal signal transmission. In future studies this could serve as a sensitive indicator to assess sublethal and early effects of mercury in polar bears (Basu *et al.* 2008).

### 7.8.2 Polyaromatic hydrocarbons (PAH) and possible effects on biota

At present, PAH levels are relatively low in Greenland biota. With increasing human activities, e.g. in relation to oil exploration, this may change and reliable environmental monitoring tools are required to identify any potential impact on the biota.

PAHs are taken up by marine organisms directly from the water (via the body surface or gills) or through diet. Many studies have indicated that PAHs are more or less easily metabolised by invertebrates and generally efficiently metabolised by vertebrates such as fish (review Hylland *et al.* 2006). Therefore, and in contrast to most persistent organic pollutants, PAHs are not biomagnified in the marine food web. Dietary exposure to PAHs may however be high in species that preferentially feed on organisms with low ability to metabolise PAHs, such as bivalves (Peterson *et al.* 2003). At the other end of the food chain, filter-feeding zooplankton can be exposed to high levels through filtering out oil droplets containing PAHs from the surrounding water.

The effects of PAHs on organisms are extensive and occur on various levels, including biochemical and physiological and / or genotoxic effects (Hylland *et al.* 2006). The responses and tolerance to PAHs can vary considerably in organisms, depending on the geographical range of the species but also on the particular PAH mixture. PAHs are a large group of diverse substances, ranging from two-ring naphthalenes and naphthalene derivates to complex ring structures containing up to 10 rings.

PAHs are also major contributors to the toxicity of produced water released during oil and gas production. Produced water is a complex mixture, and its composition varies from well to well and over time at any individual well. Inputs of effluents from offshore oil and gas production platforms in the Norwegian sector of the North Sea have been monitored through an integrated chemical and biological effects programme since 2001 (Hylland *et al.* 2008).

To test potential effects on organisms, cages with either Atlantic cod or blue mussels were positioned at various distances (0 – 5000 m) and different directions from the oil platforms. In addition, two reference locations were used, both 8000 m away from the respectively platform. PAH tissue residues in blue mussels ranged between 0-40ng / g wet weight depending on the distance to the oil rigs. PAH bile metabolites in cod confirmed exposure to effluents but levels were low when compared to those found in cod from coastal waters (Hylland *et al.* 2008). The found biological effects in the blue mussels reflect exposure gradients and that the mussels were affected by components in the produced water.

The results also indicate synergistic and antagonistic interactions between low- and high-molecular-weight PAHs.

The response of marine animals to petroleum exposure via water, food or sediment has also been studied extensively in the laboratory and in the field by means of a number of biochemical, physiological and histological indicators. Their applicability and limitations in relation to ecological risk assessment after an oil spill has been assessed (Anderson & Lee 2006). However, as indicated before, most of these studies have been performed in temperate regions.

In regard to the Arctic and Greenland, up to now only a few studies have been carried out to better understand how polar organisms are affected by and respond to PAH exposure.

**Effect studies on Arctic species**

The biological responses to oil-contaminated sediment were studied in the Arctic bivalve *Mya truncata*, a filter feeder living buried in the sediment, which represents an important food source for bearded seals (*Erignathus barbatus*) and walrus (*Odobaenus rosmarus*). A small-scale field experiment was carried out in the Isfjorden at Svalbard. After 2 weeks of exposure to sediment contaminated with a PAH mixture (crude oil), responses of three biomarkers (total oxyradical scavenging capacity-assay (TOSC), plasma membrane stability of haemocytes and respiration rates) were measured. It was shown that PAHs were taken up by *M. truncata* and resulted in destabilisation of the haemocyte membranes, suggesting a direct pollution impact at least under experimental conditions (Camus *et al.* 2003). A range of established biomarkers in temperate areas were studied experimentally on the Arctic spider crab *Hyas araneus*, common in Svalbard fjords (Norway), to validate their use in polar ecosystems. The effects of oil were tested at 2° C via injection and contaminated sediment. After two weeks of exposure, the heart rate and oxygen consumption was measured in the crab and the level of oxidative stress. An increase in heart rate was observed, whereas the respiration rates were similar to those in the controls. There were also signs of oxidative stress in the spider crabs after PAH exposure (Camus *et al.* 2002a). The Arctic scallop, *Chlamys islandicus*, was selected as a key species for biomonitoring because of wide distribution in Arctic waters and its commercial value. Test animals maintained at 2° C, were injected with benzo(a)pyrene in the adductor muscle in low and high doses. Benzo(a)pyrene was metabolised in the Arctic scallops, resulting in the production of reactive oxygen species (ROS), indicating effects on the redox status and the susceptibility to oxidative stress (Camus *et al.* 2002b).

Cellular energy allocation (CEA) is another indicator to assess possible effects of PAHs on organisms. It is expressed as the energy budget of organisms by assessing changes in energy available (carbohydrates, protein and lipid content) and the integrated energy consumption. The energy budget was measured in three Arctic benthic species (*Gammarus setosus* (Amphipoda), *Onisimus litoralis* (Amphipoda) and *Liocyma fluctuosa* (Bivalvia) subjected experimentally to water-accommodated fraction (WAF) of crude oil or drill cuttings (DC). It was shown that the three species differed in their responses. The energy budget in *G. setosus* was affected by WAF, while DC affected the energy budget in *O. litoralis*. In contrast, *L. fluctuosa* was not affected by any of the treatments. The different responses to oil-related compounds in the three species are likely to result from differences in feeding and burrowing behaviour and species-specific sensitivity to petroleum-related compounds (Olsen *et al.* 2007).

In the Arctic another important aspect is the effects of oil-related compounds on sea-ice species. Amphipods are dominant species in sea ice and they represent a direct link between lower and higher trophic levels. Exposure to pollutants may increase their energy requirement and hence result in reduced energy available for growth and reproduction. The cellular energy allocation (CEA) was measured in the sea-ice amphipod, *Gammarus wilkitzkii* after exposure for one month to the water soluble fraction (WSF) of oil. Significantly higher protein contents were observed in specimens exposed to a medium dose, suggesting a disturbed protein metabolism. However, the total energy budget was not affected (Olsen *et al.* 2008). In the same species (*G. wilkitzki*) the malformation of embryos was estimated after exposure to the WSF. No differences in reproductive stage were observed among the different treatments after 30 days of exposure. However, frequency of embryo aberrations was significantly higher in specimens exposed to a higher dose compared to controls, indicating that the embryos were affected by oil. No differences in the developmental stages were seen among treatments, indicating that WSF did not alter the period of embryogenesis. It was concluded that embryo development of the sea-ice amphipod can be impaired by WSF (Camus & Olsen 2008).

**Biological effects of PAH in Greenland biota**

Species of the harpacticoid copepod genus *Microsetella* are commonly reported to occur in Arctic and sub-Arctic coastal waters, but nothing is known about their sensitivity to toxic substances. Effects of the PAH pyrene on *Microsetella* spp. from Western Greenland were investigated based on survival of females, feeding status, and nucleic acid content after a 96-h exposure (Hjorth & Dahllöf 2008). At a high exposure concentration (100 nM) less than 10 % survived and a 50 % reduced survival was also evident when the copepod was exposed to 0.1 and 10 nM. A reduced DNA content was found at exposure concentrations between 1–100 nM, suggesting inhibition of egg development. Exposure to higher concentration of pyrene resulted also in a reduced feeding activity. The data suggests higher sensitivity of *Microsetella* spp. compared to other Arctic copepods, which implies more severe effects from oil on the pelagic food web in the areas and periods where *Microsetella* spp. dominates Arctic plankton food webs.

The effects of pyrene on grazing and egg production in the ecologically important Arctic copepods, *Calanus finmarchicus* and *Calanus glacialis* were studied in Disko Bay, Western Greenland. The effects of pyrene were investigated experimentally, both as passive uptake via diffusion through membranes and active uptake through ingestion of contaminated food. Furthermore, the hatching success of eggs from exposed females was studied, and from eggs directly exposed to pyrene. In the non-fed *Calanus* spp no reduction in egg production was found, indicating that the uptake of pyrene through passive diffusion was limited. A significant reduction in grazing and egg production was observed in the fed *C. finmarchicus* exposed to 100nM pyrene. In this exposure group also the time-dependent development in grazing and egg production was reduced in both species. The observed differences in the response time between the two species were attributed to differences in the amount of storage lipid and in their reproductive strategies (Jensen *et al.* 2008).

How pyrene might affect natural algae and bacteria communities in Arctic sediment was studied near Sisimiut (West Greenland) using microcosms. Benthic microalgae were especially sensitive to pyrene and increased toxicity was found at high levels of UV light already at low pyrene concentrations (Petersen & Dahllöf 2007, Petersen *et al.* 2008). The pronounced pyrene effects caused algal death and organic matter release, which in turn stimulated bacterial degradation of organic matter.

To day no studies on PAH related biological effects have been performed in the assessment area.

**Future studies**

When assessing potential PAH effects two possible major sources have to be considered.

1) Effluents from offshore production platforms (e.g. produced water or drilling mud discharges)
2) Accidental oil spill during exploration and production.

1) The studies described in this section, which have mainly been carried out in the sea, indicate that there is a potential risk that organisms might be impacted by components present in these effluents (e. g. PAH, alkylphenols or metals). The release and occurrence of toxic substances into the assessment area during the production phase will very much depend on the technology being applied as well as on the specific hydrographical conditions at the potential production sites. In order to detect and assess any impact on the biota, a site specific monitoring programme has to be developed taking into account the specific arctic conditions. Caging of indicator species and analysis of a set of biological markers could be part of such a monitoring programme.

2) Accidental oil spills
The studies described in this section also document that exposure to PAHs cause effects on different biological levels and that the thresholds can differ depending on the species. However, in most of the studies listed, pyrene has been used as "model" substance to evaluate potential effects of PAHs under laboratory conditions. The chosen concentrations are in the range of those found in the sediment in coastal areas which were directly impacted by oil, e.g. after the Exxon Valdez oil spill (Anderson & Lee 2006) or represent concentrations in the water column (Boehm *et al.* 2007) found directly after an oil spill. Neverthe-

less, the applied concentrations in the experiments are often at the "high end" and do not reflect possible impacts of medium or long term PAH exposure in the environment.

To be able to better assess potential risk of larger oil spill or other potential PAH sources on biota and the environment more integrated studies are needed. We also have to improve our knowledge concerning the sensitivity of key species in the assessment area and their responses to PAH and related substances.

# 8 Impact of climate change on the Arctic marine environment

The Arctic marine environment has changed over the past several decades, and these changes are part of a broader global warming that exceeds the range of natural variability over the past 1,000 years as documented in the Arctic Climate Impact Assessment (ACIA 2005). Projections of 21st century climate change by global climate models indicate an additional warming of several degrees Celsius in much of the Arctic marine environment by 2050. Based on two different emissions scenarios (A2 and B2) and five global climate models it is projected that mean annual Arctic surface temperatures north of 60º N will be 2 to 4 ºC higher, compared to the present, by the middle of the 21st century, and 4 to 7 ºC higher toward the end of the century (ACIA 2005, Walsh 2008). All of the various projections show a similar trend. Other changes predicted for 2050 are a general decrease in sea level pressure and an increase in precipitation (ACIA 2005, Walsh 2008). The most pronounced physical changes are likely to include a substantial loss of sea ice, changes in the wind patterns and moisture transport.

Continued and future warming will have an impact on the marine ecosystem and its biota (ACIA 2005, Moline *et al.* 2008) (Figure 46). An increase in water temperature has a direct influence on metabolism, growth and reproduction of organisms. Whether organisms remain in the area and adapt or relocate further north will depend on their acclimation capacity. Thus, potential long-term ecological effects will include changes in species distribution and diversity, affecting community composition and production and influencing ecosystems on local and regional scales. Reduction in sea ice, changes in snow cover, and rise in sea level will cause main habitat changes with severe consequences for marine mammals and seabirds. Changes in sea ice, water temperature, freshwater input and wind stress will also affect primary production and thus the timing, location and species composition of phytoplankton blooms. This will in turn affect the zooplankton community and the productivity of fish, e.g. mismatch in timing of phytoplankton and zooplankton production due to early phytoplankton blooms will reduce the efficiency of the food web. Food web effects could also occur through changes in the abundance of top-level

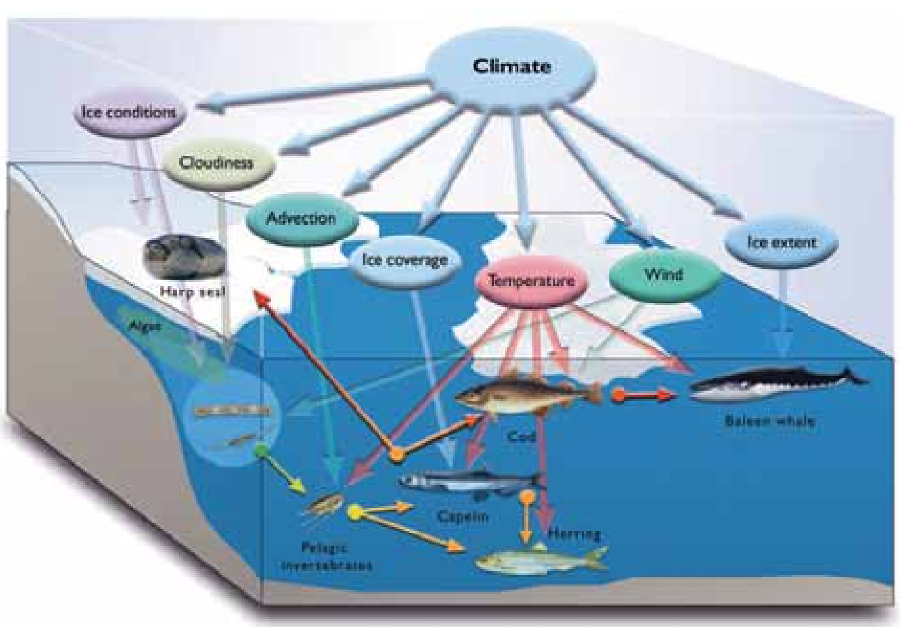



**Figure 46.** Different climate parameters that may impact the marine food chain, both directly and indirectly (From ACIA 2005).

predators, but the effects of such changes are more difficult to predict. However, generalist predators are likely to be more adaptable to changed conditions than specialist predators.

Future fluctuations in zoobenthic communities will be related to the temperature tolerance of the present species and their adaptability. If warming occurs, thermophilic species (i.e. those tolerating a wide temperature range) will become more frequent, causing changes in the zoobenthic community structure and probably its functional characteristics, especially in coastal areas.

Fish recruitment patterns are strongly influenced by oceanographic processes such as local wind patterns, mixing, and prey availability during early life stages, these are also difficult to predict. Recruitment success could be affected by changes in the timing of spawning, fecundity rates, larval survival rates, and food availability.

Poleward extension of the range of many fish species is very likely under the projected climate change scenarios. Some of the more abundant species likely to move northward due to the projected warming include Atlantic herring (*Clupea harengus*) as well as Atlantic cod (*Gadus morhua*).

The southern limits of colder water fish species, such as polar cod (*Boreogadus saida*) and capelin (*Mallotus villosus*), are likely to move northward. Greenland halibut (*Reinhardtius hippoglossoides*) might possibly shift its southern boundary northward or restrict its distribution more to continental slope regions (ACIA 2005).

The impacts of climate changes on marine mammals and seabirds are likely to be profound, but not so easy to estimate since patterns of changes are non-uniform and highly complex (ACIA 2005). There is a limit to how far north High Arctic species can shift to follow the sea ice. If the loss of sea ice is as dramatic, temporally and spatially, as has been projected by ACIA-designed models, negative consequences for Arctic animals that depend on sea ice for breeding and foraging can be expected within the next few decades.

Laidre *et al.* (2008) compared seven Arctic and four sub-Arctic marine mammal species in regard to their habitat requirements, and evidence for biological and demographic responses to climate change. Sensitivity of the different species to climate change was assessed using an quantitative index based on population size, geographic range, habitat specificity, diet diversity, migration, site fidelity, sensitivity to changes in sea ice, sensitivity to changes in the trophic web, and maximum population growth potential (Rmax). Based on the index, the hooded seal, the polar bear and the narwhal appear to be the three most sensitive Arctic marine mammal species, primarily due to their reliance on sea ice and specialised feeding behaviour. The least sensitive species were the ringed seal and bearded seal, primarily due to large circumpolar distributions, large population sizes, and flexible habitat requirements. In using a conceptual model, Moore and Huntington (2008) estimated the impacts and resilience of marine mammal species to changes in sea ice in combination with follow-up changes in benthic and pelagic communities. The response of the mammals on habitat loss (sea ice) and change in food sources will differ depending on whether they are ice-obligate (e.g. polar bear, ringed seals), ice-associated (certain seals, white whale, narwhal, bowhead whale and walrus) or seasonally migrant species (e.g. fin and minke whales).

Polar bears are at risk since their habitat is changing and there is limited scope for a northward shift in distribution (Derocher *et al.* 2004).

Change in ice climate, therefore, has a large potential to modify marine ecosystems, either through a bottom-up reorganisation of the food web in which the nutrient or light cycle is altered, or a top-down reorganisation in which the critical habitat for higher trophic levels is altered (Macdonald *et al.* 2005). At present, we have only started to understand the possible impacts and consequences of climate change for the Arctic marine environment.

## 8.1 Interactions between climate change and contaminants

Whatever the effects of habitat change on Arctic marine mammals may be, the situation must still be considered in relation to other potential threats. The Arctic environment is also already affected by human releases of contaminants as indicated in section 7 of this report.

Climate change will affect contaminant exposure and toxic effects (Macdonald *et al.* 2005) and both forms of stress will impact aquatic ecosystems and biota in many ways (Schiedek *et al.* 2007). Pathways, distribution patterns and / or toxicity of certain contaminants are likely to change, and native organisms are likely to become less tolerant to contaminant exposure due to higher temperatures (Macdonald *et al.* 2005, Schiedek *et al.* 2007). Species distribution ranges will change, and some will be displaced by temperate species which might differ in their contaminant tolerance. Additional possible risks could be caused by oil contamination due to offshore oil and gas resources being developed (Skjoldal *et al.* 2007). Climate change may also lead to increased pollution loads resulting from an increase in precipitation bringing more river-borne pollution northward (Macdonald *et al.* 2003, 2005). Biomagnification of many persistent organic pollutants (POPs) is particularly high for higher trophic levels (i.e. mammals), these animals are also among the most vulnerable to climate change as described above. Relationships between various POPs and hormones in Arctic mammals and seabirds imply that these chemicals pose a threat to the endocrine systems of these animals, in particular the thyroid hormone system (TH), but effects have also been seen in sex steroid hormones and cortisol (Jenssen 2006). Different endocrine systems are important for enabling animals to respond adequately to environmental stress, and endocrine-disrupting chemicals (EDCS) may interfere with adaptation to increased stress, e.g. that induced by climate change (Jenssen 2006). Presently, possible interactions between climate change and contaminants have not been studied in great detail and therefore our knowledge is still very limited.

## 8.2 Potential implications for the KANUMAS East area

Annual mean temperatures for selected stations in East Greenland, reaching back to 1873, document that there has been a warming period in the first three decades of the twentieth century, followed by cooling until the mid-1970s before temperatures increased again (Stendel *et al.* 2008).

Based on a regional study using the HIRHAM4 model a clear increase in air temperature has been projected for Greenland, with greatest warming in winter and spring (Stendel *et al.* 2008). Simulated mean near surface (2 m) air temperature change projected a temperature increase of 3° C in winter, 4° C in spring and 2° C in summer and autumn for the early period 2021–2051 compared to the modelled present day situation (1961–1990). For the later period (2051–2080), winter temperature increases accelerate considerably according the model, reaching a temperature increase of 7–8 ° C throughout the Arctic and 12° C along the east coast (Figure 47). Precipitation is projected to increase by about 8 % by the middle of the century and by approx. 20 % towards the end of the 21st century.

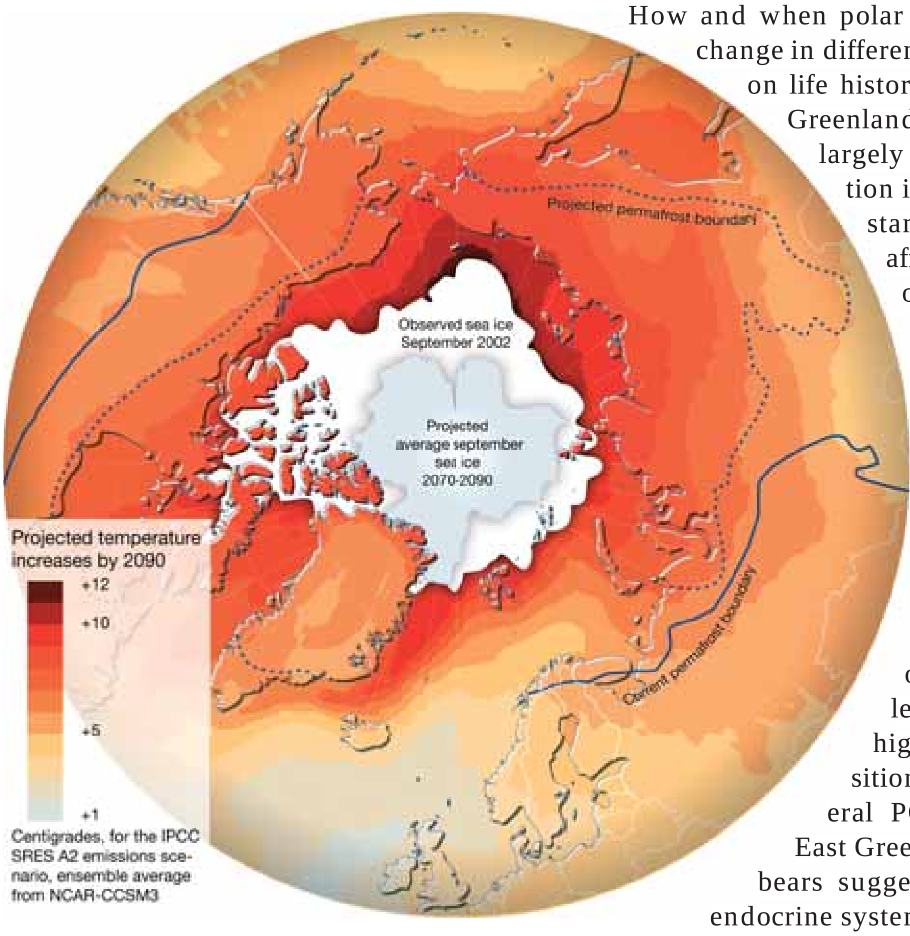



**Figure 47.** Projected temperature increases in the Arctic due to climate change, 2090 (NCAR-CCM3, SRES A2 experiment). From UNEP/GRID-Arendal Maps and Graphics Library (designer Hugo Ahlenius) 2008. Available at: http://maps.grida.no/go/graphic/projected-temperature-increases-in-the-arctic-due-to-climate-change-2090-ncar-ccm3-sres-a2-experimen.

How and when polar bears will respond to climate change in different areas is uncertain, and based on life history characteristics. In Southeast Greenland their distribution patterns is largely determined by annual variation in sea ice. An improved understanding of habitat use and factors affecting the movement patterns of polar bears in these areas will allow insights into how polar bears will respond to climate change (Derocher *et al.* 2004). Such a study has been initiated as a one of the projects related to this SEIA (see Section 13).

As pointed out in a previous chapter, many persistent organic pollutants reach high levels in polar bears due to their high-fat diet and high trophic position, and concentrations of several POPs were particular high in East Greenland. Recent studies on polar bears suggest that pollutants impact the endocrine system, immune system, and subsequent reproductive success of polar bears (Derocher *et al.* 2004). If polar bears become food stressed and their immune system is further challenged, it is possible that they may become more vulnerable to disease or parasites.

Studies performed in West Greenland have shown that the previous warming period off Greenland had clear consequences for the abundance and distribution of key fish species (Stein 2007, Drinkwater 2006) and distribution of other species (Jensen 1939, Jensen & Fristrup 1950). For the east coast such information is not available but the examples from West Greenland have shown that a warming period resulted in a clear, radical shift in the abundance and occurrence of certain species, with significant impact on community structure and thereby the functioning of the ecosystem off West Greenland. With the predicted rising temperatures in the near future, similar changes and associated effects are likely to occur also on the coast off East Greenland.

Presently, we do not know what the adaptation capacity of species is or the extent to which they might be more sensitive to the potential impact of oil exposure under changing environmental conditions. Changes in species composition and occurrence of fish species with relevance for commercial fisheries are very likely, resulting in increased fishing activity in the area. This has to be taken into account in consideration of future oil exploration activities.

# 9 Impact assessment

## 9.1 Methodology and scope

The following assessment is based on available background information compiled from studies published in scientific journals and reports. For many ecosystem components this information is inadequate. Several studies were initiated specifically for the present assessment (Nielsen et. al. 2008, Johansen 2008, Boertmann *et al*. 2009a, NERI unpublished, GINR unpublished). Most of these are still in progress, why only preliminary results have been available at present, but the final results will be incorporated into the final version.

### 9.1.1 Boundaries

The assessment area is the area described in the introduction (Figure 1). This is the region which potentially can be impacted by the activities and particularly by a large and long-lasting oil spill deriving from activities in the expected licence areas. However, it cannot be excluded that the area affected might be even larger, including coasts both north and south of the assessment area and waters within the Norwegian and Icelandic EEZs.

The assessment includes, as far as possible, all activities associated with an oil field, from exploration to decommissioning. The almost permanent presence of sea ice in the major part of the assessment area makes it difficult (or even impossible) with the present technology to operate in the area, but in this assessment it is assumed that exploration activities will take place in the summer and autumn (July–September) when ice conditions are relatively light.

Production activities will, if approved and initiated, take place throughout the year. How potential production facilities will be constructed is presently not known, but the setup could be similar to that described from the Disko West area by the APA study (2003), *cf*. section 2.4.

### 9.1.2 Impact assessment procedures

The first step of an assessment is to identify potential interactions (overlap / contact) between potential petroleum activities and ecosystem components in the area both in time and space. Interactions are then evaluated for their potential to cause impacts.

Since it is not possible to evaluate all ecological components in the area, the concept of Valued Ecosystem Components (VECs) has been aaplied.

VECs can be species, population, biological events or other environmental features that are important to the human population (not only economically), have a national or international profile, can act as indicators of environmental change or can be the focus of management or other administrative efforts.

VECs include important flora and fauna, habitats (also temporary and dynamic like the marginal ice zone and polynyas) as well as processes such as the spring bloom in primary production.

The VECs selected here are species and events which potentially can be impacted by oil activities in the assessment area, and also species and events where changes can be detected (see section 4.8)

The spatial extent of effects is indicated as local, regional, national or global. Local refers to impacts in the nearby environment (up to ~ 100 $km^2$). Regional encompasses effects on wider areas including the entire assessment area. The extent of the national and global scale is evident.

The nature and extent of environmental impacts from petroleum activities can be evaluated on different scales (or a combination of these):

- from individuals to populations
- temporal, from immediate over short term to long term
- spatial, from local to global

However, quantification of the impacts on ecosystem components is very difficult and in most cases impossible. The spatial overlap of the expected activities cannot be assessed as it is unknown where oil activities will take place. Furthermore, the physical properties of potentially spilled oil are likewise not known. Moreover, there is still a lack of knowledge concerning important ecosystem components and how they interact. In addition, ecosystem functioning will possibly be altered in the near future due to climate change.

Relevant research on toxicology, ecotoxicology and sensitivity to disturbance has been used, and conclusions from various sources – the Arctic Council Oil and Gas Assessment (AMAP 2007, Skjoldal *et al.* 2007), the extensive literature on the Exxon Valdez oil spill in Alaska in 1989 as well as the Norwegian EIA of hydrocarbon activities in the Lofoten-Barents Sea (Anonymous 2003) – have been drawn upon.

Many uncertainties still remain and expert judgement or general conclusions from research and EIAs carried out in other Arctic or near-Arctic areas have been applied in order to evaluate risks and to assess the impacts. Much uncertainty in the assessment is inevitable and is conveyed with phrases such as ‘most likely’ or ‘most probably’.

# 10 Impacts of the potential routine activities

## 10.1 Exploration activities

In general all activities related to exploration are temporary and will be terminated after a few years if no commercial discoveries are made. Another important aspect in relation to exploration is that activities only can take place during the few months when the sea is more of less free of ice.

Environmental impacts of explorations activities relate to:
Noise from seismic surveys and drilling
Cuttings and drilling mud
Disposal of various substances
Emissions to the air
Placement of structures

In relation to exploration only the most significant impacts (from noise, cuttings and drilling mud) will be considered. The other issues will be dealt with in the production and development sections, as they are much more significant during these phases in the life cycle of a petroleum field.

### 10.1.1 Assessment of noise

**Noise from seismic surveys**
The main potential impacts on fish and marine mammals from the seismic sound generators include:

- physical damage: injury to tissue and auditory damage from the sound waves
- disturbance / scaring: behavioural impacts, including masking of underwater communication by marine mammals.

A recent review of the effects of seismic sound propagation on different biota concluded 'that seismic sounds in the marine environment are neither completely without consequences nor are they certain to result in severe and irreversible harm to the environment' (DFO 2004). But there are some potential detrimental consequences. Short-term behavioural changes (such as avoiding areas with seismic activity) are known and in some cases well documented, but longer-term changes are debated and studies are lacking.

In Arctic waters there are certain special conditions which should be considered. It cannot be assumed that there is a simple relationship between sound pressure levels and distance to source due to ray bending caused, for example, by a strongly stratified water column. It is therefore difficult to base impact assessments on simple transmission loss models (spherical or cylindrical spreading) and to apply assessment results from southern latitudes to the Arctic (Urick 1983). For example, the sound pressure may be very strong in convergence zones far (> 50 km) from the sound source, and this is particularly evident in stratified Arctic waters. This has recently been documented by means of acoustic tags attached to sperm whales, which recorded high sound pressure levels (160 dB re µPa, pp) more than 10 km from a seismic array (Madsen *et al*. 2006).

Another issue rarely addressed is that airgun arrays generate significant sound energy at frequencies many octaves higher than the frequencies of interest for geophysical studies. This increases concern regarding potential impacts, particularly on toothed whales with poor low frequency hearing (Madsen *et al.* 2006).

The VECs potentially impacted by seismic surveys are primarily fish and marine mammals, while habitats will not be affected.

**Impact of seismic noise on fish**

Several experts agree that adult fish will generally avoid seismic sound waves, seek towards the bottom, and will not be harmed. Young cod and redfish, as small as 30–50 mm long, are able to swim away from the mortal zone near the airguns (comprising a few metres) (Nakken 1992).

It has been estimated that adult fish react to an operating seismic array at distances of more than 30 km, and that intense avoidance behaviour can be expected within 1–5 km (see below). Norwegian studies measured declines in fish density at distances more than 10 km from sites of intensive seismic activity (3D). Negative effects on fish stocks may therefore occur if adult fish are scared away from localised spawning grounds during spawning season resulting in reduced recruitment. Spawning grounds for herring and Atlantic cod are therefore closed for seismic activities in the Lofoten-Barents Sea area during the cod and herring spawning period in May–June (Anonymous 2003). Outside spawning grounds, fish stocks are probably not affected by the disturbance, but fish can be displaced temporarily from important feeding grounds (Engås *et al.* 2003, Slotte *et al.* 2004).

Adult fish held in cages in a shallow bay and exposed to an operating airgun (0.33 l, source level at 1 m 222.6 dB rel. to 1 µPa peak to peak) down to 5–15 m distance sustained extensive ear damage, with no evidence of repair nearly 2 months after exposure (McCauley *et al.* 2003). It was estimated that a comparable exposure could be expected at ranges < 500 m from a large seismic array (44 l) (McCauley *et al.* (2003). So it appears that the fish avoidance behaviour demonstrated in the open sea protects the fish from damage. In contrast to these results, marine fish and invertebrates monitored with a video camera on an inshore reef did not move away from airgun sounds with peak pressure levels as high as 218 dB (at 5.3 m relative to 1 µPa peak to peak) (Wardle *et al.* 2001). The reef fish showed involuntary startle reactions but did not swim away unless the sound source was visible to the fish at a distance of only approx. 6 m. Despite a startle reaction displayed by each fish every time the gun was fired, continuous observation of fish in the vicinity of the reef using time-lapse TV and tagged individuals did not reveal any sign of disorientation, and fish continued to behave normally in similarly quite large numbers, before, during and after the gun firing sessions (Wardle *et al.* 2001). Another study during a full-scale seismic survey (2.5 days) also showed that seismic shooting had a moderate effect on the behaviour of the lesser sandeel (*Ammodytes marinus*) (Hassel *et al.* 2004). No immediate lethal effect on the sandeels was observed, either in cage experiments or in grab samples taken during night when sandeels were buried in the sediment (Hassel *et al.* 2004).

The studies quoted above indicate that behavioural and physiological reactions to seismic sounds among fish may vary between species (for example, according to whether they are territorial or pelagic) and also according to the seismic equipment used. Generalisations should therefore be interpreted with caution.

**Impact of seismic noise on zoo- and ichtyoplankton**

Zooplankton and fish larvae and eggs (=ichtyoplankton) cannot avoid the pressure wave from the airguns and can be killed within a distance of less than 2 m, and sublethal injuries may occur within 5 m (Østby *et al.* 2003). The relative volume of water affected is very small and population effects, if any, are considered to be very limited in e.g. Norwegian and Canadian assessments (Anonymous 2003). However, in Norway, specific spawning areas may have very high densities of fish larvae in the uppermost water layers. This fact contributes to the closure for seismic activities on such spawning grounds in the Lofoten-Barents Sea area when cod and herring spawn in May–June (Anonymous 2003). It was concluded in the assessment of seismic activities in the Disko West Area that it was most likely that impacts of seismic activity (3D) were negligible on the recruitment to fish stocks in West Greenland waters. Because densities of fish eggs and larvae generally are low in the upper 10 m and because most fish species spawn in a dispersed manner in winter or spring with no temporal overlap with seismic activities. There is very limited data on fish egg and larvae densities as well as zooplankton from the assessment area, but it can be assumed that the density will not be higher than in other Greenland waters.

**Impact of seismic noise on fisheries**

Norwegian studies (Engås *et al.* 1995) have shown that 3D seismic surveys (a shot fired every 10 seconds and 125 m between 36 lines 10 nm long) reduced catches of Atlantic cod (*Gadus morhua*) and haddock (*Melanogramma aeglefinus*) at 250–280 m depth. This occurred not only in the shooting area, but as far as 18 nautical miles away. The catches did not return to normal levels within 5 days after shooting (when the experiment was terminated), but it was assumed that the effect was short term and catches would return to normal after the studies. The effect was moreover more pronounced for large fish compared with smaller fish.

The only commercial fishery which may be impacted by seismic surveys in the assessment area is the offshore trawling for Greenland halibut in the southernmost part. A Canadian review (DFO 2004) concluded that the ecological effect of seismic surveys on fish is low and that changes in catchability are probably species dependent. A Norwegian review (Dalen *et al.* 2008) concluded that the above described results of Engaas *et al.* (1995) results cannot be applied to other fish species and to fisheries taking place in other water depths.

It is therefore difficult to assess the effect on the offshore Greenland halibut fisheries, because reactions of this species have not been studied. However, if catches are reduced by a seismic survey, the effect is most likely temporary and will probably only affect specific fisheries for a few days. The fishery of Greenland halibut in the assessment area is relatively small compared to the overall Greenland fishery (Figure 38). However, the trawling grounds are restricted to specific depths at approx. 1,500 m, thus alternative fishing grounds would be limited if Greenland halibut are displaced by seismic activity.

It should be mentioned that there also are examples where fisheries have increased after seismic shooting, which was assumed to be an effect of changes of vertical distribution of fish (Hirst & Rodhouse 2000).

**Impact of seismic noise on birds**

Seabirds are generally not considered to be sensitive to seismic surveys, because they are highly mobile and able to avoid the seismic sound source. However, in inshore waters, seismic surveys carried out near the coast may disturb (from the presence and activity of the ship) breeding and moulting congregations.

**Impact of seismic noise on marine mammals**

There is strong evidence for behavioural effects on marine mammals from seismic surveys (Compton *et al.* 2008). Mortality has not been documented, but there is a potential for physical damage, primarily auditory damage. Under experimental conditions temporary elevations in hearing threshold (TTS) have been observed (Richardson *et al.* 1995, National Research Council 2005). Such temporary reduced hearing ability is considered unimportant by Canadian researchers, unless it develops into permanent threshold shift (PTS) or it occurs in combination with other threats normally avoided by acoustic means (DFO 2004). In the USA a sound pressure level of 180 dB re 1µPA) (rms) or higher is believed to provoke TTS or PTS and is adopted by the US National Marine Fisheries Service as a mitigation standard to protect whales (NMFS 2003, Miller *et al.* 2005).

Displacement is a behavioural response, and there are many documented cases of displacement from feeding grounds or migratory routes of marine mammals exposed to seismic sound. The extent of displacement varies between species and also between individuals within the same species. For example, a study in Australia showed that migrating humpback whales avoided seismic sound sources at distances of 4–8 km, although they occasionally came closer (McCauley *et al.* 2000). In the Beaufort Sea autumn-migrating bowhead whales avoid areas where the noise from exploratory drilling and seismic surveys exceeds 117–135 dB and they may avoid the seismic source by distances of up to 35 km (Reeves *et al.*, 1984, Richardson *et al.*, 1986, Ljungblad *et al.*, 1988, Brewer *et al.*, 1993, Hall *et al.*, 1994, NMFS 2002, Gordon *et al.*, 2004), although a Canadian study showed somewhat shorter distances (Lee *et al.*, 2005). However, minke whales have also been observed as close as 100 m from operating airgun arrays (NERI unpublished). The ecological significance of such displacement effects is generally unknown, but if alternative areas are available the significance probably will be low, and the temporary character of seismic surveys also will allow displaced animals to return after the surveys.

Evidence from West Greenland waters indicated that humpback whales, which had been satellite tracked, utilised extensive areas and moved between widely spaced feeding grounds, they therefore most likely still had access to alternative foraging areas if they were displaced from one area by seismic activities (Dietz *et al.* 2002, Heide-Jørgensen & Laidre 2007).

A behavioural effect widely discussed in relation to whales and seismic surveys is the masking effect of communication and echolocation sounds. There are, however, no studies which document such effects, mainly because the experimental setups are extremely challenging. Masking requires overlap in frequencies, overlap in time and sufficiently high sound pressures. The whales in the assessment area use a wide range of frequencies (from < 10 Hz to > 100 kHz), why seismic surveys are likely to overlap in frequency with at least some of the sounds produced by these whales. However, a Canadian study assessedd that it is not likely that overlap in frequencies, occur during seismic surveys (Gordon *et al.* 2004). If sound pressures will be high enough at the received distances to mask biologically significant sounds is another uncertainty. Masking is more likely to occur from the continuous noise from drilling and ship propellers and this have been demonstrated for white whales and killer whales in Canada (Foote *et al.* 2004, Scheifele *et al.* 2005). Sperm whales showed diminished forage effort during air gun emission, but it is not clear if this was due to masking of echolocation sounds or to behavioural responses of the whales or the prey (Miller *et al.* 2005 in Jochens 2008).

The most noise-vulnerable whale species in the assessment area will be narwhal and bowhead whale, and there will be a risk of temporary displacement from critical habitats. Other whales occurring in summer and autumn will also be vulnerable, but their occurrence in the assessment area is less regular and no concentrations areas are known.

In general, seals display considerable tolerance to underwater noise (Richardson *et al.* 1995), confirmed by a study in Arctic Canada in which ringed seals showed only limited avoidance to seismic operations (Lee *et al.* 2005). In another study, ringed seals had habituated to industrial noise (Blackwell *et al.* 2004). However 'hauled-out' walruses and whelping hooded and harp seals on the drift ice may be disturbed and displaced by the activity (not by the seismic noise), although the whelping period is early in the spring at a time when seismic surveys are not possible.

**Mitigation of impacts from seismic noise**

Mitigation measures generally recommend a soft start or ramp up of the airgun array each time a new line is initiated (review by Compton *et al.* 2008). This will allow marine mammals to detect and avoid the sound source before it reaches levels dangerous to the animals. Secondly it is recommended to bring skilled marine mammal observers onboard the seismic ships, in order to detect whales and instruct the crew to delay shooting when whales are within a certain distance (usually 500 m) from the array. The detection of nearby whales in sensitive areas can be more efficient if supplemented by the use of hydrophones for recording whale vocalisations. However, a problem exists with respect to visual observations, especially in Arctic waters, and that is the phenomenon of convergence zones where very high sound pressures may occur far from the sound source and out of sight of the observer. A third mitigating measure is to close areas in sensitive periods. The spawning grounds for herring and cod are closed for seismic surveys in the Lofoten-Barents Sea area during the spawning season. A preliminary EIA for seismic activities in West Greenland waters recommends that seismic surveys are avoided in specific narwhal areas (Mosbech *et al.* 2000). Finally it is recommended that local authorities and the hunters' organisations be informed before seismic activities take place in their local area. This may help hunters to take into account that animals may be disturbed and displaced from certain areas at times when seismic activities are taking place.

In Arctic Canada a number of mitigation measures were applied to minimise impacts from seismic surveys on marine mammals and subsistence hunting targeting these (Miller *et al.* 2005). Some were identical to those mentioned above, and the most important was a delay in the start of seismic operation both until the end of the white whale hunt and the period of occupation of especially important white whale habitats. Some particularly important white whale areas were even completely closed for surveys.

In a note on seismic surveys and marine mammals from NERI (Boertmann *et al.* 2009b), important points to consider in an assessment of seismic surveys will be:

- The species that could be affected; as tolerance to seismic surveys varies between species
- The natural behaviour of these species when surveys are taking place. Disturbance varies according to the species' annual cycles – the degree of sensitivity of animals engaged in mating or calving or those feeding or migrating
- The severity and duration of impact. Even a strong startle reaction to an approaching survey vessel may have only a small total impact on the animal, whereas a small, but prolonged (days or weeks) disturbance to feeding behaviour could have a much larger impact.
- Total number of animals likely to be affected. It is not possible to conduct seismic surveys in the Arctic without affecting marine mammals at all. The number of animals likely to be affected should be assessed in relation to the size of the population, local stocks and season.
- Local conditions for sound transmission, as hydrographic and bathygraphic conditions may result in highly unusual sound transmission properties. Potential consequences of these effects should be included in the assessment.

**Conclusions on disturbance from seismic noise**

The most sensitive VECs in the assessment area are the narwhals, bowhead whales and walrus. Narwhals occur widely along the fast-ice edge in spring and summer and many later move into the fjords. At both habitats concentrations may occur, as for example in the Northeast Water Polynya and in Scoresby Sund, and at such sites there is a risk of displacement from critical habitats. The impact is most likely temporary, and may in the southern part comprise lower numbers of narwhal available for local hunters.

Bowhead whales are also sensitive to seismic surveys. Effects from seismic surveys will also be temporary and include potential displacement from critical habitats. However, the bowheads are rare and there are too few observations to identify critical habitats.

Walruses occur gregariously at specific feeding gounds and may be displaced by seismic activity nearby.

As seismic surveys are temporary, the risk of long-term impacts is low. But long-term impacts have to be assessed if a number of surveys are carried out simultaneously or in the same potentially critical habitats in consecutive years (cumulative effect).

The only fishery which can be impacted by seismic surveys is the relatively small Greenland halibut fishery in the southern part of the assessment area. There is a risk of a temporary displacement of fish from the trawling grounds.

**Table 5.** Overview of potential impacts from a single seismic 2D survey on KANUMAS East VECs. The risk of long-term impact on the commercial fishery is evaluated as minor as the effects of a single seismic survey are temporary.

| VEC | Overlap | Risk of impact on critical habitats | Potential impacts – levels (worst case) | | | Risk of long term pop impacts |
|---|---|---|---|---|---|---|
| | | | Biological | Temporal | Spatial | |
| Prim. prod. | no | No | | | | none |
| Zooplankton | medium | Yes | indv. | short term | local/regional | minor |
| Benthos | no | No | | | | none |
| Greenland halibut | pot. large | No | pop. | short term | local | minor |
| Arctic char | no | No | | | | none |
| Polar cod | small | No | indv. | short term | local | minor |
| Fish egg and larvae | small | Yes | local pop. | pot. long term | local/regional | minor |
| Seabirds | small | No | no effect | no effect | no effect | neglig |
| Walrus | small | Yes | pop. | short term | local | minor |
| Harp seal | no | No | indv. | short term | local | none |
| Hooded seal | no | No | indv. | short term | local | none |
| Ringed seal | no | No | indv. | short term | local | none |
| Narwhal | pot. large | Yes | pop. | short term | local | minor |
| Bowhead whale | pot. large | Yes | indv./pop. | short term | local | minor |
| Polar bear | small | No | indv. | short term | local | minor |
| | | **Risk of impact on important sites** | | | | **Risk of income impacts** |
| Comm. fisheries | pot. large | Yes | | short term | local | minor |
| Hunting | small | No | | short term | local | minor |

### Noise from drilling rigs

This noise has two sources, the drilling process and the propellers keeping the drill ship / rig in position. The noise is continuous in contrast to the pulses generated by the seismic airguns.

Generally a drill ship generates more noise than a semi-submersible platform, which in turn is noisier than a jack-up. Jack-ups will most likely not be employed within the assessment area, due to depth and the hazard risk from drift ice and icebergs.

Whales are believed to be the organisms most sensitive to this kind of underwater noise, because they depend on the underwater acoustic environment for orientation and communication, and it is believed that this communication can be masked by the noise. But also seals (especially bearded seal) and walrus communicate when underwater. However, systematic studies on whales in relation to noise from drill rigs are limited. It is generally believed that whales are more tolerant of fixed noise than noise from moving sources (Davis *et al.* 1990). In Alaskan waters migrating bowhead whales avoided an area with a radius of 10 km around a drill ship (Richardson *et al.* 1990) and their migrating routes were displaced away from the coast during oil production on an artificial island, although this reaction was mainly attributed to the noise from support vessels (Greene *et al.* 2004).

**Table 6.** Overview of potential noise and discharge impacts from a single exploration drilling on KANUMAS East VECs. The effects on walrus is evaluated as major compared to moderate for bowhead whale and narwhal, because walruses in the assessment area are dependent on very few specific and critical habitats, where significant numbers may be impacted.

| VEC | Overlap | Risk of impact on critical habitats | Potential impacts – levels (worst case) | | | Risk of long term pop impacts |
|---|---|---|---|---|---|---|
| | | | Biological | Temporal | Spatial | |
| Prim. prod. | no | no | | | | none |
| Zooplankton | neglig. | no | indv. | | | neglig |
| Benthos | small | pot. yes | pop. | long term | local | neglig. |
| Greenland halibut | neglig. | no | indv. | no | local | neglig. |
| Arctic char | no | no | | | | none |
| Polar cod | neglig. | no | indv. | no | local | neglig. |
| Fish egg and larvae | neglig. | no | indv. | no | local | neglig. |
| Seabirds | neglig. | no | indv. | short | local | neglig. |
| Walrus | small | yes | pop. | short | local | pot. major |
| Harp seal | neglig. | no | indv | | | neglig. |
| Hooded seal | neglig. | no | indv | | | neglig. |
| Ringed seal | small | no | indv. | short | local | neglig. |
| Narwhal | small | yes | pop. | short | local | pot. moderate |
| Bowhead whale | small | yes | pop. | short | local | pot. moderate |
| Polar bear | small | no | indv. | short | local | minor |
| | | **Risk of impact on important sites** | | | | **Risk of income impacts** |
| Com. fisheries | small | yes | | short | local | minor |
| Hunting | small | no | | short | local | minor |

Bowhead whales, narwhals and walruses are the most sensitive species in this context, and there is a risk of their displacement from critical habitats. Particularly walruses are sensitive because they are dependent on highly localised feeding areas. In the Baffin Bay off West Greenland, particularly narwhals follow specific and delineated migration pathways. Similar pathways may also be used in the assessment area.

**Conclusion on noise from exploration drilling rigs**

Walruses, narwhals and bowhead whales are at risk from being temporarily displaced from critical habitats by the noise from an exploration drilling rig. If alternative habitats of equal quality are available no effects are expected, but if several rigs operate in the same region there is a risk for cumulative effects and displacement even from alternative habitats in the region.

### 10.1.2 Drilling mud and cuttings

Drilling creates substantial quantities of drilling wastes composed of rock cuttings and the remnants of drilling mud (*cf.* section 2.2). Cuttings and mud have usually been deposited on the seafloor beneath the drill rig where they can change the physical and chemical composition of the substrate (e.g. increased concentrations of certain metals and hydrocarbons) (Breuer *et al.* 2008). The liquid base of the drilling mud may be water, oil or other organic (synthetic) fluids (ethers, esters, olefins, etc). The general pattern of impacts on benthic animals from cuttings from Norwegian wells is that oil-based cuttings elicit the most widespread impacts and water-based cuttings the least. Ester-based cuttings have been shown to cause severe but short-lived effects due to their rapid degradation and resulting oxygen depletion in the sediments. Olefin-based cuttings are also degraded fairly rapidly, but without causing oxygen deficiency, and hence have short-lived and moderate effects on the fauna.

The effects of drilling mud and drill cuttings have been studied widely (e.g. Neff 1987, Ray & Engelhardt 1992, Breuer *et al.* 2004). The disposal of drilling mud and cuttings at marine drill sites poses a localised risk to benthic organisms nearby (e.g. Davies *et al.* 1984). Mud and drill cuttings are normally released during the drilling phase, although the ecological effects persist longer than the release phase. Olsgard & Gray (1995) applied sensitive statistical techniques to drill sites on the Norwegian Shelf were oil-based mud was used and found subtle effects on benthic animals extending out as far as 6 km and areas affected around sites ranging from 10 to 100 $km^2$. In the most heavily affected areas, diversity of fauna was low and dominated by opportunistic species (Gray *et al.* 1990, Olsgaard & Gray, 1995). Further away from the platform, faunal diversity was similar to control sites, but with detectable differences in species composition. Furthermore, examination of sites no longer in production revealed that the area affected continued to increase in size for several years after discharges ceased (Breuer *et al.* 2008). The effects of these releases may not be confined to benthic invertebrates. Sublethal effects on fish living near drill sites have been detected in some species (Davies *et al.* 1984). However, these results are from the time when oil-based drilling mud was used and discharged. Following the introduction of controls on the discharge of oil-based mud and cuttings, synthetic-based muds have been applied, which have also led to impacts on benthic fauna, although less pronounced than impacts around platforms where oil-based muds have been used (Jensen *et al.* 1999). Field studies on water-based muds are relatively scarce, but a few specially designed surveys indicate that effects are restricted to a distance of less than 100 m from the platforms (Schaaning *et al.* 2008 and references therein). The use of water-based mud combined with cleaning of the cuttings may therefore limit the effects on the benthos to highly localised areas around each exploration drill site.

A number of recent findings give reason for concern. Chronic exposure to the fine-grained suspended solids of muds (primarily barite and bentonite) significantly inhibit bivalve growth, reproduction and efficiency of food intake, and this inhibition takes place at environmentally relevant concentrations (Armsworthy *et al.* 2005). This impact may take place in an area exceeding 200 $km^2$ from a single exploration drilling site (Cranford *et al.* 2003). This effect may potentially impact critical feeding grounds for walruses where food abundance may be reduced, indirectly impacting the walrus population.

More widespread effects on the benthos and its composition may be the result of the multiple drillings carried out during development of a field.

Another risk from discarding cuttings polluted with oil residues is tainting of commercial fish (see section 9.3.8).

As very little is known about the seafloor fauna in the assessment area, it is difficult to assess the impact of discharges of drilling mud and cuttings precisely. However, in the Lofoten-Barents Sea areas of Norway cuttings and drilling mud are not discharged due to environmental concerns, it is rather re-injected in wells or brought to land (Anonymous 2003). This on the other hand increases the amount of ship transport and the emission of $CO_2$, moreover, impacts at disposal sites on land have to be considered and evaluated.

Within the assessment area only very local effects on the benthos may be expected from exploratoration discharging water-based muds, and almost none if a zero-discharge approach is followed. In any case, baseline and monitoring studies at drill sites should be conducted to document effects and assess if there are unique communities or species that could be harmed.

## 10.2 Development and production activities

In contrast to the temporary activities of the exploration phase, activities in development and production are usually long lasting, depending on the amount of producible petroleum products and the production rate. The activities are numerous and extensive, and the effects on the environment can be summarised under following headings:

- solid and fluid waste materials to be disposed of placement of structures
- noise from construction, activities at the facilities and transport emissions to air

### 10.2.1 Produced water

During production several by-products and waste products are produced and have to be disposed of in one way or another. Produced water is by far the largest contribution from an oil field, although a gas field will not discharge as much (see section 2.4).

Generally it is believed that the environmental impacts from produced water are small due to dilution. For example the discharges during the 5 % ‘off normal time’ in the Barents Sea have been assessed not to impact stocks of important fish species. But in the same assessment it is also stated that the long-term effects of the release of produced water are unknown (Rye *et al.* 2003). There is particular concern surrounding the hormone-disrupting phenols, radioactive components, and nutrients in relation to toxic concentrations, bioaccumulation, fertilisation, etc (Rye *et. al.* 2003).

Nutrient concentrations can be very high in produced water (e.g. up to 40 mg/l ammonia). When larges amounts of these nutrients are released they may act as fertiliser, which has the potential to impact ecosystem structure (Rivkin *et al.* 2000 in Armsworthy *et al.* 2005).

Even though oil concentrations in produced water are low, oil sheen may occur on the water surface where the water is discharged, especially in calm weather. This gives reason for concern, because sheen is sufficient to

**Table 7.** Overview of potential impacts from discharges to the marine environment (primarily produced water) in relation to exploitation activities on KANUMAS East VECs.

| VEC | Overlap | Risk of impact on critical habitats | Potential impacts – levels (worst case) | | | Risk of long term pop impacts |
|---|---|---|---|---|---|---|
| | | | Biol level | Temporal | Spatial | |
| Prim. prod. | pot. large | yes | pop. | long term* | regional | pot. moderate |
| Zooplankton | pot. large | yes | pop. | long term* | regional | pot. moderate |
| Benthos | small | yes | | long term | regional | minor |
| Greenland halibut | small | yes | pop. | long term | regional | minor |
| Arctic char | small | no | pop. | long term | regional | minor |
| Polar cod | pot large | yes | pop. | long term | regional | pot. major |
| Fish egg and larvae | pot large | yes | pop. | long term | regional | minor** |
| Seabirds | pot. large | yes | indv. | long term | regional | pot. moderate |

*as long as activities takes place; **in ice-free waters

impact seabirds, and together with other low concentration oil discharges such impacts may be significant (Fraser *et al.* 2006).

Finally the release of produced water under ice gives reason for concern, because there is a risk of accumulation just below the ice, where degradation, evaporation, etc are slowed, and sensitive under-ice ecosystems including eggs and larvae from the key species polar cod may be exposed (Skjoldal *et al.* 2007).

### 10.2.2 Other discharged substances

Besides produced water, discharges of oil components and different chemicals occurs in relation to deck drainage, cooling water, ballast water, bilge water, cement slurry and testing of blowout preventers. Sanitary wastewater is also usually released to the sea. The environmental impacts of these discharges are generally small from a single drilling rig or production facility, but releases from many facilities and / or over long time periods may be of concern. BAT (Best Available Technology), BEP (Best Environmental Practice), introduction of less environmentally damaging chemicals or reduction in volume of the releases are ways in which the effects can be reduced.

Ballast water from ships poses a special biological problem. That is the risk of introduction of non-native and invasive species to the local ecosystem (Anonymous 2003). This is generally considered as a severe threat to marine biodiversity and, for example, blooms of toxic algae in Norway have been ascribed to release of ballast water from ships. There are also many examples of introduced species which have impacted fisheries in a negative way (e.g. the comb jelly *Mnemiopsis* in the Black Sea, Kideys 2002).

Presently, the Arctic Ocean is the area least affected by non-native, invasive species, as shown by Molnar *et al.* (2008). However, many tankers releasing ballast water near an oil terminal and the increasing water temperatures, particularly in the Arctic, may increase the risk of introduction of alien, invasive species in future.

There are methods to minimise the risk, and the MARPOL convention has issued a management plan for ship ballast water, but it has not yet been ratified by a sufficient number of states to enter into force. Denmark (incl. Greenland) has not yet ratified the convention

### 10.2.3 Placement of structures

The construction of subsea wells and pipelines has the potential to destroy parts of important habitats on the seafloor. However, there is limited knowledge on such sites in the assessment area, although some areas are important for walrus and common eider which live on benthic mussels and other invertebrates (Figures 18, 24 and 28). An assessment of the impact of such constructions must wait until production site location is known and site-specific EIAs and background studies have been carried out. Structures may also have a disturbance effect, particularly on marine mammals which may be displaced from important habitats. Most vulnerable in this respect are the walruses, narwhals and bowhead whales (see also section 2.1.1).

Placement of structures will affect fisheries due to exclusion (safety) zones. These areas, however, are small compared with the total fishable area. A drilling platform incl. exclusion zone with a radius of 500 m covers approx. 0.7 $km^2$. In the Lofoten-Barents Sea area the effects of exclusion zones on fisheries are generally assessed as low, except in areas where very localised and intensive fishery activity takes place. In such areas reduced catches may be expected, because there are no alternative areas available (OED 2006). Pipelines in the Lofoten-Barents Sea area are not expected to impact fisheries, because they will be constructed in a way allowing trawling across them, although a temporary exclusion zone must be expected during the construction phase of pipelines. Experience from the North Sea indicates that large ships will trawl across subsea structures and pipelines, while small ships often choose to avoid the crossing of such structures (Anonymous 2003).

Illumination and flaring can attract birds migrating in the dark hours. This is especially a problem in areas with intensive seasonal migrations of songbirds, as in the North Sea (Bourne 1979, Jones 1980). No such migrations take place in the assessment area. However, concern for night-time migrating little auks has recently been expressed (Fraser *et al.* 2006), and this species occurs in very large densities within the assessment area. Also eiders are known to be attracted by light at night, particularly during fog and snowy weather (Boertmann *et al.* 2006).

Placement of structures onshore in coastal habitats may impact rivers with spawning and wintering Arctic char by creating obstructions they cannot cross, resulting in the loss of a local population. Another potential conflict is with denning female polar bears. Dennning areas are critical to polar bear populations, but dens are apparently rather dispersed on the coast and their location probably varies between seasons.

Placement of structures onshore also imposes a risk of spoiling unique coastal flora and fauna.

When dealing with placement of structures, particularly inland and in coastal habitats, aesthetic aspects must be considered in a landscape conservation context. The risk of spoiling the impression of pristine wilder-

**Table 8.** Overview of potential impacts from placement of structures (footprint) in the marine environment (incl. terrestrial coastal habitats) and on KANUMAS East VECs.

| VEC | Overlap | Risk of impact on critical habitats | Potential impacts – levels (worst case) | | | Risk of long term pop impacts |
|---|---|---|---|---|---|---|
| | | | Biol level | Temporal | Spatial | |
| Prim. prod | neglig. | no | | | | none |
| Zooplankton | neglig. | no | indv. | long term | local | none |
| Benthos | small | yes | pop. | long term | local | moderate |
| Greenland halibut | small | yes | pop. | long term | local | minor |
| Arctic char | small* | yes | pop. | long term | local | minor** |
| Polar cod | neglig | no | indv. | long term | local | minor |
| Fish egg and larvae | neglig. | no | indv. | long term | local | minor |
| Seabirds | small* | yes | pop. | long term | local | moderate |
| Walrus | pot. large | yes | pop. | long term | local | major |
| Harp seal | small | yes | pop. | long term | local | moderate |
| Hooded seal | small | yes | pop. | long term | local | moderate |
| Ringed seal | small | no | indv. | long term | local | minor |
| Bearded seal | small | no | indv. | long term | local | minor |
| Narwhal | small | yes | indv. | long term | local | moderate |
| Bowhead whale | pot. large | yes | indv. | long term | local | moderate |
| Polar bear | small | yes | indv. | long term | local/reg. | moderate |
| | | Risk of impact on important sites | | | | Risk of income impacts |
| Comm. fisheries | pot. large | yes | | | | moderate |
| Hunting | small | yes | | | | moderate |
| Tourism | pot. large | yes | | | | moderate |

*small local populations are very vulnerable; ** provided critical habitats are not impacted

ness, an essential component of the National Park of North and Northeast Greenland, is high. Background studies in the field combined with careful planning can reduce such impacts on the landscape. Landscape aspects are also the most important when dealing with potential effects on the tourism industry. Greenlandic tourism's main asset – its unspoilt nature – is readily rendered much less attractive by the erection of structures.

### 10.2.4 Noise/Disturbance

Noise from drilling and the positioning of machinery is described under the exploration heading (section 2.1.1). These activities continue during the development and production phase, supplemented by noise from many other activities. If several production fields are active for example in one of the polynyas, the impacts of noise particularly on narwhals and walrus must be addressed. Bowhead whales in the Beaufort Sea avoided oil rigs (up to a distance of 50 km), which resulted in significant habitat loss (Schick & Urban 2000), an impact which also could occur in the assessment area, depending on location.

**Table 9.** Overview of potential impacts from disturbing activities during development and production in the KANUMAS East assessment area. Only marine mammals and seabird VECs, and fishing and hunting activities are considered.

| VEC | Overlap | Risk of impact on critical habitats | Potential impacts – levels (worst case) | | | Risk of long term pop impacts |
|---|---|---|---|---|---|---|
| | | | Biol level | Temporal | Spatial | |
| Fulmar | pot. large | yes | pop. | long term | regional | moderate |
| Common eider | pot. large | yes | pop. | long term | regional | moderate |
| King eider | pot. large | yes | pop. | long term | regional | moderate |
| Long-tailed duck | small | yes | indv. | long term | regional | |
| Sabines gull | pot. moderate | yes | pop. | long term | regional | moderate |
| Ross's gull | pot. large | yes | pop. | long term | regional | major |
| Ivory gull | pot. large | yes | pop. | long term | regional | moderate |
| Arctic tern | pot. moderate | yes | pop. | long term | regional | moderate |
| Thick-billled murre | pot. large | yes | pop. | long term | regional | major |
| Little auk | pot. moderate | | pop. | long term | regional | moderate |
| Walrus | pot. large | yes | pop. | long term | regional | major |
| Harp seal | pot. large | yes | pop. | long term | regional | moderate |
| Hooded seal | pot. large | yes | pop. | long term | regional | moderate |
| Ringed seal | small | no | indv. | long term | regional | minor |
| Bearded seal | small | no | indv. | long term | regional | minor |
| Narwhal | pot. large | yes | pop. | long term | regional | major |
| Bowhead whale | pot. large | yes | pop. | long term | regional | major |
| Polar bear | moderate | yes | pop. | long term | regional | moderate |
| | | **Risk of impact on important sites** | | | | **Risk of income impacts** |
| Comm. fisheries | neglig. | no | | | | minor |
| Hunting | pot. large | yes | | | | moderate |

Masking of the communication and echolocation sounds of whales and seals are widely discussed in the literature and constitute a possible effect from drill rigs. It is, however, not possible to assess any impacts, as there is very little experience to draw on from field studies, and in addition an assessment also will require specific knowledge of the actual placement of drill rigs and other noisy equipment.

One of the more significant sources of noise during development and production is ships and helicopters used for intensive transport operations (Overrein 2002). Ships and helicopters are widely used in the Greenland environment today, but the level of these activities is expected to increase significantly in relation to development of one or more oil fields within the assessment area. Supply ships will sail between offshore facilities and coastal harbours. Shuttle tankers will sail between crude oil terminals and the trans-shipment facilities on a regular basis, perhaps even in winter. The loudest noise levels from shipping activity result from large icebreakers, particularly when they operate in ramming mode. Peak noise levels may then exceed the ambient noise level up to 300 km from the sailing route (Davis *et al.* 1990).

Ship transport (incl. ice-breaking) has the potential to displace marine mammals, particularly if the mammals associate negative events with the noise, which is the case in the southern part of the assessment area, where narwhals and walruses are hunted from motor boats. Also seabird concentrations may be displaced by regular traffic. The impacts can be mitigated by careful planning of sailing routes.

Helicopters produce a strong noise which can scare marine mammals as well as birds. Particularly walruses hauled out on land or ice will be sensitive to this activity, and there is a risk of displacement of the walruses from important feeding grounds. Denning polar bears are apparently relatively tolerant to noisy activities as their snow dens provide acoustic insulation (Linell *et al.* 2000).

Seabird concentrations are also sensitive to helicopter flyover. The most sensitive species are thick-billed murres, when they are breeding on the bird cliffs. They will often abandon their nests for long periods of time and there is also a risk that they push their egg or chick out over the edge when scared off from their breeding ledges, resulting in a failed breeding attempt (Overrein *et al.* 2002). There are only two breeding colonies for this species in the region, both at the entrance to Scoresby Sund.

Concentrations of moulting geese and seaducks occur at several sites in the region, such as the king eiders in one of the fjords of Blosseville Kyst and long-tailed ducks in many shallow bays. The effects of disturbance can be mitigated by applying specific flight altitudes and routes, as many birds will habituate to regular disturbances as long as these are not associated with other negative impacts such as hunting.

Offshore construction activities such as blasting have the potential to produce behavioural disturbance and physical damage among marine mammals, particularly whales (Ketten 1995, Nowacek *et al.* 2007). Off Newfoundland, Ketten *et al.* (1993, in Gordon *et al.* 2004) found damage consistent with blast injury in the ears of humpback whales trapped in fishing gear after blasting operations in the area. In this case, the blasting did not provoke obvious changes in behaviour among the whales, even though it may have caused severe injury, suggesting that whales may not be aware of the danger posed by loud sound. Such impacts are, however, local and will mainly be a threat on an individual level.

### 10.2.5 Air emissions

The large amounts of greenhouse gases released from an oil field will increase the total Greenland emission significantly. The emission from Statfjord in Norway (section 2.8), for example, is twice the total Greenland $CO_2$ emission, which in 2003 was 634,000 tonnes (Illerup *et al.* 2005). Such amounts will have a significant impact on the Greenland greenhouse gas emission in relation to the Kyoto Protocol (to the United Nations Framework Convention on Climate Change). Another very active greenhouse gas is methane ($CH_4$) which is released in small amounts together with other VOCs from produced oil during trans-shipment.

Emissions of $SO_2$ and NOx contribute, among other effects, to acidification of precipitation and may impact particularly on nutrient-poor vegetation types inland far from the release sites. The large Norwegian field Statfjord emitted almost 4,000 tonnes NOx in 1999. In the Norwegian strategic EIA on petroleum activities in the Lofoten-Barents Sea area it was concluded that NOx emissions even from a large-scale scenario would have insignificant impact on the vegetation on land, but also that there was no knowledge about tolerable depositions of NOx and $SO_2$ in Arctic habitats, where nutrient-poor habitats are widespread (Anonymous 2003). This lack of knowledge also applies to the terrestrial environment of the assessment area.

The international Convention on Long-Range Transboundary Air Pollution (LRTAP) includes all these emissions, but when Denmark signed the protocols covering NOx and $SO_2$, reservations were made in the case of Greenland.

### 10.2.6 Cumulative impacts

Cumulative impacts are changes to the environment that are caused by an action in combination with other past, present and future human actions. The impacts are summed up from single activities both in space and time. Impacts from a single activity can be insignificant, but the sum of impacts from the same activity carried out at many sites at the same time and / or throughout time can develop to be significant. Cumulative impacts also include interaction with other human activities impacting the environment, such as hunting and fishing, moreover, climate change is also often considered in this context (National Research Council 2003).

An example could be many seismic surveys carried out at the same time in a restricted area. A single survey will leave many alternative habitats available, but extensive activities in several licence blocks may exclude, for example, baleen whales from the available habitats. This could reduce their food uptake and their fitness due to decreased storage of the lipids needed for the winter migration and breeding activities.

The oil discharged with the produced water is very low in concentration. But the amounts of produced water from a single platform are considerable and many platforms will release even more substantial amounts. Other oil-like substances (e.g. synthetic drilling fluids) may also be discharged and together they may pose a substantial threat to seabirds resting on the water surface near the release sites.

Bioaccumulation is an issue of concern when dealing with cumulative impacts of produced water. The low concentrations of PAH, trace metals and radionuclides all have the potential to bioaccumulate, primarily in benthic fauna. This may impact the benthic population but may also be transferred to the higher levels of benthos-foraging seabird and marine mammals (Lee *et al.* 2005).

Another example is seabird hunting which takes place in the entrance of Scoresby Sund. In this area there are two breeding colonies of thick-billed murres, which are the most desired seabird quarry. These colonies are declining due to unsustainable hunting activities. Seabirds rely on a high adult survival rate, which gives the adult birds many possibilities to reproduce. Extra mortality due to an oil spill or sublethal effects from contamination from petroleum activities have the potential to be additive to the hunting impact and thereby enhance the population decline. The birds from these colonies are particularly vulnerable during the swimming migration, which is performed by flightless adults (due to moult) and chicks still not able to fly. Studies of murres at the largest of these colonies will be initiated in 2009 and will be included in the final assessment.

### 10.2.7 Mitigating impacts from development and production

As a consequence of previous experience, e.g. from the North Sea, in its 2002 guidelines (updated 2008) the Arctic Council recommended that discharges should as far as possible be prevented. When water-based muds are employed, additives containing oil, heavy metals, or other bioaccumulating substances should be avoided, or criteria for the maximum concentrations should be established (PAME 2002). Moreover, wherever possible 'zero discharge of drilling waste and produced water' should be applied. This can be obtained by application of new technologies, such as injection and cuttings re-injections (CRI). A sound environmental management has to be in place based on the Precautionary Principle, Best Available Techniques (BAT) and Best Environmental Practice (BEP). In the Arctic offshore Oil and Gas Guidelines it is also requested that 'discharge to the marine environment should be considered only where zero discharge technology or re-injection are not feasible' (PAME 2002). Based on knowledge concerning site-specific biological, oceanographic and sea-ice conditions, discharges should occur at or near the seafloor or at a suitable depth in the water column to prevent large sediment plumes. Such plumes have the potential to affect benthic organisms, plankton and productivity and may also impact higher trophic levels such as fish and mammals. The discharges should be evaluated at on a case-by-case basis.

In the Lofoten-Barents Sea areas of Norway cuttings and drilling muds are not discharged due to environmental concerns, instead they are re-injected in wells or brought to land (Anonymous 2003).

Disturbance can be mitigated by careful planning of the noisy activities in order to avoid activities in sensitive areas and periods, based on detailed background studies of the sensitive components of the environment.

As an example, activities impacting polar bear areas could be regulated according to guidelines provided by Linnell *et al.* (2000) in a review of the vulnerability of denning bears (modified to suit polar bears and oil activities):

Den concentration should be indentified.

- Winter activity should be minimised in suitable or traditional denning areas.
- If winter activities are unavoidable, they should be around the time when bears naturally enter dens, so they can choose to avoid disturbed areas.
- Winter activity should be confined to regular routes as much as possible, activity on level areas should generally have less effect than activty on slopes and steep snow covered hill sides.
- Activity should avoid known bear dens by at least 1 km.
- The slightest degree of off-road activity is likely to cause greater effects than any degree of fixed-point or predictable-route activity and should therefore be minimised.

Impacts of placement of structures inland is best mitigated by the same measures as described for activities involving disturbance: i.e. careful planning based on detailed background studies of the sensitive components of the environment in order to avoid unique and sensitive habitats.

### 10.2.8 Conclusions on development and production activities

Drilling will continue during development and production phases, and drilling mud and cuttings will be released in much larger quantities than during exploration. If these substances are released to the seabed impacts must be expected on the benthic communities near the release sites.

However, the release giving most reason for environmental concern is produced water. Recent studies have indicated that the small amounts of oil and nutrients can impact birds and primary production, and there is also concern surrounding the long-term effects of the radionuclides and hormone-disruptive chemicals.

There will be a risk of release of non-native and invasive species from ballast water, and this risk will increase with the effects of climate change.

Emissions from production activities to the atmosphere are substantial and will contribute significantly to the Greenland contribution of greenhouse gases.

Well drilling and ships produce noise, which can affect marine mammals. The most sensitive species are bowhead whales, narwhals, white whales and walruses. There is a risk of permanent displacement of populations from critical habitats and therefore for negative population effects.

Helicopters also produce a considerable noise, which may scare away birds and marine mammals (particularly seals and walrus hauled-out on ice or land).

Placement of structures both has biological and aesthetic impacts. The biological impacts include mainly permanent displacement from critical habitats – walrus is the most sensitive. The aesthetic impacts primarily include the impact on the pristine landscape, and besides these, knock-on effects on the local tourism industry must be expected.

The commercial fishery may by effected by closure zones if rigs, pipelines and other installations are placed in the Greenland halibut fishing ground. But the impact on the fishery will probably be low.

There is a risk of reduced availability of quarry species, because these can be displaced from traditional hunting grounds.

The best way of mitigating impacts from development and production activities is to combine a detailed background study of the environment (in order to locate sensitive ecosystem components) with careful planning of structure placement and transport corridors. Then the Precautionary Principle, BEP (e.g. PAME 2002) and BAT can do much to reduce emissions to air and sea. Particularly a zero-discharge policy, as will be applied in the Barents Sea, can contribute to minimisation of the impacts.

## 10.3 Decommissioning

Impacts from decommissioning activities are mainly noise at the sites and from traffic, assuming that all material and waste are taken out of the assessment area and deposited at safe sites. There will also be a risk of pollution from accidental releases. However, decommissioning activities are short-term and careful planning and adoption of BAT and BEP would minimise impacts.

# 11 Impacts from accidental oils spills

## 11.1 Oil spill properties

The main issue of environmental concern for the marine Arctic environment is a large oil spill, which particularly in ice-covered waters represents a threat to populations and even to species (AMAP 2007). The probability is however low while the impacts can be severe and long lasting.

Several circumstances enhance the potential for severe impacts of a large oil spill in the assessment area. The Arctic conditions reduce the degradation of oil, prolonging potential effects. The occurrence of ice during most of the year may influence the distribution and conservation of oil (see below), and in addition ice is a significant obstacle to oil spill response, making it more or less inefficient. The complete lack of infrastructure in the major part of the assessment area also contributes to the improbability of an oil spill response of any efficiancy in case of a spill, e.g. in the Northeast Water polynya.

According to the AMAP (2007), oil and gas assessment tankers are the main potential spill source. Another potential risk is oil spill from a blowout during drilling, which may be continuous and last for many days. Blowouts can have their origin on the platform or at the wellhead on the seafloor (subsea blowout).

### 11.1.1 Probability of oil spills

The probability of large oil spills is low. However, the risk cannot be eliminated and in a frontier area it is difficult to calculate the risk based on experience from more developed areas. In relation to the oil drilling in the Barents Sea it has been calculated that statistically a blowout between 10,000 and 50,000 tonnes would happen once every 4,600 years in a small-scale development scenario and once every 1,700 years in an intensive development scenario (Anonymous 2003). The likelihood of a large oil spill from a tanker ship accident is estimated to be higher than for an oil spill from a blowout (Anonymous 2003).

It should be mentioned that there is a risk of oils spills from other sources in the assessment area. A German trawler / weathership, 'Sachsen' was scuttled during the Second World War in Hansa Bugt off Sabine Ø in 1943. The wreck is still there with an estimated 60 tonnes of fuel oil in the tanks, which could rupture and cause a significant oil spill in a very sensitive area (M. Elander pers. comm.).

### 11.1.2 The fate and behaviour of spilled oil

Previous experience with spilled oil in the marine environment gained in other parts of the world shows that fate and behaviour of the oil vary considerably. Fate and behaviour depend on the physical and chemical properties of the oil (light oil or heavy oil), how it is released (surface or sub-sea, instantaneous or continuous) and on the conditions of the sea into which it is spilled (temperature, ice, wind and current). Oil released to open water spreads rapidly resulting in a thin slick (often 0.1 - 1 mm thick in the first days) that covers a large area. Wind-driven surface currents move the oil at approx. 3 % of the wind speed and cause turbulence in the surface water layer which potentially breaks the oil slick up into patches and causes some of the oil to disperse in the upper water column. This dispersed oil will usually stay in the upper 10 m (Johansen *et al.* 2003).

General knowledge on the potential fate and degradation of spilled oil relevant for the Greenland marine environments has been reviewed by Pritchard & Karlson (in Mosbech 2002). Ross (1992) evaluated the behaviour of potential offshore oil spills in West Greenland with special regard to the potential for cleanup. Simulations of oil spill trajectories in West Greenland waters have previously been performed by Christensen *et al.* (1993) using the SAW model, and by SINTEF (Johansen 1999) using the OSCAR model in preparation for the Statoil drilling in the Fylla area in 2000. When the Disko West area was assessed, DMI simulated oil spill drift and fate (Nielsen *et al.* 2006).

### 11.1.3 The DMI oil spill simulations

As part of this SEIA of oil activities in the assessment area, DMI has prepared a number oil drift and fate simulations for hypothetical oil spills in the assessment area (Nielsen *et al.* 2008).

The simulations were carried out for three hypothetical spill events all located on the shelf of the KANUMAS East area. The locations were selected by GEUS to represent potential sites for offshore well drilling. The crude oil, Statfjord, a medium-type crude oil (API density 886.3 kg / $m^3$), was selected by GEUS from eight types in the DMI database as the most representative oil potentially to be discovered in the assessment area. This is a medium oil type, lighter than seawater, which will evaporate by around one third during the first 24 hours of a surface spill period (Figure 48).

For the continuous spills oil is released at a constant rate during the first ten days of the simulation period. The amount of oil released is fixed at a rate of 3,000 tonnes / day (in total: 30,000 tonnes). For instantaneous spills the amount of oil released is 15,000 tonnes. These are very large spills with a very low probability of occurrence.

Three one-month wind periods have been selected within the design year July 2004–June 2005.

A total of 18 oil spill scenarios with continuous release have been simulated: 3 release sites, 3 simulation periods and 2 release depths. Additionally, and for comparison, one simulation of an instantaneous surface spill has been carried out for each spill site.

#### Shores affected

By tracking all particles, the relative amount of oil settling on the shore as well as the lengths of shoreline affected are calculated. When the spill is located far offshore, the coast is not affected by any of the chosen wind conditions. Only two of the modelled spills are predicted to reach the shore. One from a spill site off Scoresby Sund reaches the southern Blosseville Kyst in October and one at approx. 75° 30’ N reach coasts between Shannon and Hold With Hope in April.

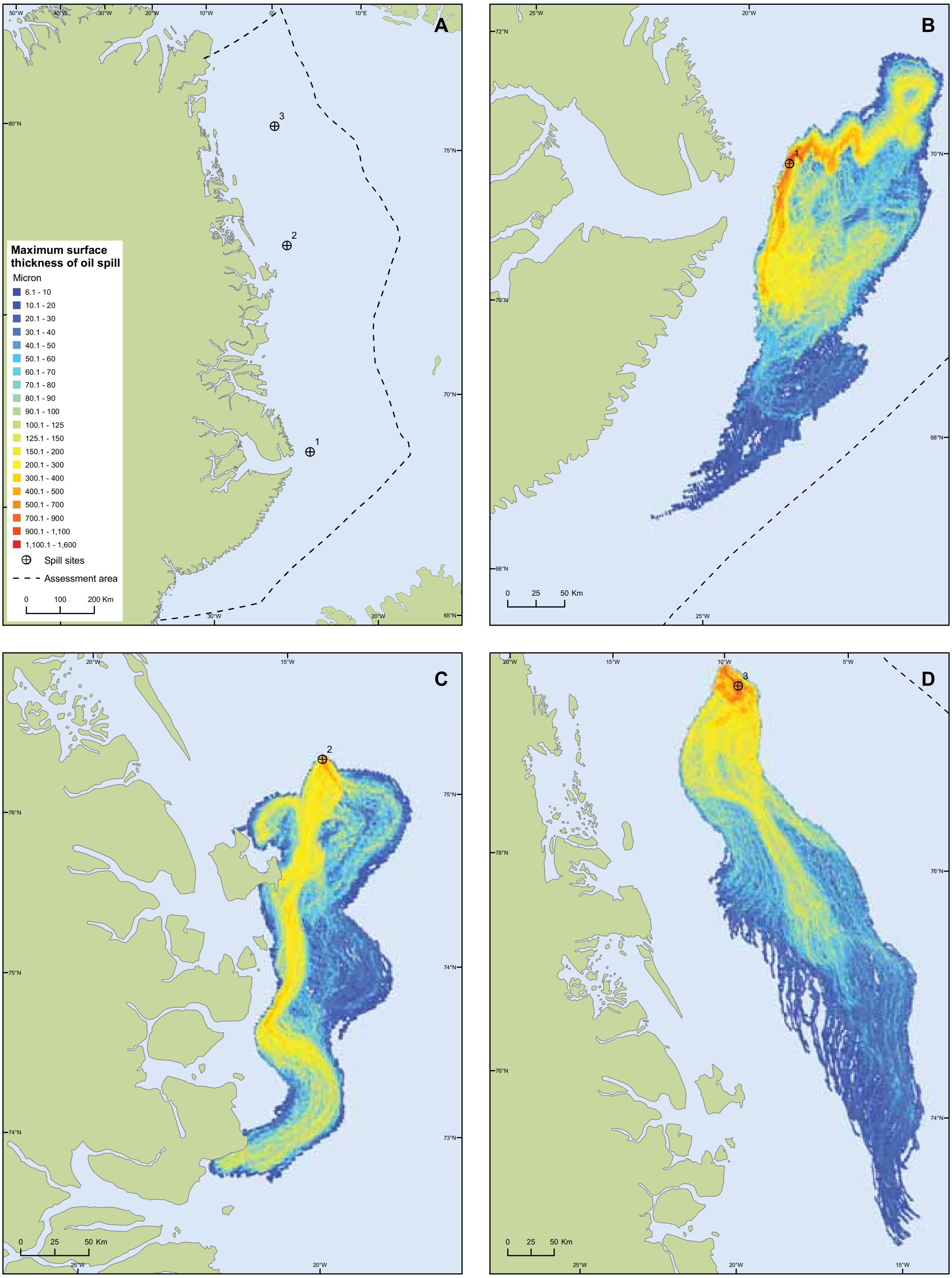



**Figure 48.** Examples of the DMI oil spill trajectory simulations. The maps B-D show the entire area swept by three different surface spills. The scale indicates the maximum thickness of the sea surface oil layer attained in the different cells during the 30 day simulation periods. Map A shows the four spill sites. B is a continuous spill from site 1 in August 2004. C is a continuous spill from site 2 in April 2005. Map D is a continuous spill from site 3 in October 2004. Note that C hits the coasts, while the two other spills are far from any coasts.

**Sea surface area covered**
The slick area after 10 days is 100–110 km², equivalent to a disc with a radius of 5–6 km in the case of a continuous spill, and the slick typically covers an area of 1,400–1,500 km² of very irregular shape after 30 days.

In practice, the oil will form isolated patches within this area, with regions of high concentration interspersed with regions with no oil at a given time. This means that the area actually covered with oil is smaller than figured. The model gives no indication of how much smaller the actual oil-covered area is.

**Oil spill in ice-covered waters**
Due to the roughness of the subsurface of the ice, oil will not move as far away from the spill site in ice-covered waters as it would in open waters. If an oil slick is 1 cm thick on average, a spill of 15,000 $m^3$ will cover only approx. 1.5 $km^2$ below the ice and less if thicker. This also means that very high oil concentrations may occur and persist for prolonged periods. Fauna under the ice or in leads and cracks may therefore risk exposure to highly toxic hydrocarbon levels.

**Subsurface concentrations**
Quantification of subsurface concentrations based on output from the DMI model is complicated. In the Disko West assessment this issue is discussed further based on the oil spill simulations in southern Baffin Bay (Nielsen *et al.* 2006, Mosbech *et al.* 2007a).

**Subsea blowout**
A subsea blowout may cause high concentrations of oil in the water column, but depending on oil type, magnitude of spill and oceanographic conditions it is most likely that high concentrations will only occur in a limited area. In the subsea blowout simulations of the DMI model the oil did not disperse very much in the deeper water column but quickly rose to the surface and formed a surface spill. Thus values from the corresponding modelled surface spill can be regarded as relatively similar.

However, a subsea blowout was assessed in relation to the exploration drilling in 2000 near Fyllas Bank in Davis Strait (Johansen 1999). Here it was estimated that oil would not reach the surface at all, but rather form a subsea plume at a depth of 300–500 m. High total hydrocarbon concentrations (>100 ppb by weight) were estimated in a restricted area close to the outflow.

### 11.1.4 The SINTEF oil spill drift simulations

In addition to the DMI simulations, SINTEF also have carried out some simulations in relation to description of oil spills in ice in the Greenland Sea (Johansen 2008). Only very preliminary results were available when this report was written, but overall they agree fairly well with the DMI results.

**Dissolution of oil and toxicity**
Total oil concentration in water is a combination of the concentration of small dispersed oil droplets and the oil components dissolved from these

and the surface slick. The process of dissolution is of particular interest as it increases the bioavailability of the oil components. The rate and extent to which oil components dissolve in seawater depends mainly on the amount of water-soluble fractions (WSF) of the oil. The degree of natural dispersion is also important for the rate of dissolution, and also+ surface spreading and water temperature may also have some influence.

The highest polyaromatic hydrocarbon concentration found in the water column in Prince William Sound within a six-week period after the Exxon Valdez spill was 1.59 ppb, at a 5 m depth. This is well below levels considered to be acutely toxic to marine fauna (Short and Harris 1996).

SINTEF (Johansen *et al.* 2003) reviewed available standardised toxicity studies and found acute toxicity down to 0.9 mg oil /l (0.9 ppm or 900 ppb) and applied a safety factor of 10 to reach a PNEC (Predicted No Effect Concentration) of 90 ppb oil for 96-hour exposure. This is based on fresh oil which leaks a dissolvable fraction, most toxic for eggs and larvae. Later the weathered oil will be less toxic.

Water soluble components (WSC) could leak from oil encapsulated in ice. Controlled field experiments with oil encapsulated in first-year ice for up to 5 months have been performed for Svalbard, Norway (Faksness & Brandvik 2005). The results show that the concentration of water-soluble components in the ice decreases with ice depth, but that the components could be quantified even in the bottom ice core. A concentration gradient as a function of time was also observed, indicating migration of water-soluble components through the porous ice and out into the water through the brine channels. The concentration of water-soluble components in the bottom 20 cm ice core was reduced from 30 ppb to 6 ppb in the experimental period. Although the concentrations were low, the exposure time was long (nearly four months). This might indicate that the ice fauna are exposed to a substantial dose of toxic water-soluble components. Leakage of water-soluble components to the ice is of special interest, because of a high bioavailability to marine organisms, relevant both in connection with accidental oil spills and release of produced water.

## 11.2 Oilspill impacts on the environment

### 11.2.1 Oil spill impact on plankton and fish

**Adult fish**

In the open sea, an oil spill will usually not result in oil concentrations that are lethal to adult fish, due to dispersion and dilution. Furthermore, fish such as cod and salmon can detect oil and will attempt to avoid it, and therefore populations of adult fish in the open sea are not likely to be significantly affected by an oil spill. In coastal areas the situation is more complicated and oil may be trapped in bays and inlets resulting in high mortality among adult fish. Arctic char, a common, important species in the coastal waters of the assessment area, will be vulnerable during such conditions.

Adult fish are able to metabolise oil, so they may recover from intoxication, but they may also act as vectors of toxic oil residues to higher levels in the food chain.

### Fish eggs and larvae

Eggs and larvae of fish are more sensitive to oil than adults. Theoretically impacts on fish larvae may be significant and reduce annual recruitment strength, with some effect on subsequent populations and fisheries for a number of years. However, such effects are extremely difficult to identify / filter out from natural variability and they have never been documented after spills.

The distribution of fish eggs and early larval stages in the water column is governed by water density, currents and turbulence. In the Barents Sea the pelagic eggs of cod will rise and be distributed in the upper part of the water column. As oil is also buoyant, the highest exposure of eggs will be under calm conditions while high energy wind and wave conditions will mix eggs and oil deeper into the water column, where both are diluted and the exposure limited. As larvae grow older their ability to move around becomes increasingly important for their depth distribution.

In general, species with distinct spawning concentrations and with eggs and larvae in distinct geographic concentrations in the upper water layer will be particularly vulnerable. The Barents Sea stock of Atlantic cod is such a species where eggs and larvae can be concentrated in the upper 10 m in a limited area. Based on oil spill simulations for different scenarios and different toxicities of the dissolved oil, the individual oil exposure and population mortality has been calculated. The population impact is to a large degree dependent on whether there is a match or a mismatch between high oil concentrations in the water column (which will only occur for a short period when the oil is fresh) and the highest egg and larvae concentrations (which will also only be present for weeks or a few months, and just be concentrated in surface water in calm weather). For combinations of unfavourable circumstances and using the PNEC with a 10 X safety factor (Johansen *et al.* 2003), there could be losses in the region of 5 %, and in some cases up to 15 %, for a blowout lasting less than two weeks, while very long-lasting blowouts could give losses of eggs and larvae in excess of 25 %. A 20 % loss in recruitment to the cod population is estimated to cause a 15 % loss in the cod spawning biomass and to take approx. eight years to recover fully (Figure 49).

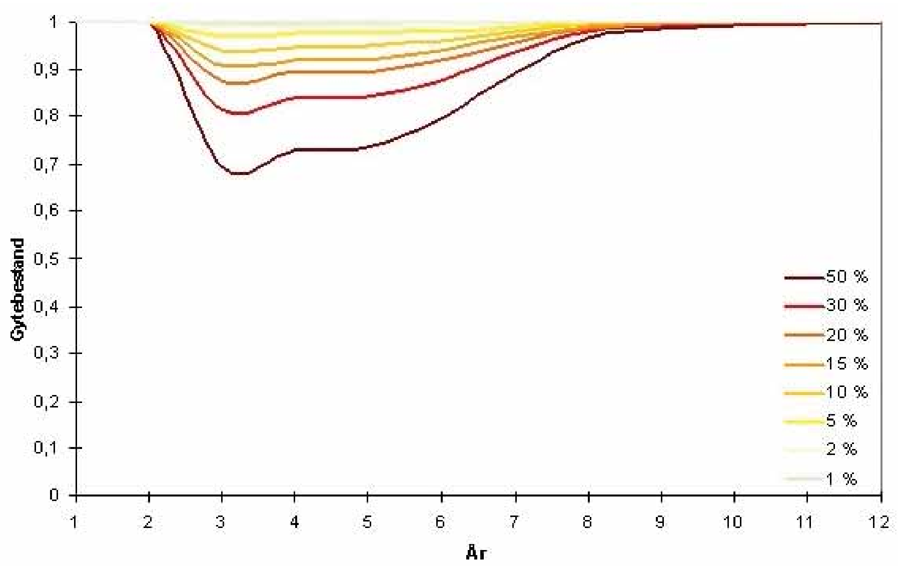



**Figure 49.** Estimated reduction and recovery in Barents Sea cod spawning biomass following large losses of eggs and larvae due to a large' worst case' oil spills. Gydebestand = spawning stock, År = year. Source: Anonymous 2003, Johansen *et al*. 2003.

There is no knowledge available on concentrations of eggs and larvae in East Greenland waters. However, the highly localised spawning areas with high concentrations of egg and larvae for a whole stock near the surface known from the Lofoten-Barents Sea are not likely to occur. The overall picture is that the relatively few fish larvae are widespread, although perhaps occurring in patches which may hold somewhat elevated concentrations. Another factor of importance is the vertical distribution of eggs and larvae. Eggs of Atlantic cod concentrate in the upper 10 m of the water column, whereas larvae of Greenland halibut also are found deeper and will therefore be less exposed to harmful oil concentrations from an oil spill, unless the oil is released from a subsea blowout.

For Greenland halibut, it generally must be expected that an oil spill in the assessment area will impact on a smaller proportion of a season's production of eggs and / or larvae than modelled for cod in the Barents Sea. However, a subsea blowout may have effects on this bottom living species. Polar cod eggs in contrast accumulate just below the ice. The eggs have a long incubation time and they hatch when the ice starts to disintegrate and melt. As oil spill under ice will tend to accumulate in the same space, there is a potential risk of overlap and impacts on the recruitment of the polar cod population. Presently, we have no knowledge on potential aggregations of spawning polar cod and subsequent accumulation of eggs and larvae. But if it occurs, an oil spill may have the potential to impact recruitment and stock size. This may have effects up in the trophic web, as polar cod is an ecologically key species.

### Copepods, the food chain and important areas

Copepods are very important in the food chain and can be affected by the toxic oil components (WSF and PAH) in the water below an oil spill. However, given the usually restricted vertical distribution of these components to the upper zone and the wider depth distribution of the copepods this is not likely to cause major population effects. Ingestion of dispersed oil droplets at greater depth from a subsea blowout or after a storm can also be a problem. Studies of the potential effects of oil spills on copepods in the Barents Sea (Melle *et al.* 2001) showed that populations were distributed over such large areas that a single oil spill would only impact a minor part and not pose a major threat (Anonymous 2003). Recent studies showed effects of pyrene (PAH) on reproduction and food uptake among *Calanus* species (Jensen *et al.* 2008) and on survival of females, feeding status, and nucleic acid content in *Microsetella* spp. from Western Greenland (Hjorth & Dahllöf 2008). The pyrene concentrations applied were however difficult to compare to actual spill situations.

Important areas for plankton including fish larvae are often where hydrodynamic discontinuities occur. Special attention should therefore be given to the implication of oil spills in connection with such sites, particularly during the spring bloom. Fronts, upwelling areas and the marginal ice zone are examples of such hydrodynamic discontinuities where high surface concentrations of phytoplankton, zooplankton, including fish larvae, can be expected. There is, however, very little information available on such events in the assessment area.

The most sensitive season for primary production and plankton – i.e. where an oil spill can be expected to have the most severe ecological consequences

– is April to June where high biological activity of the pelagic food web from phytoplankton to fish larvae is concentrated in the surface layers.

### 11.2.2 Oil spill impacts on benthos

Bottom-living organisms (benthos) are generally very sensitive to oil spills and high hydrocarbon concentrations in the water. However, effects will occur in shallow water (<50 m) where toxic concentrations can reach the seafloor. In such areas intensive mortality has been recorded following an oil spill, for example among crustaceans and molluscs (McCay *et al.* 2003a, 2003b). Oil may also sink to the seafloor as tar balls, which happened after the *Prestige* oil spill off Northern Spain in 2002. No effects on the benthos were detected (Serrano *et al.* 2006), but the possibility of an impact is apparent. Many benthos species, especially bivalves, accumulate hydrocarbons, which may cause sublethal effects (e.g. reduced reproduction). Such bivalves may act as vectors of toxic hydrocarbons to higher trophic levels, particularly bearded seals and walruses. Knowledge on benthos in the assessment area is too fragmentary to assess impacts of potential oil spills.

### 11.2.3 Oil spill impacts on sympagic habitats

There is very little knowledge available on oil spill impact on the sea-ice ecosystem (Camus & Dahle 2007, Skjoldal *et al.* 2007). Oil may accumulate under the ice and stay until it breaks up and melts, weathering processes are inhibited which means that toxicity may persist much longer than in open waters. The sympagic ecosystem is however very resilient as it necessarily has to re-establish each season when new ice is formed, at least in areas dominated by first-year ice.

Polar cod is apparently particularly sensitive due to the fact that their eggs stay for a long period just below the ice, where also oil will accumulate (Skjoldal *et al.* 2007) (see also section 9.3.4).

### 11.2.4 Oil spill impacts in coastal habitats

In coastal areas where oil can be trapped in shallow bays and inlets, oil concentrations can build up in the water column to levels that are lethal to adult fish and invertebrates (e.g. McCay 2003).

An oil spill from an activity in the assessment area which reaches the coast has the potential to reduce stocks of Arctic char, which may be forced to stay in oil-contaminated shallow waters when they assemble before they move up into the native river to spawn and winter.

In coastal areas where oil may be buried in sediment, among boulders and imbedded in crevices in rocks, a situation with chronic oil pollution may persist for decades and cause small to moderate effects (Table 10). Many coastlines in the assessment area are similar to those of Prince William Sound, where oil was trapped below the surface after the Exxon Valdez oil spill.

In a study performed 12 years after the oil spill it was estimated how much oil remained on the beaches of Prince William Sound. Oil was found on 78 of 91 beaches, randomly selected according to their oiling history. The analysis of terpanes revealed that over 90 % of the surface oil and all of the subsurface oil originated from the Exxon Valdez (Short *et al.* 2004).

Oil may also contaminate terrestrial habitats that are occasionally inundated at high water levels. Salt marshes are particularly sensitive and they represent important feeding areas for geese.

### 11.2.5 Oil spill impacts on fisheries

Tainting by oil residues in fish meat is a severe problem related to oil spills. Fish exposed even to very low concentrations of oil in the water, in their food or in the sediment where they live may be tainted, leaving them useless for human consumption (GESAMP 1993). The problem is most pronounced in shallow waters, where high oil concentrations can persist for longer periods. Flatfish and bottom-living invertebrates are particularly exposed. Tainting has, however, not been recorded in flatfish after oil spills in deeper offshore waters, where degradation, dispersion and dilution reduce oil concentrations to low levels. Tainting may also occur in fish living where oil-contaminated drill cuttings have been disposed of.

In the case of oil spills, it will be necessary to suspend fishery activities in the affected areas, mainly to avoid the risk of marketing fish that are contaminated or even just tainted by oil (Rice *et al.* 1996). This may apply to the Greenland halibut fisheries within the assessment area. Large oil spills may cause heavy economic losses due to problems arising in the marketing of the products. Strict regulation and control of the fisheries in contaminated areas are necessary to ensure the quality of the fish available on the market. In offshore areas suspension usually will last some weeks and in coastal waters longer. The coastal fishery was banned for four months after the Braer incident off the Shetland Islands in 1993, and for nine months after the Exxon Valdez incident in Alaska in 1989 (Rice *et al.* 1996). Some mussel fishing grounds were closed for more than 18 months after the Braer incident.

The fishery for Greenland halibut in the assessment area is very small (annual catch 2005-2007 approx. 250 tonnes) compared to the total for Greenland as a whole (approx. 35,000 tonnes), so closure of the fishery for a season will only have minor economic consequences, and none on the local community in the assessment area as they do not participate in the fishery.

The tourism industry may be impacted by a large oil spill hitting the coasts. Tourists travelling to Greenland to encounter the pristine, unspoilt Arctic wilderness will most likely avoid oil-contaminated areas.

### 11.2.6 Oil spill impacts on seabirds

It is well documented that birds are extremely vulnerable to oil spills in the marine environment (Schreiber & Burger 2002). Birds which rest and dive from the sea surface, such as auks, seaducks, cormorants and divers (loons) are most exposed to floating oil, compared with birds which spend more time flying than on land. But all seabirds face the risk of coming into contact with spilled oil on the surface. This particular vulnerability is caused by feather plumage. Oil soaks easily into the plumage and destroys its insulation and buoyancy properties. Therefore, oiled seabirds readily die from hypothermia, starvation or drowning. Birds may also ingest oil by cleaning their plumage and by feeding on oil-contaminated food. Oil irritates the digestive organs, damages the liver, kidney and salt gland function, and causes anaemia. Sublethal and long-term effects may be the result. However, the main cause of seabird losses following an oil spill is direct oiling of the plumage.

Many seabirds aggregate in small and limited areas for certain periods of their life cycles. Even a small oil spill in such areas may cause very high mortalities among the birds present. The high concentrations of seabirds found at coasts and polynyas (e.g. breeding colonies, moulting areas, spring staging areas; Figures 18 and 19) are particularly vulnerable.

Oiled birds which have drifted ashore are often the focus of the media when oil spills occur, witnessing the high individual sensitivity to oil spills. However, the concern must be the case where populations suffer due to oiling. To assess this issue, extensive studies of the natural dynamics of the affected populations and the surrounding ecosystem are necessary (Figure 50).

The seabird populations most vulnerable to oil spills are those with low reproductive capacity and a corresponding high average lifespan (low population turnover). Such a life strategy is found among auks, fulmars and many seaducks. Thick-billed murres (an auk) for example do not breed before 4–5 years of age and the females only lay a single egg per

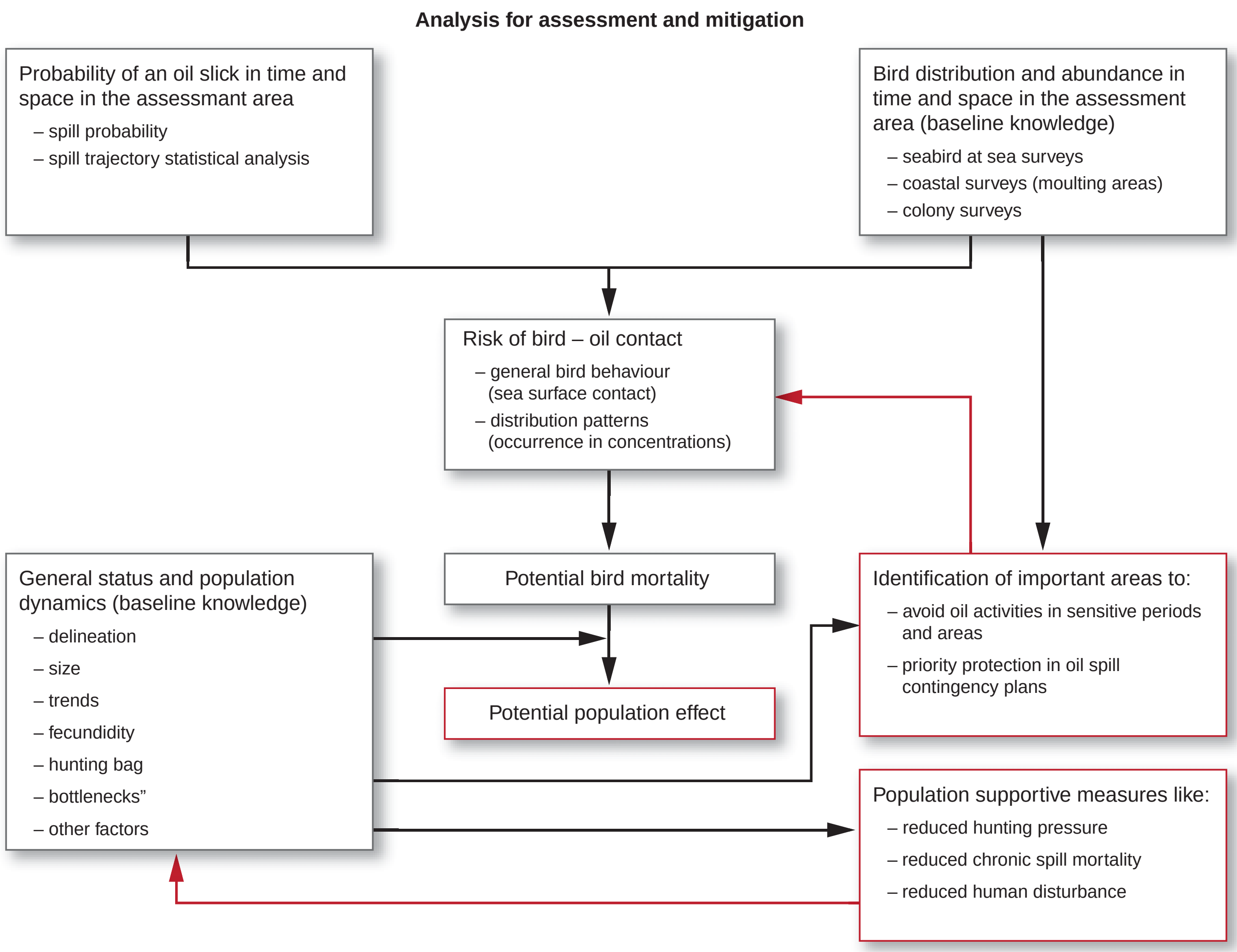



**Figure 50.** Basic principles of assessing a seabird populations vulnerability to oil spills. Black lines indicate main analysis of effects on bird populations, red lines analysis of potential mitigative measures. Indirect effects not included for simplicity.

year. This very low annual reproductive output is counterbalanced by a very long expected life span of 15–20 years or more. Such seabird populations are therefore particularly vulnerable to additional adult mortality caused for example by an oil spill.

If a breeding colony of birds is completely wiped out by an oil spill it must be re-colonised from neighbouring colonies. Re-colonisation is dependent on proximity, size and productivity of these colonies. If the numbers of birds in neighbouring colonies are declining, for example due to hunting, as in the Scoresbysund area, there will be no or only few birds available for re-colonisation of a site.

Only two breeding colonies of thick-billed murre are known from the assessment area. They are both situated at the entrance to Scoresby Sund. Here the birds assemble on the water below the colony and also at feeding areas far from the colony. Another risk situation is when the chicks and flightless adults leave the colony on a swimming migration. The breeding population is declining and therefore particularly sensitive to additional mortality. Another factor making this population particularly sensitive to increased mortality is the fact that neighbouring colonies are very far away. The nearest are found in Iceland and on Svalbard.

Other important bird colonies where the population could be severely impacted by an oil spill in the assessment area include kittiwake colonies at several sites, the large common eider colony at Daneborg and the very large litte auk colonies at the entrance to Scoresby Sund. Common to all these colonies is that they are situated at polynyas where open water is accessible in spring and where many birds congregate. But there are numerous other seabird colonies which will be at risk in case of an oil spill.

A very important seabird breeding colony is found on the islands of Henrik Krøyer Holme in the Northeast Water Polynya. The largest assemblage of red-listed ivory gulls in Greenland are found here and also the rare (and red-listed) Ross's gull occur here, besides many Arctic terns, Sabines gulls and common eiders. Such a colony is highly vulnerable to oil spills, and completely inaccessible as far as oil spill response is concerned due to its remoteness and because it usually is surrounded by sea ice even in summer.

Moulting concentrations are also vulnerable to oil spills with potential population effects. The aerial survey in July 2008 showed that common eiders moult in flocks distributed along many coasts, without very large concentrations. Long-tailed ducks were more concentrated and assembled at specific bays and coasts, but usually in relatively low numbers. Satellite tracking of common eiders and long-tailed ducks in 2007 and 2008 indicates, consistent with the aerial survey, that the post-breeding moult generally takes place close to the breeding areas (Box 1 and 2). In contrast king eiders were only found moulting at one site, a fjord on the Blosseville Kyst. A large proportion of the East Greenland population may be assembled here to moult and therefore potentially very vulnerable to an oil spill.

More than 5 million seabirds from Svalbard and possibly Arctic Russia migrate through the assessment area in autumn and again in spring. These birds stage during the migration and may become exposed to oil spills. However, no information on concentration areas and the relation to the ice distribution is available. But potentially numerous seabirds may be killed and breeding populations outside the assessment area impacted.

### 11.2.7 Oil spill impacts on marine mammals

Marine mammals are generally less sensitive to oiling than many other organisms, because they (except polar bears) are rather robust in response to fouling and contact with oil. The adults are not dependent on an intact fur layer for insulation, and some species of toothed whales can apparently avoid oil in the open sea (Geraci & St Aubin 1990). Seal pups are more sensitive to direct oiling, because they have not developed the insulating blubber layer and are dependent on their natal fur.

There are, however, some especially sensitive populations in the assessment area, and some conditions also cause marine mammals to be more exposed.

In ice-covered waters where oil may fill the spaces between the ice floes, marine mammals may be forced to surface in an oil spill, where there is a risk for inhaling oil vapours. This is a potential hazard, and a recent study indicate that the loss of killer whales after the Exxon Valdez oil spill in 1989 could be related to inhaling oil vapours from the spill (Matkin *et al.* 2008). These killer whales did not avoid the oil spill and were observed surfacing in oil-covered water. Harbour seals found dead shortly after the Exxon Valdez oil spill had evidence of brain lesions caused by oil exposure, and many of these seals were disoriented and lethargic over a period of time before they died (Spraker *et al.* 1994).

There is also concern relating to damage to eye tissue on contact with oil as well as for toxic effects and injury in the gastrointestinal tract if oil is ingested during feeding at the surface (particularly in the case of the bowhead whale) (Albeert 1981, Braithwaite *et al.* 1983, St. Aubain *et al.* 1984).

Marine mammals may be affected through the food chain and particularly exposed are those which feed on on benthic fauna. Especially walrus is sensitive because it feeds in shallow waters where toxic concentrations of oil can reach the seafloor.

It is difficult to assess the impacts of an oil spill on seals and whales in the assessment area. There is at least a risk of major impacts on individuals if oil is trapped in a polynya or along an ice edge, where also marine mammals assemble. Also the occurrence of marine mammals in local areas can be significantly altered and hunting in the Scoresbysund area may thereby be affected.

Among the marine mammal VECs, the walrus population is particularly vulnerable due to the gregariousness of the species, as opposed to the highly dispersed bearded seal and ringed seal populations. Harp seals and hooded seals are vulnerable during the whelping season when they concentrate at whelping areas and particularly the pups can be fouled by oil. The bowhead whale may be considered as especially vulnerable because the population is very small and the survival of single individuals is crucial for the recovery of the population.

Polar bears are particularly sensitive to oil. Contact with oil through grooming of fouled fur, consumption of tainted food or even direct consumption (because polar bears are attracted to fatty substances) can be lethal (Durner & Amstrup 2000). Furthermore, will oil in the fur reduce the isolation properties. Polar bears live in ice-covered waters and the population density is low and probably also declining. Polar bears are already considered as vulnerable (IUCN 2008) due to climate change, which is expected to reduce their habitat, the ice-covered Arctic waters.

### 11.2.8 Long-term effects

A synthesis of 14 years of oil spill studies in Prince William Sound since the Exxon Valdez spill has been published in the journal 'Science' (Petersen *et al.* 2003), and here it is documented that delayed, chronic and indirect effects of marine oil pollution occur (Table 10). Oil persisted in certain coastal habitats beyond a decade in surprisingly high amounts and in highly toxic forms. The oil was sufficiently bio-available to induce chronic biological exposure and had long-term impacts at the population level. Heavily oiled coarse sediments formed subsurface reservoirs of oil where it was protected from loss and weathering in intertidal habitats. In these habitats e.g. harlequin ducks, preying on intertidal benthic invertebrates, showed clear differences between oiled and un-oiled coasts. At oiled coasts they displayed the detoxification enzyme CYP1A nine years after the spill. Harlequin ducks at oiled coasts had lower survival, their mortality rate was 22 % instead of 16 %; their body mass was lower; and they showed a decline in population density as compared with stable numbers on un-oiled shores (Petersen *et al.* 2003).

Many coasts in the assessment area in East Greenland have the same morphology as those of Prince William Sound, where oil wasn trapped. This indicates that similar long-term impacts must be expected if spilled oil strands on the coasts of the assessment area. The High Arctic conditions in the assessment area may even prolong the impact period in relation to that experienced in Prince William Sound.

Another indication of long-term effects was seen 17 months after the Prestige oil spill off northern Spain in November 2002. Increased PAH levels were found in both adult gulls and their nestlings, indicating not only exposure from the residual oil in the environment but also that contaminants were incorporated into the food chain, because nestlings would only have been exposed to contaminated organisms in their diet (e.g. fishes and crustaceans) (Alonso-Alvarez *et al*. 2007, Perez 2008).

### 11.2.9 Mitigation of oil spills

Risk of oil spills and their potential impact can be minimised with high HSE standards, BAT, BEP and a high level of oil spill response. However this is difficult in the assessment area, where ice prevents effective oil recovery methods.

An important tool in oil spill response planning and implementation is oil spill sensitivity mapping, which has not yet been carried out in the assessment area.

A supplementary way to mitigate the potential impact on animal populations that are sensitive to oil spills, e.g. seabirds, is to try to manage populations by regulation of other population pressures, so that they are fitter and better able to compensate for extra mortality due to an oil spill (see Figure 50).

Before activities are initiated, information on the local society both on a regional and local scale is very important. In the context of mitigating impacts, information on activities potentially causing disturbance should be communicated to e.g. local authorities and hunters' organisations which may be impacted, for example, by the displacement of important quarry species. Such information may help hunters and fishermen to plan their activities accordingly.

**Table 10.** Changing paradigms in oil ecotoxicology, moving from acute toxicity based on single species toward and ecosystem-based synthesis of short-term direct plus longer term chronic, delayed and indirect impacts. From Petersen *et al*. 2003.

| Old paradigm | Emerging appreciation |
|---|---|
| ***Physical shoreline habitat*** | |
| Oil that grounds on shorelines other than marshes dominated by fine sediments will be rapidly dispersed and degraded microbially and photolytically. | Oil degrades of varying rates depending on environment, with subsurface sediments physically protected from disturbance, oxygenation, and photolysis retaining contamination by only partially weathered oil for years. |
| ***Oil toxicity to fish*** | |
| Oil effects occur solely through short-term (~4 day) exposure to water-soluble fraction (1- to 2-ringed aromatics dominate) through acute narcosis mortality at parts per million concentrations. | Long-term exposure of fish embryos to weathered oil (3- to 5-ringed PAHs) at ppb concentrations has population consequences through indirect effects on growth, deformities, and behaviour with long-term consequences on mortality and reproduction. |
| ***Oil toxicity to seabirds and marine mammals*** | |
| Oil effects occur solely through short-term acute exposure of feathers or fur and resulting death from hypothermia, smothering, drowning, or ingestion of toxics during preening. | Oil effects also are substantial (independent) of means of insulation) over the long term through interactions between natural environmental stressors and compromised health of exposed animals, through chronic toxic exposure from ingesting contaminated prey or during foraging around persistent sedimentary pools of oil, and through disruption of vital social functions (care giving or reproduction) in socially organized species. |
| ***Oil impacts on coastal communities*** | |
| Acute mortality through short-term toxic exposure to oil deposited on shore and the shallow seafloor or through smothering accounts for the only important losses of shoreline plants and invertebrates. | Clean-up attempts can be more damaging than the oil itself, with impacts recurring as long as clean-up (including both chemical and physical methods) continues. Because of the pervasiveness of strong biological interactions in rocky intertidal and kelp forest communities, cascades of delayed, indirect impacts (especially of trophic cascades and biogenic habitat loss) expand the scope of injury well beyond the initial direct losses and thereby also delay recoveries. |

# 12 Assessment summary

The assessments presented here are based on our present knowledge concerning the distribution of species and their tolerance and threshold levels toward human activities in relation to oil exploration. However, as pointed out previously, the Arctic is changing due to climate change, and this process might accelerate even more in the future.

Presently, we do not know much about the adaptation capacity of important species in the assessment area and how their sensitivity to human impacts might change under changing environmental conditions. Changes in habitat availability, e.g. due to reduced ice coverage, are to be expected, with consequences for the local fauna. This, as well as increased temperatures will affect the distribution patterns of relevant species, with consequences for the food web. Relocation of species could also mean that fish species with relevance for commercial fisheries may occur in the assessment area, resulting in increased fishing activities.

## 12.1 Normal operations – exploration

Noise from seismic activities has the potential to scare adult fish away from fishing grounds; but if scared away the effect is temporary and normal conditions will re-establish after some days or weeks, probably depending on fish species and foraging opportunities. It is assessed that potential impacts of seismic activity on the commercially utilised Greenland halibut populations will be low and temporary.

It is also assessed that effects on fish larvae and eggs will be very low due to the low concentrations in the assessment area, and consequently no effects will be expected on recruitment to adult fish stocks.

It is well known that seismic noise can scare away marine mammals, but it is expected that the effect is temporary and that seals and whales will return when seismic surveys have terminated. If displacement from traditional hunting grounds occurs, a temporary reduction in hunting yield must be expected.

Noise from exploration drilling platforms is known to displace migration routes of whales in Alaska and, depending on the location in the assessment area, displacement of migrating and staging whales (mainly narwhal and bowhead whale), and within shorter distances walrus and seals (bearded seal), must also be expected. There is a risk for displacement of populations from critical feeding grounds and also for reduced availability of species for local hunters. The effects are however temporary and it is expected that displaced species will return when the drilling is over.

## 12.2 Normal operations – development and production

Drilling will continue throughout the development and production phase. Just as with exploration drilling there will be a risk of displacement of marine mammals from critical habitats. However, now the effect is permanent (or at least long-term). Whales, particularly narwhal and bowhead whale are sensitive in this respect and may be permanently displaced from specific habitats. Walruses are probably the most sensitive at the population level, because large proportions of the population are dependent on highly localised, critical habitats.

Intensive helicopter flying also has the potential to displace seabirds and marine mammals from habitats (e.g. feeding grounds important for win-

**Table 11.** Overview of potential impacts (worst case) from a large oil spill in the KANUMAS East assessment area.

| VEC | Overlap | Risk of impact on critical habitats | Potential impacts - levels | | | Risk of long term pop impacts |
|---|---|---|---|---|---|---|
| | | | Biol level | Temporal | Spatial | |
| Prim. prod. | large | yes | pop. | short term | regional | minor |
| Zooplankton | large | yes | pop. | short term | regional | minor |
| Benthos | large | yes | pop. | long term | local | moderate |
| Ice flora and fauna | arge | yes | pop. | short term | regional | minor |
| Greenland halibut | small | yes | indv. | short term | local | minor |
| Arctic char | large | yes | pop. | long term | local | major |
| Polar cod | large | yes | pop. | long term | local | moderate |
| Fish egg and larvae | large | yes | pop. | short term | regional | moderate |
| Fulmar | large | yes | indv. | long term | local | minor |
| Common eider | large | yes | pop. | long term | local | major |
| King eider | large | yes | pop. | long term | local | major |
| Sabines gull | large | yes | indv. | short term | local | moderate |
| Ross's gull | large | yes | pop. | short term | local | moderate |
| Arctic tern | large | yes | indv. | short term | local | moderate |
| Thick-billled murre | large | yes | pop. | long term | regional | extreme |
| Little auk | large | yes | pop. | long term | regional | major |
| Walrus | large | yes | pop. | long term | regional | major |
| Harp seal | large | yes | short | short term | regional | minor |
| Hooded seal | large | yes | pop. | long term | regional | moderate |
| Ringed seal | small | no | indv | short term | local | minor |
| Bearded seal | small | no | indv | short term | local | minor |
| Narwhal | large | yes | indv. | short term | regional | moderate |
| Bowhead whale | large | yes | indv. | long term | regional | moderate |
| Polar bear | large | yes | pop. | short term | regional | moderate |
| | | **Risk of impact on important sites** | | | | **Risk of income impacts** |
| Com. fisheries | large | yes | | long term | regional | major |
| Hunting | large | yes | | long term | local | moderate |
| Tourism | large | yes | | long term | regional | moderate |

ter survival) as well as from traditional hunting grounds, reducing availability to hunters.

Illuminated structures and the flame from flaring may attract seabirds in the dark hours, and there is a risk for mass mortality for especially eiders and perhaps little auks.

Discharges from drilling, development and production operations have the potential to pollute extensive areas. The main concern is produced water, particularly if released in ice-covered waters. With current knowledge there is a risk for considerable ecological effects, even if current OSPAR standards are applied.

Also discharge of ballast water is of concern as there is a risk of introducing non-native and invasive species. This is currently not a severe problem in the Arctic, but the risk will increase with climate change and intensive tanker traffic associated with a producing oil field.

Development of an oil field and production of oil are energy-consuming activities which will contribute significantly to the Greenland emission of greenhouse gases. A single, large Norwegian production field emits $CO_2$ at more than twice the total Greenland emission of today.

Placement of offshore structures and infrastructure may locally impact seabed communities and there is a risk of spoiling important feeding grounds particularly for walrus. Inland structures primarily have aesthetic impacts on landscapes, but there is also a risk for obstruction of rivers with implications for anadromous Arctic char and damage to unique coastal flora and fauna.

A specific impact on fisheries is the exclusion zones which will be established around both temporary and permanent installations.

There is also a risk for impacting the tourism industry in the southern part of the assessment area, as large and obvious industrial installations will compromise the impression of an unspoilt Arctic wilderness, which is the main asset to tourist operators.

Cumulative impacts are difficult to evaluate when the level of activity is unknown. These will depend on the scale of activities, the density of operation sites and on the duration of the activities, and must be further assessed when such information is available.

The best way of mitigating impacts from development and production is first to perform detailed background studies of the environment in order to locate sensitive ecosystem components. Careful planning of structure placement and transport corridors can reduce inevitable impacts, and application of the Precautionary Principle in combination with BEP and BAT can do much to reduce emissions to air and sea. Particularly, a 'zero-discharge' policy, as will be applied in the Barents Sea, can contribute to minimisation of the impacts.

## 12.3 Accidents

The most severe accident in environmental terms would be a large oil spill. This has the potential to impact all levels in the marine ecosystem, from primary production to the top predators, and impacts may last for decades.

In general, oil slicks occurring in the coastal zone are more harmful and cause longer-lasting effects than oil spills staying in the open sea. This may not be the case in the assessment area, where ice is present almost throughout the year. Ice may protect coasts and it can also trap, conserve and transport oil over long distances. Ice may also limit the dispersion compared with the situation in ice-free waters. Generally the knowledge on the behaviour of spilled oil in such an environment is very limited and the technology for its clean-up in ice-covered waters needs to be further developed. The recent AMAP (2007) Oil and Gas Assessment concludes 'that a large oil spill in ice-covered waters could represent a threat to populations and even to species'.

Adding to the severity of an oil spill in the assessment area is the general lack of response methods to recover oil from icy waters. Another important factor in this respect is the remoteness, inaccessibility and lack of infrastructure in the region.

It is assessed that the impact of an oil spill in the assessment area on primary production, plankton and fish / shrimp larvae in open waters will be low due to their dispersed occurrence and the large temporal and spatial variation in this occurrence. There is, however, a risk of impacts (reduced production) on localised primary production areas; although overall production probably will not be significantly impacted. The same may be true for potential localised concentrations of plankton and fish larvae if they occur in the uppermost part of the water column, but on a broad scale no effects or only slight effects on these ecosystem components are expected. An exception to this conclusion is polar cod, as egg concentrations may occur under the ice and these will be at risk if oil accumulates below the winter ice.

In coastal areas there is a risk of impacts on concentrations Arctic char and many seabird populations in the open-water season, which may affect populations for decades.

Bottom-living organisms (benthos) such as bivalves and crustaceans are vulnerable to oil spills; however, no effects are expected in the open water. In shallow waters (< 10-15 m), highly toxic concentrations of hydrocarbons can reach the seafloor with severe consequences for local benthos and thus also for species utilising the benthos – especially walrus.

The fauna and flora living in and on the underside of the ice are probably very sensitive to oil spills. They have, however, high regenerative potential.

Impacts on adult fish stocks in the open sea are not expected. But if an oil spill occurs in ice-covered waters this presents a risk to polar cod populations. This is an ecologically key species and significant impacts on polar cod stocks may be transferred up in the food web (to seabirds and marine mammals).

In open waters seabirds are usually more dispersed than in coastal habitats.However, there are some very concentrated and recurrent seabird occurrences in offshore areas of the assessment area, particularly in the polynyas. There may also be large offshore aggregations of migrant seabirds in spring and autumn. Such concentrations are extremely sensitive to oil spills and population effects may occur if an oil spill hits one of the polynyas.

Among the marine mammals the polar bear is sensitive to oiling, and many may become fouled with oil in case of a large oil spill, for example in a polynya. The impact of an oil spill may add to the general decrease expected for the polar bear stocks as a consequence of reduced ice cover.

Recent studies indicate that whales are very sensitive to inhaling oil vapours, and this may particularly apply to narwhals and bowhead whales which can be dependent on very limited open waters. Walruses and other seals living in the ice may also be vulnerable to this impact.

There is also a risk for indirect impacts on walrus and bearded seal populations through contamination of benthic fauna especially at shallow (< 10-15 m) feeding grounds where oil may reach the seafloor.

For some animal populations mortality caused by an oil spill can to some extent be compensatory to natural mortality while for others it will be largely additional. Some populations may recover quickly while others will recover very slowly to pre-spill conditions depending on their life strategies. A general decline in a population may be enhanced by the oil spill induced mortality. For species which are vulnerable to oil spills and are also harvested, oil spill impacts could be mitigated by managing the harvest wisely and sustainably.

Hunting in oil spill impacted areas can both be affected by closure zones and by changed distribution patterns (reduced availability) of quarry species.

An oil spill in the open sea will affect fisheries mainly by a temporary closure in order to avoid contamination of catches. Closure time will depend on the duration of the oil spill, weather, etc.

The tourist industry in the assessment area will probably also be impacted negatively by a large oil spill.

Long-term effects from residual oil in the environment must be expected for a very long time following a large spill which reaches the coasts.

## 12.4 Seasonal summary of potential oil spill impacts

### 12.4.1 Winter (October–April)

During this season the sea is covered by ice, except for the polynyas where more or less open water is present. Marine mammals are active and present in winter. Many of the marine mammals are concentrated at the very limited open waters or along the MIZ. Here they will be highly exposed to oil spills and will be sensitive to disturbing activities. They have very few or no alternative habitats available during this time of the year.

Hooded and harp seals assemble in the whelping area in the drift ice in March, and are sensitive to both oil spills and disturbance.

Almost no birds are present when ice covers all the coasts, but they arrive during April and May and are particularly numerous where polynyas reach the coasts and expose the shallow feeding grounds. Migrant seabirds en route to breeding areas in Svalbard and Russia pass through during April and May, probably in their millions.

Polar cod spawn under the ice in late winter and the eggs accumulate under the ice, where they are particularly exposed to oil spills.

Figure 51 shows a preliminary, regional designation of particularly important and oil spill sensitive winter areas in the assessment area.

### 12.4.2 Spring (May–June)

The sea ice gradually disintegrates and retreats and open-water areas increase, e.g. in polynyas and along fast-ice edges. In coastal habitats the shore lead opens and gradually becomes wider given access to open waters for birds.

The spring bloom is initiated in the open waters and many seabirds assemble in the polynyas, especially off Scoresby Sund, Wollaston Forland and in the NEW polynya. These aggregations are highly sensitive to oil spills, and a worst-case accident in the Scoresby Sund polynya may kill hundreds of thousands of little auks and thousands of other seabird species, mainly thick-billed murre and common eider.

Figure 51 shows a preliminary, regional designation of particularly important and oil spill sensitive spring areas in the assessment area.

### 12.4.3 Summer, open-water season (July –September)

This is the open-water season, when the drift ice is rather dispersed and almost all coasts have at least a narrow stretch of open water (shore lead).

The marine mammals are generally more dispersed, but seabirds will be assembled near the breeding colonies. Late in this season the huge Svalbard populations of little auks and thick-billed murres move through the assessment area in company with a significant part of the breeding population of the threatened ivory gull (from North Greenland, Svalbard and Arctic Russia).

Arctic char assemble at the river mouths before moving into the freshwater spawning and wintering grounds.

Figure 51 shows a preliminary, regional designation of particularly important and oil spill sensitive summer areas in the assessment area.

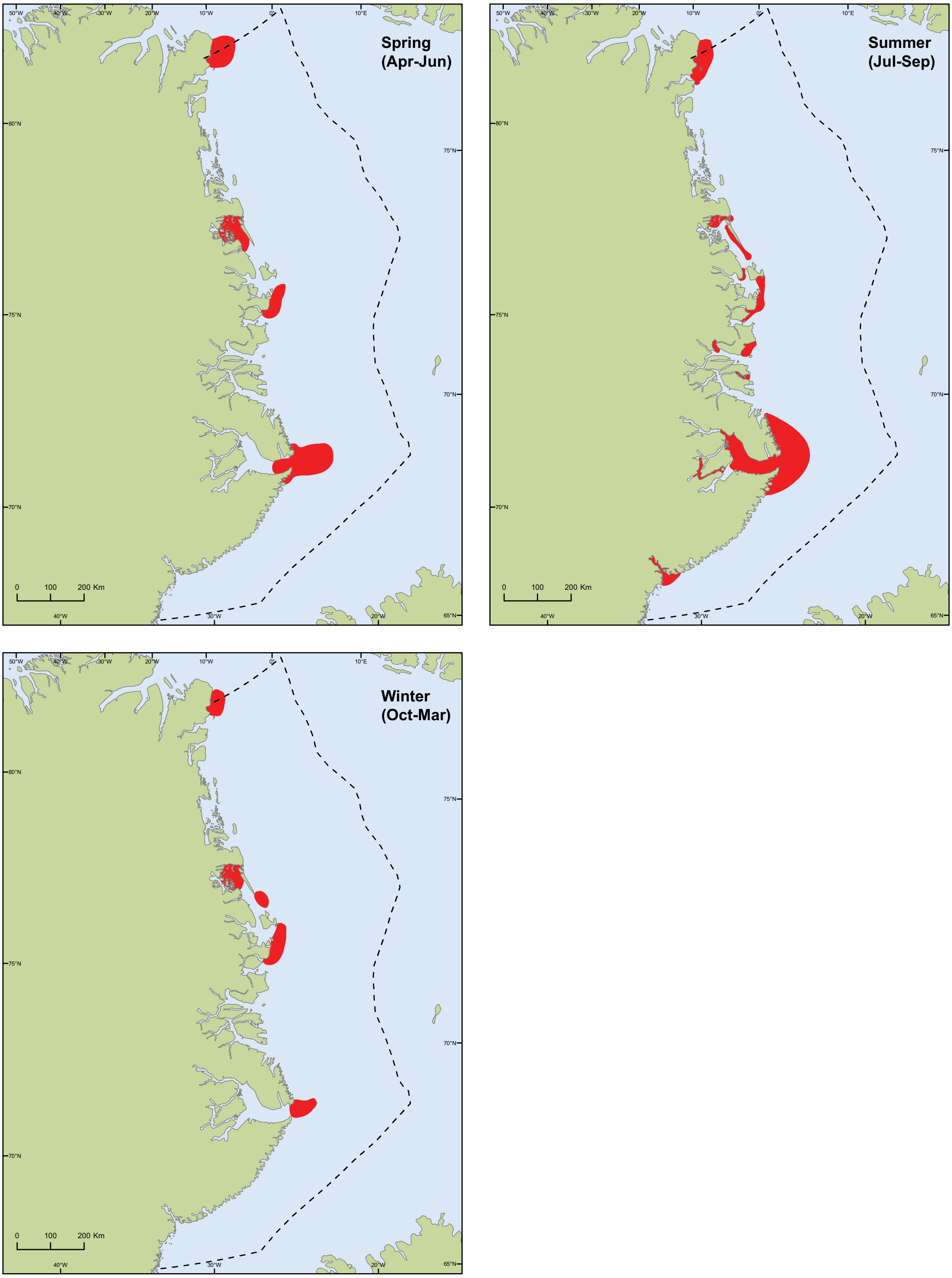



**Figure 51.** A preliminary designation of the most oil spill sensitive areas in the assessment area. The background data for this designation is not always adequate and future analyses may change the number, extend and placement of the areas, particularly when all data from the associated projects have been analysed.

# 13 Ongoing studies

To support this SEIA a number of background studies have been initiated. These are still in progress and will be completed at the latest in 2010. Further studies are expected to be initiated if licences are granted, to strengthen the knowledge base for planning, mitigation and regulation of future oil activities in the KANUMAS East area.

It should be noted that the ecology of the assessment area is dependent on several biophysical factors that manifest themselves in areas outside the area and that a comprehensive assessment of the area in question will require studies and understanding of processes in adjacent areas as well.

Ongoing and finished projects include:

**Development of hydrodynamic model and oil spill trajectories (by DMI)**
Report finished in 2008 (Nielsen *et al.* 2008).

**An evaluation of oil spills in the Greenland sea ice (by SINTEF, Norway)**
Report finished in 2008 (Johansen 2008).

**Breeding biology and migration of little auk and thick-billed murre**
Thick-billed murres and the little auks are numerous breeders along the coasts of the Scoresby Sund polynya. This area constitutes the southern part of the assessment area. Both species are highly sensitive to oil pollution, but routes of migration back and forth to the breeding colonies, foraging areas en-route, and wintering grounds outside the region are basically not known. This project aims to fill in these gaps and to add information about numbers, phenology and breeding biology that are relevant in issues of oil pollution. In 2007 several little auks were equipped with dataloggers, and some of these were retrieved in 2008. However, the results were not available for the assessment. The project continues in the 2009 field season with studies in the largest thick-billed murre colony. To be finished in 2010

**Polar bear abundance and habitat selection**
Polar bears spend their life on Arctic sea ice where they rely on access to various prey including the ice breeding ringed, harp and hooded seals. Studies of their movement during 1993–1998 showed that during most of the year polar bears roam widely on the pack ice of the Greenland Sea in East Greenland. A marked decrease of the sea ice in this area over the last decades may have severe consequences to East Greenland polar bears. Furthermore, renewed interest for oil exploration in the East Greenland area necessitates an update on the information about how polar bears exploit their prime habitat. During mid March and mid April 2007 and again in 2008 the Norwegian research vessel, ‘Nordsyssel’ operated in the pack ice between the island of Jan Mayen (Norway) and the coast of East Greenland with the purpose of studying whelping hooded seals. During these periods a team of researchers used the ship’s helicopter to track polar bears in the pack ice. Both years, twelve wears were immobilised and furnished with satellite-linked radios that provided data about movement and activity of the bears. In the best-case scenario the transmitters may

operate for up to 3 years until they potentially fall off due to wear of the collar. The data on location of the bears will be analysed in relation to satellite telemetered data on ice cover in the Greenland Sea and adjacent areas. The study aims to provide detailed information for several seasons on the nature of the area use by polar bears and habitat choice. Thereby, areas of special importance to the bears can be mapped. The study is conducted by the Greenland Institute of Natural Resources (Greenland) and the National Environmental Research Institute (Denmark) in cooperation with the Danish Technical University and several Norwegian research institutes. To be finished in 2010.

**Surveys for marine mammals and seabirds in spring and summer 2008**

The aim of this project was, during aerial surveys, to map important areas for waterbirds and marine mammals in the coastal waters of Northeast Greenland. Two surveys were conducted: a spring survey and a late summer survey. Preliminary results are presented in Figures 17, 18 19). A report presenting results from the field activities will be published in 2009 (Boertmann *et al.* 2009a).

**Tracking of different seabird species by means of satellite transmitters and geo-locator data loggers**

The project will identify migration routes and staging areas for marine birds breeding in Northeast Greenland. In 2007, common eiders and long-tailed ducks were equipped with implanted satellite transmitters and preliminary results are presented in Box 1 and 2. In 2007 several breeding Arctic terns, Sabine's gulls and common eiders were equipped with very small geolocator data loggers. Many of these were retrieved in 2008, but the results were not ready for this assessment. To be finished in 2009.

# 14 Data gaps preliminary identified during preparation of the SEIA

There is a general lack of knowledge on many of the ecological components and processes in the KANUMAS East assessment area. To fill some of these data gaps, BMP, GINR and NERI have initiated a number of studies which will proceed in 2009. The results from these studies will be incorporated in the revised and updated SEIA planned to be issued in 2010.

However, many more knowledge gaps remain to be filled in order to provide adequate data to perform further EIA work. A preliminary list of the most important data requirements are presented in the section below. Some of these issues are general for the Arctic area and also identified in the Arctic Council's Oil and Gas Assessment (AMAP 2007, Skjoldal *et al*. 2007), and it is hoped that international research will be initiated. A more detailed and adequate analysis of data gaps will be included in the revised and updated SEIA planned to be issued in 2010.

**Oceanography**
Occurrence and predictability of hydrodynamic discontinuities

**Primary productivity**
Location of recurrent hot-spots.

**Zooplankton**
Concentration areas of krill and other macro-zooplankton during summer and winter.

**Benthos**
Important areas and species.

**Fish**
Polar cod, ecology, concentration areas, importance in the food web.

**Birds**
Distribution and abundance of moulting king eiders in the Blosseville Coast area.

Location of breeding colonies for ivory gulls.

Migration concentrations of thick-billed murres and little auks.

Seabird breeding colonies along the Blosseville Coast.

**Marine mammals**
Year-round seasonal occupancy, distribution and abundance of whales for identification of concentration and critical areas.

Whal (particularly narwhal) reactions to seismic sounds.

Distribution and movements of walruses in the NEW area.

Feeding ecology and movements of bearded seals and ringed seals.

**Oil spills**
Behaviour of oil in ice-covered waters.

Oil vapours and marine mammals.

Polar cod sensitivity to oil (all life stages).

PAH levels in the environment.

Mulitidiciplinary projects

Spatial distribution of prey and top predators (marine mammals and birds) in relation to oceanography (i.e. multispecies, boat-based, hydroacoustic / hydrographic / visual survey).

**Produced water**
Behaviour and toxicity of produced water in ice-covered waters

# 15 List of reports in preparation or issued as a part of the SEIA

Nielsen, J.W., Murawski, J. & Kliem, N. 2008. Oil drift and fate modelling off NE and NW Greenland. – DMI technical report 08-12.

Johansen, Ø. 2008. Statistical oil drift simulations east of Greenland. – SINTEF.

Boertmann, D. , Olsen, K. & Nielsen, R.D. 2009. Aerial surveys for seabirds and marine mammals in NE-Greenland spring and summer 2008. – NERI Technical Report, in prep.

# 16 References


Aars, J., Andersen, M. & Fedak, M. 2007. Swimming and diving behavior of female polar bears. – 17th Biennial Conference on the Biology of Marine Mammals, Cape Town, December 2007.

Aars, J., Lunn, N. J. & Derocher, A. E. (eds.). 2006. Polar Bears. Proceedings of the 14th Working Meeting of the IUCN/SCC Polar Bear Specialist Group, 20-24 June 2005, Seattle, Washington, USA. – Occasional Paper of IUCN/SSC No. 32. IUCN, Gland, Switzerland and Cambridge, UK.

Aastrup, P. & Boertmann, D. 2009. Udpegning af biologiske kerneområder i Nationalparkområdet, Nord- og Østgrønland. – NERI Technical Report in prep.

Aastrup, P. J., Egevang, C., Tamstorf, M. P. & Lyberth, B. 2005. Naturbeskyttelse og turisme i Nord- og Østgrønland. Danmarks Miljøundersøgelser. – Faglig rapport fra DMU 545: 133 s.

ACIA 2005. Impacts of a warming Arctic: Arctic Climate Impact Assessment (ACIA). Cambridge University Press, Cambridge, UK.

Acquarone, M. Born, E. W. & Speakman, J. 2006. Walrus (Odobenus rosmarus) field metabolic rate measured by the doubly labeled water method. – Aquatic Mammals 32: 363-369.

Ajiad, A. M & Gjøsætter, H. 1990. Diet of polar cod, *Boreogadus saida*, in the Barents Sea related to fish size and geographical distribution. – International Council for the Exploration of the Sea, Council Meeting 1990/G:48. 9 p.

Akvaplan-niva & Acona. 2003. Muligheder for og konsekvenser ved deponering av borekaks på land og konsekvenser ved reinjektion. – Akvaplan-niva, Tromsø.

Albert, T. F. 1981. Some thoughts regarding the possible effects of oil contamination on the bowhead whale, Balaena mysticetus. Pp. 945–953 in: Tissue Structural Studies and Other Investigations on the Biology of Endangered Whales in the Beaufort Sea. Final Report for the period April 1, 1980 through June 30, 1981, Vol. 2., T.F. Albert, ed. – Prepared for U.S. Department of the Interior, Bureau of Land Management, Alaska OCS Office.

Allen, R. C. & Keay, I. 2006. Bowhead whales in the Eastern Arctic, 1611-1911: Population reconstruction with historical whaling records. – Enviro. Hist. 12: 89–113.

Alonso-Alvarez, C., Munilla, I., Lopez-Alonso, M., Velando, A. 2007. Sublethal toxicity of the Prestige oil spill on yellow-legged gulls. – Environment International 33: 773-781.

Alton, M. S., Bakkala, R. G., Walters, G. E. & Munto, P. T. 1988. Greenland turbot *Reinhardtius hippoglossoides* of the Eastern Bering Sea and Aleutian Islands region. – NOAA Technical Report, National Marine Fisheries Service, 71. 31 p.

AMAP 2004. AMAP Assessment 2002: Persistent organic pollutants in the Arctic. – Arctic Monitoring and Assessment Programme (AMAP) Oslo, Norway. xvi+310 pp.

AMAP 2007. Arctic Oil and Gas 2007. – Arctic Monitoring and Assessment Programme (AMAP), Oslo.

Amstrup, S. C. & DeMaster, D. P. 1988. Polar bear (Ursus maritimus). Biology, management and conservation, Pp. 39-56 in Lentfer, J.W. (ed.). Selected marine mammals of Alaska: Species accounts with research and management recommendations. – Marine Mammal Commission, Washington, DC.

Amstrup, S. C. & Gardner, C. 1994. Polar bear maternity denning in the Beaufort Sea. – J Wildl Manage 58: 1-10.

Amstrup, S. C., Durner, G. M., Stirling, I. & Messier, F. 2000. Movements and distribution of polar bears in the Beaufort Sea. – Can J Zool 78: 948-966.

Amstrup, S. C., Marcot, B. G. & Douglas, D. C. 2007. Forecasting the Rangewide Status of Polar Bears at Selected Times in the 21st Century. - USGS Alaska Science Center, Anchorage, Administrative Report.

Andersen, J. 1984. Zoological observations made during "The Kayak-expedition from Station Nord to Scoresby Sund". – Unpublished field notes (cited in Dietz *et al*. 1985).

Andersen, L. W., Born, E. W., Gjertz, I., Wiig, Ø., Holm, L. E. & Bendixen, C. 1998. Population structure and gene flow of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in the eastern Atlantic Arctic based on mitochondrial DNA and microsatellite variation. – Molecular Ecology 7: 1323-1336.

Andersen, L. W., Born, E. W., Doidge, D. W., Gjertz, I., Wiig, Ø. & Waples, R. S. in prep. Genetic signals of historic and recent migration between sub-populations of Atlantic walrus (*Odobenus rosmarus rosmarus*) west and east of Greenland. - Endangered Species Research, submitted.

Anderson, J. W. & Lee, R. F. 2006. Use of biomarkers in oil spill risk assessment in the marine environment. – Human and Ecological Risk Assessment 12: 1192-1222.

Andriguetto-Filho, J. M., Ostrensky, A., Pie, M. R., Silva, U. A. & Boeger, W. A. 2005. Evaluating the impact of seismic prospecting on artisanal shrimp fisheries. – Continental Shelf Research 25: Issue 14: 1720-1727.

Anker-Nilssen, T. 1987. Metoder til konsekvensanalyser olje/sjøfugl. – Vildtrapport 44, Norsk Institutt for Naturforskning, Trondheim 114 pp.

Anker-Nilssen, T., Bakken, V., Strøm, H., Golovkin, A. N., Bianki, V. V. & Tatarinkova, I. P. 2000 (eds). The status of marine birds breeding in the Barents Sea Region. – Norsk Polarinstitutt, Rapportserie, nr. 113.

Anonymous 1998. Grønlandske fugle, havpattedyr og landpattedyr – en status over vigtigste ressourcer. – Teknisk rapport nr. 16. Grønlands naturinstitut. http://www.natur.gl/filer/Nr.16-1998-Gr%C3%B8nlandske_fugle_havpattedyr_og_landpattedyr.pdf

Anonymous 2003. Utredning av konsekvens av helårlig petroleumsvirksomhet i området Lofoten-Barentshavet. Sammendragsrapport. – Olje- og Energiministeriet, Oslo.

Anonymous 2006. Kvote for fangst af hvalros og isbjørn for kvoteårene 2007 – 2009. Tusagassiorfinnut nalunaarut/Pressemeddelelse 18. december 2006. –Namminersornerullutik Oqartussat Aalisarnermut, Piniarnermut Nunalerinermullu Naalakkersuisoq/Grønlands Hjemmestyre Landstyremedlemmet for Fiskeri, Fangst og Landbrug: 2 pp.

Anonymous 2008. Norwegian Spring Spawning Herring. http://www.fisheries.no/marine_stocks/fish_stocks/herring/marine_stocks_norwegian_spring_spawning_herring.htm [Site visited 1 Oct 2008]

APA 2003. Greenland offshore (West Disko) oil development feasibility assessment. Project no. 10166. – APA Petroleum Engeneering Inc.

Armstrong, D. A., Dinnel, P. A., Orensanz, J. M., Armstrong, J. L., McDonald, T. L., Cusimano, R. F., Nemeth, R. S., Landholt, M. L., Skalski, J. R., Lee, R. F. & Huggett, R. J. 1995. Status of selected bottomfish and crustaceans species in Prince William Sound following the Exxon Valdez oil spill. Pp. 485-547 in Wells, P.G, Buttler, J.N. & Hughes J.S. (eds): The Exxon Valdez oil spill: fate and effects in Alaskan waters. – American Society for Testing and Materials STP1219, Philadelphia.

Armsworthy, S. L., Cranford, P. J. & Lee, K, 2005. Offshore oil and gas environmental effects monitoring. Approaches and technologies. – Batelle Press, Columbus, Ohio.

Ashjian, C. J., Smith, S. L., Bignami, F., Hopkins, T.S., & Lane, P. V. Z. 1997. Distribution of zooplankton in the Northeast Water Polynya during summer 1992. – J. Mar. Syst. 10: 279–298.

Ashjian, C. J., Campbell, R. G., Harold E. Welch, H. E., Butler, M. & Van Keuren, D. 2003. Annual cycle in abundance, distribution, and size in relation to hydrography of important copepod species in the western Arctic Ocean. – Deep-Sea Research I 50 (2003) 1235–1261.

Atkinson, E. G. & Percy, J. A. 1992. Diet comparison among demersal marine fish from the Canadian Arctic. – Polar Biol. 11: 567-573.

Auel, H. & Werner, I., 2003. Feeding, respiration and life history of the hyperiid amphipod *Themisto libellula* in the Arctic marginal ice zone of the Greenland Sea. – Journal of Experimental Marine Biology and Ecology 296. 183– 197.

Auel, H. Harjed, M., da Rocha, R., Stuebing, D. & Hagen, W. 2002. Lipid biomarkers indicate different ecological niches and trophic relationships of the Arctic hyperiid amphipods *Themisto abyssorum* and *T. libellula*. – Polar Biology 25: 374-383.

Baird, R.W. 2000. The killer whale, foraging specializations and group hunting. Pp. 127-154 in Mann, J., Connor, R.C., Tyack, P.L. & Whitehead, H. (eds), Cetacean Societies, Field Studies of Dolphins and Whales. – University of Chicago Press.

Baird, R. W. & Dill, L. M. 1995. Occurrence and behaviour of transient killer whales: seasonal and pod-specific variability, foraging behaviour, and prey handling. – Can. J. Zool. 73: 1300-1311.

Barrett-Lennard, L. G. 2000. Population structure and mating patterns of killer whales, *Orcinus orca*, as revealed by DNA analysis. – PhD thesis, University of British Columbia, Vancouver.

Basu, N., Scheuhammer, A. M., Sonne, C., Letcher, R. J., Born, E. W. & Dietz, R. 2009. Is Dietary Mercury of Neurotoxicological Concern to Wild Polar Bears (*Ursus maritimus*)? – Environmental Toxicology and Chemistry 28: 133-140.

Bay, C. & Boertmann, D. 1989. Biologisk-arkæologisk kortlægning af Grønlands østkyst mellem 75°N og 79°30'N. Del 1: Flyrekognoscering mellem Mestersvig (72°12'N) og Nordmarken (78°N). – Greenland Home Rule, Dpt. Wildl. Mgmt., Technical report no. 4: 63 pp. (Danish, with English summary).

Bechmann, R.K., Westerlund, S., Baussant, T., Taban, C., Pampanin, D.M., Smit, M., & Lowe, D. 2006. Impacts of drilling mud discharges on water column organism and filter feeding bivalves. – IRIS report 2006/038, ISBN: 978-82-490-0526-0.

Bechshøft, T. Ø., Wiig, Ø., Sonne, C., Riget, F. F, Dietz, R., Letcher, R. J. & Muir, D. C. G. 2008a. Temporal and spatial variation in metric asymmetry in skulls of polar bears (*Ursus maritimus*) from East Greenland and Svalbard. - Ann. Zool. Fennici 45: 15-31.

Bechshøft, T. Ø., Riget, F. F., Sonne, C., Wiig, Ø., Dietz, R. & Letcher, R.J. 2008b. Skull foramina assymmetry in East Greenland and Svalbard polar bears (*Ursus maritimus*) in relation to stressful environments. – Ann. Zool. Fennici 45: 32-38.

Bechshøft, T. Ø., Sonne, C., Riget, F. F., Wiig, Ø. & Dietz, R. 2008c. Differences in growth, size and sexual dimorphism in skulls of East Greenland and Svalbard polar bears (*Ursus maritimus*). – Polar Biology 31:945–958.

Benjaminsen, T.& Christensen, I. 1979. The natural history of the bottlenose whale, *Hyperoodon ampullatus* (Foster). In: Winn, H.G., Ollaa, B.L. (Eds.), Behaviour of Marine Animals, Vol 3. – Plenum Press, New York, pp. 143-164.

Bennike, O., Mikkelsen, N., Forsberg, R. & Hedenäs, L. 2006. Tuppiap Qeqertaa (Tobias Island): a newly discovered island off northeast Greenland. – Polar Record 42: 309-314.

Bensch, S. & Hjort, C. 1990. Late autumn observations of birds within the Greenland Sea pack ice. – Dansk Orn. Foren. Tidsskr. 84: 74-76.

Berreville, O. F., Vézina, A. F., Thompson, K. R. & Klein, B. 2008. Exploratory data analysis of the interactions among physics, food web structure, and function in two Arctic polynyas. – Canadian Journal of Fisheries and Aquatic Sciences 65: 1136-1146.

Berzin A. A. 1971. (translated into English in 1972). The sperm whale. – Israel Program for Scientific Translations, Jerusalem. 394 pp.

Best P. B. 1979. Social organization in sperm whales, *Physeter macrocephalus*. Pp 227-289 in: Winn, H.E. & Olla, B.L. (eds), Behaviour of marine animals, vol 3. – Plenum Press, New York.

Bigg, M. A., Olesiuk, P. F., Ellis, G. M., Ford, J. K. B. and Balcomb III, K.C. 1990. Social organization and genealogy of resident killer whales (*Orcinus orca*) in the coastal waters of British Columbia and Washington State. – Report of the International Whaling Commission (Special Issue 12): 383-405.

BirdLife International 2000. Important Bird Areas in Europe: Priority sites for conservation 1, Northern Europe. – Cambridge, UK, Birdlife International (Bird Life International Conservation Series No. 8).

BirdLife International 2006. *Pagophila eburnea*. In: IUCN 2007. 2007 IUCN Red List of Threatened Species. <www.iucnredlist.org>. Downloaded on 12 March 2008.

Bjørke, H. 2001. Predators of the squid *Gonatus fabricii* (Lichtenstein) in the Norwegian Sea. – Fisheries Research 52:113-120.

Blackwell, S.B., Lawson, J.W. & Williams, M.T. 2004. Tolerance by ringed seals (*Phoca hispida*) to impact pipe-driving and construction sounds at an oil production island. – J. Acoust. Soc. Am. 115: 2346-2357.

Boehm, P.D., Neff, J. M., & Page, D. L. 2007. Assessment of polyaromatic hydrocarbon exposure in the waters of Prince William Sound after the Exxon Valdez oil spill: 1989-2005. – Mar Pollut Bull 54: 339-367.

Boertmann, D. 1994. An annotated checklist to the birds of Greenland. – Meddr. Grønland Biosc. 38: 64 pp.

Boertmann, D. 2005. Råstofaktiviteter og natur- og miljøhensyn i Grønland. – Faglig Rapport fra DMU, nr. 524.

Boertmann, D. 2008. Redlist 2007 of plants and animals in Greenland. In Danish: Rødliste 2007 over planter og dyr i Grønland. – Danmarks Miljøundersøgelser og Grønlands Hjemmestyre. Pp. 152.

Boertmann, D. & Glahder, C. 1999. Grønlandske gåsebestande - en oversigt. – Faglig rapport fra DMU, nr. 276: 59 sider..

Boertmann, D., Mosbech, A. & Merkel, F. R. 2006. The importance of Southwest Greenland for wintering seabirds. – British Birds 99: 282-298.

Boertmann, D., Olsen, K. & Nielsen, R.D. 2009a. Aerial surveys for seabirds and marine mammals in NE-Greenland spring and summer 2008. – NERI Technical Report, in press.

Boertmann, D., Tougaard, J., Mosbech, A. & Johansen, K. 2009b. Guidelines to environmental impact assessment of seismic activities in Greenland waters. – NERI Technical Report, in press.

Booth, B. C., Larouche, P., Bélanger, S., Klein, B., Amiel, D. & Mei, Z. P. 2002. Dyna-mics of *Chaetoceros socialis* blooms in the North Water. – Deep-Sea Research II 49: 5003-5025.

Booth, J. A. 1984. The Epontic Algal Community of the Ice Edge Zone and iys Significance to the Davis Strait Ecosystem. – Arctic 37: 234-243.

Born, E. W. 1983. Havpattedyr og havfugle i Scoresby Sund: Fangst og forekomst. – Danbiu Aps.

Born, E. W. 1987. Aspects of present-day maritime subsistence hunting in the Thule area, Northwest Greenland. Pp 109-132 in: L. Hacquebord & R. Vaughan (eds.). Between Greenland and America. Cross cultural contacts and the environment in the Baffin Bay area. – Works of the Arctic Centre No. 10. Arctic Centre. University of Groningen. CIP-Gegevens Koninklijke Bibliotheek, Den Haag, The Netherlands.

Born, E. W. 1990. Distribution and numbers of Atlantic walruses (*Odobenus rosmarus rosmarus*) in Greenland, Pp. 95-153 in Fay, F.H., Kelly, B.P. & Fay, B. (eds.). The ecology and management of walrus populations. – Report of an international workshop. Seattle, Washington, USA, October 1990. U.S. Marine Mammal Commission, Washington, USA: 186 pp.

Born, E. W. 1995. Status of the polar bear in Greenland, Pp. 81-103 in Wiig, Ø., Born, E.W. & Garner, G. (eds.). Polar Bears. Proceedings of the 11th Working Meeting of the IUCN/SSC Polar Bear Specialist Group. – Occasional Paper of IUCN/SSC No 10. Gland Switzerland and Cambridge, UK.

Born, E. W. 2001 Reproduction in female Atlantic walruses (*Odobenus rosmarus rosmarus*) from northwestern Greenland. – Journal of Zoology (London) 255: 165-174.

Born, E. W. 2003. Reproduction in male Atlantic walruses (*Odobenus rosmarus rosmarus*) from the North Water (N Baffin Bay). – Marine Mammal Science 19(4):819-831.

Born, E. W. 2005a. An assessment of the effects of hunting and climate on walruses in Greenland. – Greenland Institute of Natural Resources and Oslo University: 347 pp.

Born, E. W. 2005b. Estimates of the catch of walruses in Greenland (1946-2002). – Working paper submitted to NAMMCO Scientific Committee Working Group on Walrus, 11-14 January 2005, Copenhagen: 7 pp.

Born, E. W. 2007. The catch of polar bears in Greenland. – Report to the meeting of the Canadian Polar Bear Technical Committee, 6-9 February 2007, Edmonton, Canada: 5 pp.

Born, E. W. & Acquarone, M. 2000. Tilbage til Hvalrosodden (Returning to the Walrus Spit). – Tidsskriftet Grønland 2: 51-61.

Born E. W. & Acquarone, M. 2007. An estimation of walrus predation on bivalves in the Young Sound area (NE Greenland). In: S. Rysgaard & Glud, R.N. (eds.) Carbon cycling in Arctic marine ecosystems: Case study Young Sound. – Meddelelser om Grønland, Bioscience 58: 176-191.

Born, E. W. & Berg, T. B. 1999. A photographic survey of walruses (*Odobenus rosmarus*) at the Sandøen haul-out (Young Sund, eastern Greenland) in 1998. – Technical Report no. 26. Greenland Institute of Natural Resources, Nuuk: 1-19.

Born, E. W. & Gjertz, I. 1993. A link between walruses (*Odobenus rosmarus*) in northeast Greenland and Svalbard. – Polar Record 29: 329.

Born, E. W. & Knutsen L. Ø. 1990. Satellite tracking and behavioural observations of Atlantic walrus (*Odobenus rosmarus rosmarus*) in NE Greenland in 1989. – Grønlands Hjemmestyres Miljø- og Naturforvaltning. Teknisk Rapport Nr.20: 1-68.

Born, E. W. & Knutsen, L. Ø. 1992. Satellite-linked radio tracking of Atlantic walruses (*Odobenus rosmarus rosmarus*) in northeastern Greenland, 1989-1991. – Zeitschrift für Säugetierkunde 57: 275-287.

Born, E. W. & Knutsen, L. Ø. 1997. Haul-out activity of male Atlantic walruses (*Odobenus rosmarus rosmarus*) in northeastern Greenland. – Journal of Zoology (London) 243:381-396.

Born, E. W. & Rosing-Asvid, A. 1989. Isbjørnen (*Ursus maritimus*) i Grønland: En oversigt. – Grønlands Hjemmestyres Miljø- og Naturforvaltning, Teknisk Rapport Nr. 8: 126 pp.

Born, E. W. & Sonne, C. 2006. Research on polar bears in Greenland, 2001-2005, Pp. 135-143 in Aars, J., Lunn, N.J. & Derocher, A.E. (eds.). Polar Bears. Proceedings of the 14th Working Meeting of the IUCN/SCC Polar Bear Specialist Group, 20-24 June 2005, Seattle, Washington, USA. – IUCN Gland, Switzerland & Cambridge, UK.

Born, E. W. & Wiig, Ø. 1995. Polar bear and walrus studies in Central East Greenland, Pp. 103-107 in Hubberten, H.W. (ed.). The Expedition ARKTIS-X/2 of RV "Polarstern" in 1994. – Bericht Polarforsch 174.

Born, E. W., Heide-Jørgensen, M.P. & Davis, R.A. 1994. The Atlantic walrus (*Odobenus rosmarus rosmarus*) in West Greenland. – Meddelelser om Grønland, Bioscience. 40: 33 pp.

Born, E. W., I. Gjertz & Reeves , R.R. 1995. Population Assessment of Atlantic Walrus. – Norsk Polarinstitutts Meddelelser 138: 1-100.

Born, E. W., Dietz, R., Heide-Jørgensen, M.P. & Knutsen, L. Ø. 1997. Historical and present status of the Atlantic walrus (*Odobenus rosmarus rosmarus*) in eastern Greenland. - Meddelelser om Grønland, Bioscience 46:1-73.

Born, E. W., Andersen, L.W., Gjertz, I. & Wiig, Ø. 2001. A review of genetic relationships of Atlantic walruses (*Odobenus rosmarus rosmarus*) east and west of Greenland. – Polar Biology 24 (10): 713-718.

Born, E. W., Rysgaard, S., Ehlmé, G., Sejr, M., Acquarone, M. & Levermann, N. 2003. Underwater observations of foraging free-living walruses (*Odobenus rosmarus*) including estimates of their food consumption. – Polar Biology 26: 348-357.

Born, E. W., Andersen, L.W., Dietz, R., Heide-Jørgensen, M.P., Doidge, B.W., Teilmann, J. & Stewart, R.E.A. 2005. Walruses in West Greenland: Where do they belong? – Abstract and poster presentation at the Marine Mammal Conference in San Diego 11-16 December 2005.

Born, E. W., Kinglsey, M.C.S., Rigét, F.F., Dietz, R., Møller, P., Haug, T., Muir, D.C.G., Outrigde, P. & Øien, N. 2007. A multi-elemental approach to identification of subpopulations of North Atlantic minke whales (*Balaenoptera acutorostrata*). – Wildl. Biol. 13: 84-97.

Bossi, R., Riget, F. F. & Dietz, R. 2005. Temporal and Spatial Trends of Perfluorinated Compounds in Ringed Seal (*Phoca hispida*) from Greenland. – Environ. Sci. Technol, 39, 7416-7422.

Bourne, W. R. P. 1979. Birds and gas flares. – Marine Pollution Bulletin 10: 124-125.

Bowering, W. R. & Brodie, W. B. 1995. Greenland halibut (*Reinhardtius hippoglossoides*). A review of the dynamics of its distribution and fisheries off eastern Canada and Greenland. Pp. 113-160 in: Hopper A.G. (Ed.), Deep-water fisheries of the North Atlantic Oceanic slope. – NATO ASI Series.

Braithwaite, L. F., Aley, M. G. & Slater, D. L. 1983. The Effects of Oil on the Feeding Mechanism of the Bowhead Whale. AA851-CTO-55. – Prepared for the Department of the Interior, from Brigham Young University, Provo, UT.

Breuer, E. A. G. Stevenson, A. G., Howe, J. A. ,Carroll, J. C. & Shimmield, G. B. 2004. Drill cutting accumulations in the Northern and Central North Sea: a review of environmental interactions and chemical fate. – Marine Pollution Bulletin, 12–25.

Breuer, E., Shimmield, G. & Peppe, O. 2008. Assessment of metal concentrations found within a North Sea drill cutting pile. – Mar. Pollut. Bull. 56: 1310-1322.

Brewer, K., Gallagher, M., Regos, P., Isert, P. & Hall, J. 1993. Kuvlum #1 Exploration Prospect: Site Specific Monitoring Program. Final Report. – Prepared by Coastal and Offshore Pacific Corporation, Walnut Creek, CA, for ARCO Alaska, Inc., Anchorage, AK. 80 pp.

Brown, R. G. B. 1984. Seabirds in the Greenland, Barents and Norwegian Seas, February–April 1982. – Polar Research 2 (n.s.) 1-18.

Buckland, S.T., Anderson, D.R., Burnham, K.P., Laake, J.L. Borchers, D.L. & Thomas, L. 2001. Introduction to Distance Sampling: Estimating abundance of biological populations. – Oxford University Press.

Buckland, S. T., Bloch, D. & Cattanach, K.L. 1993. Distribution and abundance of long-finned pilot whales in the North Atlantic, estimated from NASS-87 and NASS89 data. – Rep. of the IWC Spec. Iss. 14: 33-49.

Burns, J. J. 1981. Bearded seal (*Erignathus barbatus*) Erxleben, 1777. Pp 145-170 in: Ridgway, S.H., & Harrison, R.J. eds. Handbook of marine mammals. Vol 2. Seals. – Academic Press, London.

Burns, J. J., Montague, J. J. & Cleveland, J. C. 1993. The Bowhead Whale. – The Society for Marine Mammalogy. Spec. Pub. No 2. Pp. 787.

Byrkjedal, I. & Madsen J. 2008. Autumn bird observations in the Northheast Greenland sea ice. – Dansk Ornitologisk Foreningsn Tidskrift. 102: 325-330.

Camus, L. & Dahle S. 2007. Biological Impact of Oil on the Sea Ice of the Arctic. – Exploration & Production, Oil & Gas Review 2007, 11: 28-30.

Camus, L. & Olsen, G. H. 2008. Embryo aberrations in sea ice amphipod *Gammarus wilkitzkii* exposed to water soluble fraction of oil. – Marine Environmental Research 66: 221-222.

Camus, L., Jones, M. B., Børseth, J. F., Regoil, F. & Depledge, M. H. 2002a. Heart rate, respiration and sum oxyradical scavenging capacity of the Arctic spider crab *Hyas araneus*, following exposure to polycyclic aromatic compounds via sediment injection. – Aquat. Toxicol. 62: 1–13.

Camus, L., Jones, M. B., Børseth, J. F., Grosvik, B. E., Regoil, F. & Depledge, M. H. 2002b. Total oxyradical scavenging capacity and cell membrane stability of haemocytes of the Arctic scallop, Chlamys islandicus, following benzo(a)pyrene exposure. – Mar. Environ. Res. 54: 425–430.

Camus, L., Birkely, S. R., Jones, M.B., Børseth, J. F., Grosvik, B. F., Gulliksen, B., Lonne, O.J., Regoli, F. & Depledge, M.H. 2003. Biomarker responses and PAH uptake in *Mya truncata* following exposure to oil-contaminated sediment in an Arctic fjord (Svalbard). – Sci. Total Environ. 308: 221–234.

Carmack, E. & Wassmann, P. 2006. Food webs and physical-biological coupling on pan-Arctic shelves: unifying concepts and comprehensive perspectives. – Progress in Oceanography 71: 446-477.

Carroll, G. 2007: Bowhead Whale. Pp.1. Web page visited 09042008: http://www.adfg.state.ak.us/pubs/notebook/marine/bowhead.php

Christensen, E. 1981. Havbundens planter. Pp. 253-261 in Nørrevang, A. & Lundø, J. (Red.) Danmarks Natur 11-Grønland. – Politikens Forlag.

Christensen, F. T., Steensboe, J. S. & Mosbech, A. 1993. Oil spill simulations as a contingency planning tool offshore West Greenland. – Proceedings of POAC 93, Vol. 2, pp 693-707.

Christiansen, J. S. 2003. Tunu-I expedition. The Fish fauna of the NE Greenland Fjord system. – Technical report, University of Tromsø, 33 pp.

Christiansen, J. S. 2005. Tunu-II expedition. Marine fishes of NE Greenland, diversity and adaptation. – Technical report, University of Tromsø, 22 pp.

Cohen, D. M., Inada, T., Iwamoto, T. & Labignan, I. 1990. Gadiform fishes of the world (order: Gadiformes). An annotated and illustrated catalogue of cods, hakes, grenadiers and other gadiform fishes known to date. – FAO Species Catalogue 10: 1-442.

Compton, R., Goodwin, L., Handy, R. & Abbott, V. 2008. A critical examination of worldwide guidelines for minimising the disturbance to marine mammals during seismic surveys. – Marine Policy 32: 255-262.

Craig, P. C. & McCart, P. J. 1976. Fish use of near-shore coastal waters in the western Arctic: Emphasis on anadromous species, p. 361-388. In Assessment of the Arctic marine environment: Selected Topics. – University of Alaska, Fairbanks.

Cranford, P. J., Gordon, D. C. jr., Hannah, C. G., Loder, J. W., Milligan, T. G., Muschenheim, D. K. & Shen, Y. 2003. Modelling potential effects of petroleum exploration drilling on northeastern George Bank scallop stocks. – Ecological Modelling 166: 19-39.

Caulfield, R.A. 1997. Greenlanders, whales and whaling: sustainability and self-determination in the Arctic. – University Press of New England, Darthmouth, NH.

Cronin, M. A., Hills, S., Born, E. W. & Patton, J. C. 1994. Mitochondrial DNA variation in Atlantic and Pacific walruses. – Canadian Journal of Zoology 72: 1035-1043.

D'Vincent, C. G., Nilson, R. M. & Hanna, R. E. 1985. Vocalization and coordinated feeding behaviour of the humpback whale in South-eastern Alaska. – Sci. Rep. Cet. Res. Tokyo 36, 41–47.

Dalebout, M. L., Ruzzante, D. E, Whitehead, H. & Øien, N. I. 2006. Nuclear and mitochondrial markers reveal distinctiveness of a small population of bottlenose whales (*Hyperoodon ampullatus*) in the western North Atlantic. – Molecular Ecology 15, 3115–3129.

Dalen, J. 1993. Effekter av luftkanonskytning på egg, larver og yngel. – Rapport nr. 10-1993. Senter for marint miljø, Havforskningsinstituttet, Bergen.

Dalen, J., Hovem, J.M., Karlsen, H.E., Kvadsheim, P.H., Løkkeborg, S., Mjelde, R., Pedersen, A. & Skiftesvik, A.B. 2008. Kunnskabsstatus of forskningsbehov med hensyn til skremmeeffekter og skadevirkninger av seismiske lydbølger på fisk og sjøpattedyr. – Oljedirektoratet, Fisjkeridirektoratet of Statens Forureningstilsyn, Bergen.

Davies, J. M., Bedborough D. R., Blackman, R. A. A., Addy, J. M., Appelbee, J. F., Grogran, W. C., Parker J. G. & Whitehead, A. 1984. Environmental Effects of the Use of Oil-based Drilling Muds in the North Sea. – Marine Pollution Bulletin, 15:363-370.

Davis, R.A., Richardson, J., Thiele, L., Dietz, R & Johansen, P. 1990. State of the Arctic Environment. Report of Underwater noise, November 9, 1990. – Finnish Initiative on Protection of the Artic Environment.

Degerbøl, M. & Møhl-Hansen, U. 1935. The Scoresby Sound Committee's East Greenland Expedition in 1932 to King Christian IX's Land. Birds. – Meddr Grønland 104, 18: 1-30.

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

Derocher, A.E., Lunn, N. J. & Sterling, I. 2004. Polar Bears in a Warming Climate. – Integr. Comp. Biol. 44:163–176.

Desportes, G., Pike D., Acquarone, M., Golyak, I., Gosselin, J. F., Gunnlaugsson, T., Halldórsson, S. D., Heide-Jørgensen, M. P., Lawson, J., Lockyer, C., Mikkelsen, B., Ólafsdóttir, D., Simon, M., Vikingsson, G., Witting, L., Zabavnikov, V. & Øien N. 2008. From the Barents Sea to the St. Lawrence: a trans North Atlantic Sightings Survey T-NASS 2007. – Poster presented at the 22th annual meeting of the European Cetacean Society, Netherlands.

DFO 2004. Review of scientific information on impacts of seismic sound on fish, invertebrates, marine turtles and marine mammals. – DFO Can. Sci. Advis. Sec. Habitat Status Report 2004/002. http://www.dfo-mpo.gc.ca/csas/Csas/status/2004/HSR2004_002_E.pdf

Dietz, R. 2008. Contaminants in Marine Mammals in Greenland. – National Environmental Research Institute, University of Aarhus.

Dietz, R. & Heide-Jørgensen, M. P. 1995: Movements and Swimming Speed of Narwhals (*Monodon monoceros*) Instrumented with Satellite Transmitters in Melville Bay, Northwest Greenland. – Canadian Journal of Zoology 73: 2106-2119.

Dietz, R., Heide-Jørgensen, M. P. & Born, E. W. 1985. Havpattedyr i Østgrønland: En litteraturundersøgelse. – Rapport til Råstofforvaltningen for Grønland og Grønlands Fiskeri- og Miljøundersøgelser, København, fra Danbiu ApS. (Biologiske Konsulenter), Hellerup: 277 pp.

Dietz, R., M. P. Heide-Jørgensen, E. W. Born & C.M. Glahder 1994. Occurrence of narwhals (*Monodon monoceros*) and white whales (*Delphinapterus leucas*) in East Greenland. – Meddelelser om Grønland, Bioscience 39: 69-86.

Dietz, R., Riget, F., Johansen P. 1996. Lead, cadmium, mercury and selenium in Greenland marine animals. – The Science of the Total Environment 186: 67-93.

Dietz, R., Riget, F. & Born, E. W. 2000. Geographical differences of zinc, cadmium, mercury and selenium in polar bears (*Ursus maritimus*) from Greenland. – The Science of the Total Environment 245: 25-48.

Dietz, R, Teilmann, J., Jørgensen, M. P. H. & Jensen, M. W. 2002. Satellite tracking of Humpback whales in West Greenland. – National Environmental Research Institute, Denmark. NERI Technical report No.411.38 pp. http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR411.pdf

Dietz, R., Riget, F.F., Boertmann, D., Sonne, C., Olsen, M.T., Fjeldsaa, J., Falk, K., Kirkegaard, M., Egevang, C., Asmund, G., Wille, F. & Møller, S. 2006. Time Trends of Mercury in Feathers of West Greenland Birds of Prey During 1851–2003. – Environmental Science and Technology 40: 5911-5916.

Dietz, R., Bossi, R., Rigét, F. F., Sonne, C., & Born, E. W. 2008. Increasing perfluoroalkyl contaminants in East Greenland polar bears (*Ursus maritimus*): A new toxic threat to the Arctic bears. – Environ. Sci. Technol.42: 2701-2707.

Digby, P. S. B. 1953. Plankton production in Scoresby Sound, East Greenland. – Journal of Animal Ecology 22: 289-322.

Digby, P. S .B. 1954. The biology of the marine planktonic copepods of Scoresby Sound, East Greenland. – J Anim Ecol 23: 298-338

Divine, D. V. & Dick, C. 2006. Historical variability of sea ice edge positions in the Nordic Seas. - J Geophys Res 111: 14 pp. C01001, doi:10.1029/2004JC002851, 2006.

Donovan, G. P. 1991. A review of IWC stock boundaries. Pp 39-68 in: Hoelzel, A.R. (ed.) Genetic ecology of whales and dolphins. – Rep. I.W.C. (Special Issue 13).

Dorrien v., C. 1993. Ecology and respiration of selected Arctic benthic fish species. – Ber. Polarforsch. 125: 1-99.

Dorrien von, C., Schmid, M., Piepenburg, D. & Rust, J. 1991. Benthos and Fish. In: The expedition ARKTIS VII of RV „Polarstern" in 1990 (Leg ARK VII/2). Ed. Krause, G. – Ber. Polarforsch. 93: 27-32.

Dowsley, M. & Taylor, M. K. 2006. Community consultations with Qikiqtarjuaq, Clyde River and Pond Inlet on management concerns for the Baffin Bay (BB) polar bear population: A summary of Inuit knowledge and community consultations. – Nunavut Wildlife Research Group Final Report No. 2: 83 pp.

Drinkwater, K. F. 2006. The regime shift of the 1920s and 1930s in the North Atlantic. – Progress in Oceanography 68: 134-151.

Dunbar, R. J. 1985. The Arctic marine ecosystem. Pp. 1-35 in: Engelhard, T. (ed.): Petroleum effects in the arctic environment. – Elsevier Applied Science Publishers, London, New York.

Durner, G.M. & Amstrup, S.C., 1995. Movements of a female polar bear from northern Alaska to Greenland. – Arctic 48: 338-341.

Durner, G. M & Amstrup, S. C. 2000. Estimating the impacts of oil spills on Polar Bears. – Arctic Research of the United States 14: 33-37.

Durner, G. M., Douglas, D. C., Nielson, R. M., Amstrup, S. C. & McDonald, T. L. 2007. Predicting the future distribution of polar bear habitat in the Polar Basin from Resource Selection Functions applied to 21st Century General Circulation model projections of sea ice. – U.S. Department of the Interior and U.S. Geological Survey Administrative Report, 55 pp.

Durner, G. M., Douglas, D. C., Nielson, R. M., Amstrup, S. C., McDonald, T. L., Stirling, I., Mauritzen, M., Born, E. W., Wiig, Ø., DeWeaver, E., Serreze, M. C., Belikov, S. E., Holland, M. M., Maslanik, J., Aars, J., Bailey, D. A. & Derocher, A. E. 2009. Predicting the 21st Century Distribution of Polar Bear Habitat from General Circulation Model projections of sea ice. – Ecol Monogr 79: 25-58.

Egevang, C. & Boertmann, D. 2001. The Greenland Ramsar sites. A status report. – National Environmental Research Institute, Denmark, NERI Technical Report no. 346: 1-96.

Egevang, C. & Boertmann, D. 2008. Ross's Gulls (*Rhodostethia rosea*) Breeding in Greenland: A review, with Special Emphasis on Records from 1979 to 2007. – Arctic 61: 322-328.

Egevang, C. & Stenhouse, I, J. 2007. Field report from Sand Island, Northeast Greenland – 2007. – Greenland Institute of Natural Resources.

Elander, M. & Blomqvist, S. 1986. The avifauna of central Northeast Greenland, 73°15'N.-74°05'N., based on a visit to Myggbukta, May-July 1979. – Meddr Grønland, Bioscience 19: 44 pp.

Engås, A., Løkkeborg, S., Ona, E. & Soldal, A. V. 1995. Effects of seismic shooting on local abundance and catch rates of cod (*Gadus morhua*) and haddock (*Melanogramma aeglefinus*). – Can. J. Fish. Sci. 53: 2238-2249.

Erhversvdirektoratet 2007. National Turismestrategi 2008-2010. – Grønlands Hjemmestyre. http://www.visitgreenland.dk/media(1925,1030)/National_Turismestrategi_2008-2010.pdf

Falk, K. & Kampp, K. 1997. A manual for monitoring Thick-billed Murre populations in Greenland. – Pinngortitaleriffik, Greenland Institute of Natural Resources, Technical report 7.

Falk, K. & Møller, S. 1995. Colonies of Northern Fulmars and Black-legged Kitiwakes Associated with the Northeast Water Polynya, Northeast Greenland. – Arctic 48: 186-195.

Falk, K. & Møller, S. 1997. Breeding ecology of the Fulmar *Fulmarus glacialis* and the Kittiwake *Rissa tridactyla* in high-arctic northeastern Greenland 1993. – Ibis 139: 270-281.

Falk, K., Hjort, C., Andreasen, C., Christensen, K. D., Elander, M., Ericson, M., Kampp, K., Kristensen, R. M., Møbjerg, N., Møller, S., & Weslawski, J. M. 1997a: Seabirds utilizing the Northeast Water polynya. – Journal of Marine Systems 10: 47-65.

Falk, K., Kampp, K. & Frich, A. S. 1997b. Polarlomvien i Østgrønland, 1995. – Teknisk rapport nr. 8. Pinngortitaleriffik, Grønlands Naturinstitut.

Falk, K., Pedersen, C. E. & Kampp, K. 2000. Measurements of diving depth in dovekies (*Alle alle*). – Auk 117: 522-525.

Fay, F. H. 1982. Ecology and Biology of the Pacific walrus, *Odobenus rosmarus divergens* Illiger. North American Fauna No. 74. – U.S. Department of the Interior Fish and Wildlife Service: 279 pp.

Fay, F. H. 1985. *Odobenus rosmarus*. - Mammalian Species No. 238. American Society of Mammalogists. Lawrence, Kansas: 1-7.

Fay, F. H., Ray, G. C. & Kibal´chich, A. A. 1984. Time and location of mating and associated behaviour of the Pacific walrus *Odobenus rosmarus divergens* Illiger, Pp. 89-99 in Fay, F.H. & Fedoseev, G.A. (eds.). Soviet-American Cooperative Research on Marine Mammals. Vol 1- Pinnipeds. – NOAA Technical Reports NMFS 12. Washington D.C: 104 pp.

Ferguson, S. H., Taylor, M. K., Born, E. W., Rosing-Asvid, A. & Messier, F. 1999. Determinants of home range size in polar bears. – Ecol Lett 2: 311-318.

Ferguson, S. H., Taylor, M. K & Messier, F. 2000. Influence of sea ice dynamics on habitat selection by polar bears. – Ecology 8: 761-722.

Foote, A. D., Osborne, R. W. & Hoelzel, A. R. 2004. Whale-call response to masking boat noise. – Nature 428: 910.

Forchhammer, M. 1990. Ornithological observations in Germania Land and Dove Bugt, Northeast Greenland, 1986-1988. – Greenland Home Rule, Dpt. Wildl. Mgmt., Technical report no. 12: 29 pp.

Forchhammer, M. & Maagaard, L. 1990. Distribution of breeding Sabine's Gulls in Greenland. – Dansk. Orn. Foren. Tidsskr. 84: 162-164. (Danish, with English summary)

Ford, J. K. B. & Ellis, G. M. 2003. Reassessing the social organization of resident killer whales in British Columbia. – Fourth international orca symposium and workshops, September 23-28 2002, CEBC-CNRS, France 72- 74.

Ford, J. K. B. and Ellis, G. M. 2006. Selective foraging by fish-eating killer whales *Orcinus orca* in British Columbia. – Mar Ecol Prog Ser 316: 185–199, 2006.

Fortier, L., Sirois, P., Michaud, J. & Barber, D. 2006. Survival of Arctic cod larvae (*Boreogadus saida*) in relation to sea ice and temperature in the Northeast Water Polynya (Greenland Sea). – Can J Fish Aquat Sci 63:1608–1616.

Fraser, G. S., Russell, J. & Zharen, W.M.V. 2006. produced water from offshore oil and gas installations on the grand banks, Newfoundland and Labrador: are the potential effects to seabirds sufficiently known. – Marine Ornithology 34: 147-156.

Freitas, C., Kovacs, K. M., Ims, R. A., Fedak, M. A. & Lydersen C. in prep. Deep into the ice: over-wintering and habitat selection in Atlantic walruses. – Submitted to Proc. R. Soc.

Furness, R. A. 1975. Inventory and cataloquing of Arctic area waters. – Alaska Dep. Fish Game. Fed. Aid Fish. Rest. Annu Rep. Prog., Project F-9-7, 16(G1-1):47 p.

Gabrielsen, G. W. 2007. Levels and effects of persistent organic pollutants in arctic animals. In: Arctic-alpine ecosystems and people in a changing environment, eds. Orback, J.B., Kallenborn, R., Tombre, J., Hegseth E.N., Falk-Petersen, S., Hoel, A.H. – Springer Berlin.

Geraci, J. R. & St. Aubin, D .J. (eds.). 1990. Sea Mammals and Oil. Confronting the risk. – Academic Press, San Diego.

GESAMP 1993. Impact of oil and related chemicals on the marine environment. – GESAMP reports and Studies No. 50.

Gilchrist, G., Strøm, H., Gavrilo, M.V, & Mosbech A. 2008. International Ivory Gull Conservation Strategy and Action Plan. – CAFF Technical Report No. 18.

Gilg, O. (ed.). 2005. Ecopolaris – Tara 5 expedition to NE Greenland 2004. – Groupe de Recherches en Ecologie Arctique.

Gilg, O. & Born E. W. 2005. Recent sightings of the bowhead whale (*Balaena mysticetus*) in Northeast Greenland and the Greenland Sea. – Polar Biology 10: 796-801.

Gilg. O., Sabard, B., Sittler, B. Mariaux, F., Leguesdron, P. & Gilg, V. 2003. Ecopolaris 2003. Field report. – Groupe de Recherches en Ecologie Arctique.

Gjertz, I., Kovacs, K. M., Lydersen, C. & Wiig, Ø. 2000. Movements and diving of bearded seal (*Erignathus barbatus*) mothers and pups during lactation and post-weaning. – Polar Biol. 23: 559-566.

Glahder, C. 1995. Hunting in Kangerlussuaq, East Greenland, 1951-1991. An assessment of local knowledge. – Meddelelser om Grønland, Man & Society 19: 86 pp.

Glahder, C. M., Asmund, G., Mayer, P., Lassen, P., Strand, J. & Riget, F., 2003: Marin recipientundersøgelse ved Thule Air Base 2002. Danmarks Miljøundersøgelser. 126 s. -Faglig rapport fra DMU nr. 449.

Godø, O. R. & Haug, T. 1989. A review of the natural history, fisheries and management of Greenland halibut (*Reinhardtius hippoglossoides*) in the eastern Norwegian and Barents Sea. – Journal du Conseil Ciem.(ICES Journal of Marine Science) 46 1: 62–75.

Gordon, J., Gillespie, D., Potter, J., Frantzis, A., Simmonds, M. P., Swift, R. & Thompson, D. 2004. A Review of the Effects of Seismic Surveys on Marine Mammals. – Marine Techn. Soc. Journal. Vol. 37, No 4: 16-34.

Gradinger, R. R. & Baumann, M. E. M. 1991. Distribution of phytoplankton communities in relation to the large-scale hydrographical regime in the Fram Strait. – Marine Biology 111: 311-321.

Gradinger, R., Friedich, C. & Spindler, M. 1999. Abundance, biomass and composition of the sea ice biota of the Greenland Sea pack ice. – Deep Sea Research II 46: 1457-1472.

Gray, J. S., Clarke, K. R., Warwick, R. M. & Hobbs, G. 1990. Detection of initial effects of pollution on marine benthos: an example from the Ekofisk and Eldfisk oilfields. – North Sea 66: 285-299

Greene, C. R. Jr., McLennan, M. W., Norman, R. G., McDonald,. T. L., Jakubczak, R. S, & Richardson, W. J. 2004. Directional frequency and recording (DIFAR) sensors in seafloor recorders to locate calling bowhead whales during their fall migration. – J. Acoust. Soc. Am. 1116: 799-813.

Greenland Home Rule. 2008. Quotas for Beluga and Narwhal 2007-2008. In Danish: Hvid- og narhvalskvoter for 2007-2008. Home page visited 3.5.2008. http://dk.nanoq.gl/Emner/Landsstyre/Departementer/Departement_for_fiskeri/Nyhedsforside/Nyhedsarkiv/2007/09/2007_juli_hvid_og_narhvalkvoter_2007-2008.aspx

Greenland Home Rule. 2006. Nye kvoter for hvalros og isbjørne. – http://dk.nanoq.gl/Groenlands_Landsstyre/Direktoratet_for_Fiskeri_og_Fangst/Nyheder/2006_dec_kvoter_hvalros_og_isbjoerne.aspx

Grønlands Fiskeri- og Miljøundersøgelser 1986. Ferskvandsbiologisk rekognoscering, Jameson Land 1985. – Report from Greenland Fishery and Environmental Investigations, 40 pp.

Guinet, C., Domenici P., de Stephanis, R., Barrett-Lennard, L., Ford, J. K. B. & Verborgh, P. 2007. Killer whale predation on bluefin tuna: Exploring the hypothesis of the endurance-exhaustion technique. – Mar Ecol Prog Ser 347: 111-119.

Gunnlaugsson, Þ. & Sigurjónsson, J. 1990. "NASS-87: Estimation of whale abundance based on observations made onboard Icelandic and Faroese survey vessels". – Rep.int.Whal.Commn 40: 571-580.

Gunnlaugsson, T., Víkingsson, G. A., Pike, D. G., Desportes, G., Mikkelsen, B. & Bloch, D. 2002. Sperm whale abundance in the North Atlantic, estimated from Icelandic and Faeroese NASS-2001 shipboard surveys. – NAMMCO SC/10/AE/13

Gutt, J. 1995. The occurrence of sub-ice algal aggregations off Northeast Greenland. – Polar Biology 15: 247-252.

Hall, J. D., Gallagher, M., Brewer, K., Regos, P. & Isert, P. 1994. 1993 Kuvlum Exploration Area Site Specific Monitoring Program. – Prepared for ARCO Alaska, Inc., Anchorage, AK, by Coastal and Offshore Pacific Corporation, Walnut Creek, CA.

Hammill, M. O., Lydersen, C., Ryg, M. & Smith, T. G. 1991. Lactation in the ringed seal (*Phoca hispida*). – Can J. Fish. Aquat. Sci. 48: 2471- 2476.

Hansen, J., Tøttrup, A. P. & Levermann, N. 2007. 3.3. Birds. Pp 44-58 in Klitgaard, A.B., Rasch, M., & Caning, K. (eds) ZERO, 12th annual report. – Danish Polar Centre.

Harrison, W. G., Platt, T. & Irwin, B. 1982. Primary production and nutrient assimilation by natural phytoplankton populations of the eastern Canadian Arctic. – Canadian Journal of Fisheries and Aquatic Sciences 39: 335-345.

Hassel, A., Knutsen, T., Dalen, J., Skaar, K., Løkkeborg, S., Misund, O. A., Østensen, Ø., Fonn, M. & Haugland, E. K. 2004. Influence of seismic shooting on the lesser sandeel (*Ammodytes marinus*). – ICES Journal of Marine Science, 61: 1165-1173.

Haug, T., Nilssen, K. T. and Lindblom, L. 2004. Feeding habits of harp and hooded seals in drift ice waters along the east coast of Greenland in summer and winter. – Polar Research 23: 35-42.

Head, E. J. H., Harris, R. L., Abou Debs, C. 1985. Effect of daylength and food concentration on in situ diurnal feeding rhythms in Arctic copepods. – Marine Ecology Progress Series 24: 281-288.

Heath, M. F. & M. I. Evans (eds). 2000. Important Bird Areas in Europe: Priority sites for conservation 1, Northern Europe. – Cambridge, UK, Birdlife International (Bird Life International Conservation Series No. 8).

Heide-Jørgensen, M. P. 1988. Occurrence and hunting of killer whales in Greenland. – Rit Fiskideildar 11:115-135.

Heide-Jørgensen, M. P. 1994. Distribution, exploitation and population status of white whales (*Delphinapterus leucas*) and Narwhals (*Monodon monoceros*) in West Greenland. –Meddelelser om Grønland. Bioscience 39. Pp. 135-151.

Heide-Jørgensen, M. P. 2004. Aerial digital photographic surveys of narwhals (*Monodon monoceros*) in Northwest Greenland. – Marine Mammal Science, 20:246-261.

Heide-Jørgensen, M. P. 2005. Web page visited 09042008: Bowhead Whales focus on plankton production. In Danish: Grønlandshvaler sætter produktionen af plankton under lup. Pp. 10. Web page: http://www.natur.gl/Default.asp?lang=dk&num=548.

Heide-Jørgensen, M. P. & Acquarone, M. 2002. Size and trends of the bowhead whale, white whale and narwhal stocks wintering off West Greenland. Pp. 191-210 in: Heide-Jørgensen, M.P. & Wiig, Ø. (Eds.): White whales in the North Atlantic and the Russian Arctic. – NAMMCO Scientific Publications 4.

Heide-Jørgensen, M. P. & Bunch, C. 1991. Occurrence and hunting of pilot whales in Greenland. – Working paper, ICES Study group 1-14.

Heide-Jørgensen, M. P. & Laidre K. 2006. Greenland's winter whales: The beluga, the narwhal and the bowhead whale. – Illiniusiorfik Undervisningsmiddelforlag.

Heide-Jørgensen, M. P. & Laidre, K. 2007. Autumn-space use patterns of humpback whales in West Greenland. – Journal of Cetacean Research and Management 9:121-126.

Heide-Jørgensen, M. P., Simon, M. J., Laidre, K. L. 2007. Estimates of large whale abundance in Greenland waters from a ship-based survey in 2005. – J. Cetacean Res. Manage. 9(2): 95–104.

Henrichsen, P. 1988. Preliminary results of studies of non-metrical cranial traits in polar bears. – Report to the Tenth Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 24-30 November 1988, Sochi, USSR: 2 pp. + maps.

Henrichsen, P. & Sjøvold, T. 1986. Appendix II. Preliminary report on population differentiation of polar bears based on non-metrical traits. – Proceedings of the Ninth Working Meeting of the IUCN/SSC Polar Bear Specialist Group, 9-11 August 1985, Edmonton, Canada. IUCN, Gland: 152 pp.

Herman, D. P., Burrows, D. G., Wade, P. R., Durban, J. W., Matkin, C. O., Leduc, R. G., Barrett-Lennard, L. G. & Krahn, M. M. 2005. Feeding ecology of eastern North Pacific killer whales *Orcinus orca* from fatty acid, stable isotope, and organochlorine analyses of blubber biopsies. – Mar Ecol Prog Ser. 302:275–291.

Highsmith, R. & Coyle, K. 1990. High productivity of northern Bering Sea benthic amphipods. – Nature 344: 862-864.

Hirche, H. J. & Deming, J. W. 1997. Preface. – Journal of Marine Systems 10: ix-x.

Hirche, H. J. & Niehoff, B. 1996. Reproduction of the Arctic copepod *Calanus hyperboreus* in the Greenland Sea-field and laboratory observations. – Polar Biol 16: 209- 219.

Hirche, H. J., Baumann, M. E. M., Kattner, G. & Gradinger, R. 1991. Plankton distribution and the impact of copepod grazing on primary production in Fram Strait, Greenland Sea. – Journal of Marine Systems 2: 477-494.

Hirche, H.J., Hagen, W., Mumm, N. & Richter, C. 1994. The Northeast Water Polyna, Greenland Sea. III. Meso- and macrozooplankton distribution and production of dominant herbivorous copepods during spring. – Polar Biol 14:491–503.

Hirst, A. G. & Rodhouse, P. G. 2000. Impacts of geophysical seismic surveying on fishing success. – Reviews in Fish Biology and Fisheries 10: 113-118.

Hjort, C. 1976a. Notes on the bird fauna of Hudson Land and Hold With Hope, Northeast Greenland, 1973. – Dansk Orn. Foren. Tidsskr. 70: 35-44.

Hjort, C. 1976b. An observation of Ivory Gull Pagophila eburnea migration along the East Greenland current. – Dansk Orn. Foren. Tidsskr. 70: 72-73.

Hjort, C., Håkansson, E. & Stemmerik, L. 1983. Bird observations around the Nordøstvandet polynya, Northeast Greenland, 1980. – Dansk Orn. Foren. Tidsskr. 77: 107-114.

Hjorth, M. & Dahllöf, I. 2008. A harpacticoid copepod *Microsetella* spp. from sub-Arctic coastal waters and its sensitivity towards the polyaromatic hydrocarbon pyrene. – Polar Biology 31: 1437-1443.

Hobson, K. A., Ambrose, W. G. & Renaud, P. E. 1995. Sources of primary production, benthic-pelagic coupling, and trophic relationships within the Northeast Water Polynya: insights from δ13C and δ15N analysis. – Marine Ecology Progress Series 128: 1-10.

Hobson, K. A., Fisk, A., Karnovsky, N., Holst, M., Gagnon, J.-M. & Fortier, M. 2002. A stable isotope (δ13C δ15N) model for the North Water food web: implications for evaluating trophodynamics and the flow of energy and contaminants. – Deep-Sea Res. 49: 5131-5150.

Hoelzel, A. R. Hey, J., Dahlheim, M. E., Nicholson, C., Burkanov, V. & Black, N. 2007. Evolution of Population Structure in a Highly Social Top Predator, the Killer Whale. – Mol. Biol. Evol. 24(6):1407–1415.

Hooker, S. K. & Baird, R. W. 1999. Deep-diving behaviour of the northern bottlenose whale, *Hyperoodon ampullatus* (Cetacea: Ziphiidae). – Proc. R. Soc. Lond. Ser. B. Biol. Sci. 266:671–676.

Hooker, S. K., Iverson, S. J., Ostrom, P. & Smith, S. C. 2001. Diet of northern bottlenose whales inferred from fatty-acid and stable-isotope analyses of biopsy samples. – Can. J. Zool. 79: 1442–1454.

Hop, H., Poltermann, M., Lønne, O. J, Falk-Petersen, S., Korsnes, R. & Budgell, W.P. 2000. Ice amphipod distribution relative to ice density and under-ice topography in the northern Barents Sea. – Polar Biol 23:357–367.

Hopcroft, R. R., Clarke, Nelson, R. J. & Raskoff, K. A. 2005. Zooplankton communities of the Arctic's Canada Basin: the contribution by smaller taxa. – Polar Biology 28: 198–206.

Hvidegaard, S.M., Forsberg, R., Hanson, S., Skourup, H & Pedersen, L.T. 2008. Sea ice conditions off NW and NE Greenland from satellite measurements, airborne and in-situ data. – National Space Institute (DTU-Space) and Danish Meteorological Institute, Center for Ocenas and Ice, 61 pp. ftp://ftp.dmi.dk/pub/Users/Leif.Toudal/history/ice_report_oct2008a.pdf

Hylland, K., Lang, T. & Vethaak, A. D. (eds.). 2006. Biological effects of contaminants in marine pelagic ecosystems. – Society of Environmental Toxicology and Chemistry (SETAC): Pensacola, FL (USA). ISBN 1-880611-84-8. xxix, 474 pp.

Hylland K, Tollefsen K. E., Ruus, A., Jonsson, G., Sundt, R. C., Sanni, S., Røe Utvik, T. I., Johnsen, S., Nilssen, I., Pinturier, L., Balk, L., Barsiene, J., Marigòmez, I., Feist, S.W. & Børseth, J.F. 2008. Water column monitoring near oil installations in the North Sea 2001-2004. – Mar Poll Bull. 56: 414-29

ICES 2005. Report of the ICES/NAFO Working Group on Harp and Hooded Seals (WGHARP), 30 August - 3 September 2005, St. Johns, Newfoundland, Canada. – ICES CM 2006/ACFM: 06. 53 pp.

ICES 2006. Report of the Working Group on ICES/NAFO Working Group on Harp and Hooded Seals (WGHARP), 12-16 June 2006, ICES Headquarters. – ICES CM 2006/ACFM: 32. 28 pp. Available online (11th February 2008): http://www.sealsandsealing.net/Resources/ICESharp06.pdf

ICES 2006. International Council for the Exploration of the Sea c2007-2008. Stock status report - Herring - Iceland, 2006 - FIRMS. Text compiled by B. Chemnitz. – In Fishery Resources Monitoring System [online]. Rome. Updated 16 Aug 2007. [Cited 1 Oct 2008]. http://firms.fao.org/firms/resource/10352

ICES 2007. Report of the North-Western Working Group, 24 April–3 May 2007. ICES CM 2007/ACFM:17.

ICES 2008. Report of the North-Western Working Group, 21-29 April 2008. ICES CM 2008/ACOM:03.

Illerup, J. B., Lyck, E., Nielsen, M., Winther, M., Mikkelsen, M. H., Hoffmann, L., Gyldenkærne, S., Sørensen, P. B., Fauser, P., Thomsen, M. & Vesterdal, L. 2005. Denmark's National Inventory Report 2005 – Submitted under the United Nations Framework Convention on Climate Change 1990-2003. – Research Note from NERI No. 211.

IUCN 2008: 20008 IUCN Red List of Threatened Species. Web site visited 20080918: http://www.iucnredlist.org/search/details.php/2478/summ

IUCN Polar Bear Specialist Group 2002. Polar Bears. Proceedings of the 13th working meeting of the IUCN/SSC Polar Bear Specialist Group, 23-28 June 2001, Nuuk, Greenland. – Occasional Paper of the IUCN Species Survival Commision No. 26. http://pbsg.npolar.no/

IWC 1991. Chairman's report of the forty-second annual meeting. – Rep IWC. 41:31-32.

IWC 2008a. Whale Population Estimates. The International Whaling Commission's most recent information on estimated abundance. – Web site visited 09042008: http://www.iwcoffice.org/conservation/estimate.htm

IWC 2008b. Lives of Whales. Details and characteristics of the 13 great whales, including the life histories of Baleen and Sperm Whales. –http://www.iwcoffice.org/conservation/lives.htm#sei. Web page visited 20080918.

Jacobsen, J. A. & Asmund, G. 2000. TBT in marine sediments and blue mussels (*Mytilus edulis*) from central-west Greenland. – Science of the Total Environment. 245. 131-136.

JCNB 2006. Tenth meeting of the Canada/Greenland Joint Commission on the Conservation and Management of Narwhal and Beluga. – Press release. Iqaluit, Nunavut. 9. - April 2006. Home page visited 1.5.2008: http://dk.nanoq.gl/English/Nyheder/JCNB.aspx

Jefferson, T. A., Thomas, A., Webber, M. A. & Pitman, R. L. 2008. Marine Mammals of the World, a Comprehensive Guide to their Identification. – Elsevier.

Jensen, A. S. 1926. Investigations of the "Dana" in Westgreenland waters., 1925. – Rapp.P.-V. Reun. Cons. Int. Explor. Mer. 39, 85-102.

Jensen, A. S. 1935. The Greenland halibut, Reinhardtius hippoglossoides (Walbaum): its development and migrations. – Det Kgl. Danske Videnskabernes Selsk Skr., Naturv. Math. Afd., Copenhagen, Ser. 9, 6(4): 1–31.

Jensen, A. D. S. 1939. Concerning a change of climate during recent decades in the Arctic and subarctic regions, from Greenland in the west to Eurasia in the east, and contemporary biological and geophysical changes. – Det. Kgl. Danske Videnskabernes Selskab, Biologiske Meddelelser 14 (8), 75pp.

Jensen, A. S. & B. Fristrup, 1950. Den arktiske klimaforandring og dens betydning, særlig for Grønland. – Geografisk Tidsskrift 50: 20-44.

Jensen, L. K., Carroll, J., Pedersen, G., Hylland, K., Dahle, S. & Bakke, T. 2006. A multi-generation *Calanus finmarchicus* culturing system for use in long-term oil exposure experiments. – Jour. Exp. Mar. Biol. Ecol., 333:71-78.

Jensen, M. H., Nielsen, T. G. & Dahllöf, I. 2008. Effects of pyrene on grazing and reproduction of *Calanus finmarchicus* and *Calanus glacialis* from Disko Bay, West Greenland. – Aquatic Toxicology 87: 99-107.

Jensen, T., Palerud, R., Olsgard, F. & Bakke, S. M. 1999. Spredning og effekter av syntetiske borevæsker i miljøet. (Dispersion and effects of synthetic drilling muds in the environment.). – Norwegian Ministry of Petroleum and Industry. Rapport 99–3507, rev. 1. 49 pp. (In Norwegian).

Jenssen, B. M. 2006. Endocrine-discrupting chemicals and climate change: a worst-case combination for Arctic marine mammals and seabirds? – Environmental Health Perspectives 114, Supplement 1, 76-80.

Jochens, A. D., Biggs, K., Benoit-Bird, D., Engelhaupt, J., Gordon, C., Hu, N., Jaquet, M., Johnson, R., Leben, B., Mate, P., Miller, J. , Ortega-Ortiz, A., Thode, P., Tyack, P. T & Würsig, B. 2008. Sperm whale seismic study in the Gulf of Mexico: Synthesis report. – U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2008-006. 341 pp.

Johansen, F. 1912. The fishes of the Danmark Expedition. – Meddelelser om Gønland XLV. 633-675.

Johansen, P., Riget, F., Asmund, G., Josefson, A. B. & Hansen, J. L. S. 2006. Environmental study at Maarmorilik 2005. – Technical Report NERI No. 605. 102 pp.

Johansen, Ø. 1999. Exploratory drillings at the Fylla Field south west of Greenland: Near Field spreading of oil and gas from potential deep water blowouts. – SINTEF, Trondheim.

Johansen, Ø., 2008. Statistical oil drift simulations east of Greenland. – SINTEF.

Johansen, P., Asmund, G., Aastrup, P. & M. Tamstorf. 2008. Environmental Impact of the Lead-Zinc Mine at Mestervig, East Greenland. – Research Notes from NERI No. 241, pp

Johansen, Ø., Skognes, K., Aspholm, O. Ø., Østby, C., Moe, K. A., & Fossum, P. 2003. Utredning af helårs oljevirksomhet i området Loftoten-Barentshavet, Uhellsutslipp av olje – konsekvenser i vannsøylen (ULB 7-c). – SINTEF rapport, Trondheim.

Jones, P.H. 1980. The effect on birds of a North Sea gas flare. – British Birds 73: 547-555.

Josefson, A. B., Hansen, J. L. S., Asmund, G. & Johansen, P. 2008. Threshold response of benthic macrofauna integrity to metal contamination in West Greenland. – Marine Pollution Bulletin 56: 1265-1274.

Jørgensen, O. & Akimoto, K. 1990. Results of a stratified-random bottom trawl survey off North-East Greenland in 1989. – ICES C.M 1990/G:57 (Poster).

Jørgensen, O. A. 2002. Survey for Greenland halibut in NAFO Divisions 1A-1D, 2001. – NAFO SCR Doc. 02/30. Serial No. N4637. 37 pp.

Jørgensen, O. A. 2005. Survey for Greenland halibut in the Northern part of Baffin Bay, NAFO Division 1A, 2004. – NAFO SCR Doc. 05/14. Serial No. N5093. 13 pp.

Jørgensen O. A., Hvingel, C. Møller, P. R. & Treble, M. 2005. Identification and mapping of bottom fish assemblages in Davis Strait and Southern Baffin Bay. – Can. J. Fish.Aquat. Sci. 62: 1833-1852.

Jørgensen O. A., Kristinsson, K. & Rosing, M. 2007. Bottom trawl survey in ICES Division 14AS (67°N - 72°N), September 2006. – Working paper for ICES North Western Working Group.

Kampp, K., Falk, K. & Pedersen, C.E. 2000. Breeding density and population of little auks (*Alle alle*) in a Northwest Greenland colony. – Polar Biology 23: 517-521.

Kampp, K., Meltofte, H. & Mortensen, C. E. 1987. Population size of the Little Auk *Alle alle* in East Greenland. – Dansk Orn. Foren. Tidsskr.81: 129-136.

Kanneworff, P. 1968. Preleminary results and some problems concerning capelin investigations in Greenland. – Rapp. P.-v. Reun. Cons. perm. int. Explor. Mer.: 38-40.

Kapel, F. O. 1979. Exploitation of large whales in West Greenland in the twentieth century. – Rep. Int. Whal. Commn 29: 197-214.

Kapel, F. O. 1995. Feeding ecology of harp and hooded seal in the Davis Strait – Baffin Bay region. Pp 287-304 in: Blix AS, Walløe L & Ulltang Ø (eds) Whales, seals and man. – Developments in Marine Biology 4, Elsevier.

Kapel, F. O. 1996. Recoveries in Grenland, 1949-94, of tagged or branded harp and hooded seals. – NAFO Scientific Council Studies 26: 87-99.

Kapel, C.M. & Berg, T.B. 1994. 12.6 Summarized observations of mammals. Pp. 159-162 in Hirche H.J. & Kattner, G. (eds) The 1993 Northeast Water Expedition, Scientific cruise report of RV “Polarstern” Arctic cruises ARK IX/2 and 3, USCG “Polar Sea” cruise NEWP and the NEWland expedition. – Ber. Polarforsch. 142.

Kapel, F. O. & Petersen, R. 1982. Subsistence hunting - the Greenland case. – Report of the International Whaling Commission, special issue 4: 51-74.

Kapel, F. O. & Rosing-Asvid, A. 1996. Seal hunting statistics for Greenland 1993 and 1994, according to a new system of collecting information, compared the previous lists-of-game. – NAFO Sci. Coun. Studies 26: 71-86.

Karamushko, O. V., Christiansen, J. S. & Fevolden, S. E. 2003. Diversity of marine fish. TUNU-I expedition. – University of Trømso, Norwegian College of Fishery Science, Institute of Aquatic Bioscience.

Karnowsky, N .J. & Hunt, G. L. 2002. Estimation of carbon flux to dovekies (*Alle alle*) in the North Water. – Deep Sea Reeseach II 49: 5117-5130.

Karpouzli, E. & Leaper, R. 2003 Opportunistic observations of interactions between sperm whales and deep-water trawlers based on sightings from fisheries observers in the northwest Atlantic. – Aquatic Conservation: Marine and Freshwater Ecosystem. 14 (1): 95 – 103.

Kattner, G., Hagen, W., Lee, R. F., Campbell, R., Deibel, D., Falk-Petersen, S., Graeve, M., Hansen, B. W., Hirche, H. J., Jónasdóttir, S. H., Madsen, M. L., Mayzaud, P, Müller-Navarra, D., Nichols, P. D., Paffenhöfer, G. A., Pond, D., Saito, H.,Stübing, D. & Virtue, P. 2007. Perspectives on marine zooplankton lipids. – Canadian Journal of Fisheries and Aquatic Sciences 64: 1628-1639.

Ketten, D. R. 1995. Estimates of blast injury and acoustic trauma zones for marine mammals from underwater explosions. Pp. 391–407 in: Sensory Systems of Aquatic Mammals (Ed. by R.A. Kastelein, J.A. Thomas & P.E. Nachtigall). – De Spil Publishers, Woerden.

Ketten, D. R., Lien, J. & Todd, S. 1993. Blast injury in humpback whale ears: evidence and implications. – Journal of the Acoustical Society of America, 94: 1849-1850.

Kideys, A. E. 2002. Fall and rise of the Black Sea Ecosystem. – Science 297: 1482-1483.

Kingsley M. C. S. 1998. The Number of ringed seals (*Phoca hispida*) in Baffin Bay and associated waters. Pp. 181-196. In: Heide-Jørgensen, M.P. and Lydersen C., Eds. Ringed Seals in the North Atlantic. – NAMMCO Scientific Publications vol. 1.

Kinze C. C. 2002. White-beaked dolphin. Pp. 1032-1034 in: Encyclopaedia of marine mammals (Perrin WF, Würsig B, Thewissen JGM, eds). – Academic Press, San Diego. 1032-1034.

Kirkegaard, M., Sonne, C., Leifsson, P.S., Dietz, R., Born, E. W., Letcher, R.J. & Muir, D. C. G. 2005. Histology of selected immunological organs in polar bear (*Ursus maritimus*) from East Greenland in relation to levels of organohalogens. – Sci Total Environ 341(14):119-132.

Klein, B., LeBlanc, B., Mei, Z. P., Beret, R., Michaud, J., Mundy, C. J., von Quillfeldt, C. H., Garneau, M. E., Roy, S., Gratton, Y., Cochran, J. K., Bélanger, S., Larouche, P., Pakulski, J. D., Rivkin, R. B. & Legendre, L. 2002. Phytoplankton biomass, production and potential export in the North Water. – Deep-Sea Research II 49: 4983-5002.

Koski, W. R. 1980. Distribution and migration of marine mammals in Baffin Bay and eastern Lancaster Sound, May-July 1979. – An Eames North Report prepared for Petro-Canada Explorations, Calgary, Alberta, Canada, December 1980: 317 pp.

Kovacs, K. M. & Lydersen, C. 2008: Climate change impacts on seals and whales in the North Atlantic Arctic and adjacent shelf seas. – Science Progress (2008), 91(2), 117–150.

Kühl, M., Glud, R. N., Borum, J., Roberts, R. & Rysgaard, S. 2001. Photosynthetic performance of surface associated algae below sea ice as measured with a pulse-amplitude-modulated (PAM) fluorometer and O2 microsensors. – Marine Ecology Progress Series 223: 1-14.

Labansen, A. L., Merkel, F. R., Boertmann, D. & Nyeland, J. in prep. Status of the Black-legged Kittiwake population breeding in West Greenland, 2007.

Laidre, K. L & Heide-Jørgensen, M. P. 2005. Arctic sea ice trends and narwhal vulnerability. – Biological Conservation 121 (2005) 509–517.

Laidre, K. L., Heide-Jørgensen, M. P., Dietz, R., Hobbs, R. C. & Jørgensen, O.A. 2003. Deep-diving by narwhals *Monodon monoceros*: differences in foraging behavior between wintering areas? – Marine Ecology Progress Series 261: 269-281.

Laidre K. L., M. P. Heide-Jørgensen, O. A. Jørgensen, & M. A. Treble. 2004. Deep ocean predation by a high Arctic cetacean. – ICES Journal of Marine Science 61(3): 430-440.

Laidre, K., Stirling, I., Lowry, L., Wiig, Ø., Heide-Jørgensen, M.P., & Ferguson, S. H. 2008a. Quantifying the sensitivity of Arctic marine mammals to climate-induced habitat change. – Ecological Applications, 18(2) Supplement 2008, pp. S97–S125.

Laidre, K. L., Heagerty, P.J., Heide-Jørgensen, M. P., Witting, L. & Simon, M. 2008b. Sexual segregation of common minke whales (*Balaenoptera acutorostrata*) and sex ratio of catches in Greenland. – International Whaling commission/scientific commitee /60/AWMP/8.

Larsen, F. & Kapel, F.O. 1981. Collection of biological material of minke whales off West Greenland, 1979. – Rep. Int. Whal. Commn 31: 279-285.

Larsen, T., Jonkel, C. & Vibe, C. 1983. Satellite radio-tracking of polar bears between Svalbard and Greenland. – Int Conf Bear Res and Manage 5: 230-237.

Larsen, F., Heide-Jørgensen, M. P., Martin, A. R. & Born, E. 1994. Line-transect estimation of narwhals (*Monodon monoceros*) in Scoresby Sund and adjacent waters, Pp.87-92 in Born, E. W. B., Dietz, R. & Reeves, R. R. (eds). Studies of white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) in Greenland and adjacent waters. – Meddelelser om Grønland, Bioscience 39.

Larsen, T.S., Kristensen, J.A., Asmund, G. & Bjerregaard, P. 2001. Lead and Zinc in Sediments and Biota from Maarmorilik, West Greenland: an Assessment of the Environmental Impact of Mining Wastes on an Arctic Fjord System. – Environmental Pollution 114: 275-283.

Lawson, J. Overviews: Beluga whale and noise. In J JCNB/NAMMCO 2005: Joint Scientific Meeting Nuuk, Greenland, October 13-16, 2005. – Final report. 53pp.

Lee, K., Azetsu-Scott, K., Cobanli, S. E., Dalziel, J., Niven, S., Wohlgeschaffen, G., & Yeats, P. 2005. Overview of potential impacts from produced water discharges in Atlantic Canada. Pp. 319-342 in Armsworthy *et al*. (eds.): Offshore oil and gas environmental effects monitoring. Approaches and technologies. – Batelle Press, Columbus, Ohio.

Legendre, L. & Demers, S. 1984. Towards dynamic biological oceanography and limnology. – Canadian Journal of Fisheries and Aquatic Sciences 41: 2-19.

Lehtonen, K. K., Schiedek, D., Koehler, A., Lang, T., Vuorinen, P.J., Fö rlin, L., Barsiene, J., Pempkowiak, J. & Gercken, J. 2006. BEEP project in the Baltic Sea: overview of results and outlines for a regional biological effects monitoring strategy. – Marine Pollution Bulletin 53: 523–537.

Lewis, E. L., Ponton, D., Legendre, L. & LeBlanc, B. 1996. Springtime sensible heat, nutrients and phytoplankton in the Northwater Polynya, Canadian Arctic. – Continental Shelf Research 16: 1775-1792.

LGL 2005. Husky delineation/exploration drilling program for Jeanne d'Arc Basin area environmental assessment. LGL Rep. SA845. – Rep. by LGL Limited, Canning and Pitt Associates, Inc., and PAL Environmental Services, St. John's, NL for Husky Oil Operations Limited, St. John's, NL. 340 p. + appendix.

Lien, J., Todd, S., Stevick, P., Marques, F., & Ketten, D. 1993. The Reaction of humpback whales to explosives: Orientation, movements and behaviour. – Journal of the Acoustical Society of America, 94:1849.

Linell, J. D. C., Swenson, J. E., Andersen, R. & Barnes, B. 2000. How vulnerable are denning bears to disturbance. – Wildlife Society Bulletin 28: 400-413.

Lisborg, T. D. & Teilmann, J. 1999. Spættet sæl i Kangerlussuaq / Søndre Strømfjord. – Pinngortitaleriffik, Grønlands naturinstitut, Teknisk Rapport nr. 23.

Ljungblad, D. K., Wursig, B., Swartz, S.L. & Keene, J.M. 1988. Observations on the behavioral responses of bowhead whales (*Balaena mysticetus*) to active geophysical vessels in the Alaskan Beaufort Sea. – Arctic, 41, 183–194.

Lopez, J. C. and Lopez, D. 1985. Killer whales of Patagonia and their behavior of intentional stranding while hunting near shore. – J.Mammal. 66(1):181-183.

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

Lovvorn, J. R., Samantha, E., Richman, S. E., Grebmeier, J. C. & Cooper, L.W. 2004. Diet and body condition of spectacled eiders wintering in pack ice of the Bering Sea. – Polar Biol 26:259-267.

Lowry, L. F. 1993. Foods and feeding ecology. Pp. 201-238 in Bums, J.J, Montague, J.J & C. J. Cowles (eds), The bowhead whale. – Soc. Mar. Mamm. Spec. Publ. 2.

Lyngs, P. 2003. Migration and winter ranges of birds in Greenland; an analysis of ringing recoveries. – Dansk Ornitologisk Forenings Tidskrift 97: 92-100.

Lyrholm, T. & Gyllensten, U. 1998. Global matrilineal population structure in sperm whales as indicated by mitochondrial DNA sequences. – Proceedings of the Royal Society of London. 265:1679-84.

Macdonald, R. W., Harner, T. & Fyfe, J. 2005. Recent climate change in the Canadian Arctic and its impact on contaminant pathways. – Science of the Total Environment. 342:5-86 (doi:10.1016/j.scitotenv.2004.12.059).

Madsen, P.T., Johnson, M., Miller, P., Aguilar de Soto, N. & Tyack P. 2006. Quantitative measures of airgun pulses impinging on sperm whales using onboard tags and controlled exposures. – J. Acoust. Soc. Am.: 120: 2366-2379.

Malmquist, H. J. 2004. Poster A2: paper 8 presented at ACIA International Symposium on Climate Change in the Arctic. – Reykjavik, Iceland, 9-12 November 2004.

Manniche, A. L. V. 1910. The terrestrial Mammals and Birds of North-East Greenland. – Meddr Grønland 45 (1): 1-200.

Martin, A. R. & Clarke, M. R. 1986. The diet of sperm whales (*Physeter macrocephalus*) captured between Iceland and Greenland. – J. Mar. Biol. Ass. U.K. 66:779-790

Matkin, C. O., Ellis, G. M., Olesiuk, P. & Saulitis, E. L. 1999. Association patterns and genealogies of resident killer whales (*Orcinus orca*) in Prince William Sound, Alaska. – Fish. Bull. 97:900?919.

Matkin, C. O., Saulitis, E. L., Ellis, G. M., Olesiuk, P. & Rice S. D. 2008. Ongoing population-level impacts on killer *whales Orcinus orca* following the 'Exxon Valdez' oil spill in Prince William Sound, Alaska. – Mar Ecol Prog Ser. 356: 269–281.

Mauritzen, M., Derocher, A. E., Wiig, Ø., Belikov, S. E., Boltunov, A. N., Hansen, E. & Gardner, G. W. 2002. Using satellite telemetry to define spatial population structure in polar bears in the Norwegian and western Russian Arctic. – J Appl Ecol 39: 79-90.

Mauritzen, M, Derocher, A. E., Pavlova, O. & Wiig, Ø. 2003. Polar bears (*Ursus maritimus*) on drift ice – walking the treadmill. – Anim Behavior 66: 107-113.

Mayer, M. & Piepenburg, D. 1996. Epibenthic distribution patterns on the continental slope off East Greenland at 75° N. – Mar. Ecol. Prog. Ser., 143, 151–164.

McCauley, R. D., Fewtrell, J, & Popper, A. N. 2003. High intensity anthropogenic sound damages fish ears. – J. Acoust. Soc. Am., 113:638-642. doi:10.1121/1.1527962

McCauley, R. D., Fewtrell, J., Duncan, A. J., Jenner, C., Jenner, M. N., Penrose, J. D., Prince, R. I. T., Adhitya, A., Murdoch, J. & McCabe, K. 2000: Marine Seismic Surveys – A Study of Environmental Implications. – APPEA Journal 40: 692-708.

McCay, D. F. 2003. Development and application of damage assessment modelling: example assessment for the North Cape oil spill. – Marine Pollution Bulletin. 47: 341-359.

McCay, D. P. F., Gibson, M. & Cobb, J. S. 2003a. Scaling restoration of American lobsters: combined demographic and discounting model for an exploited species. – Marine Ecology Progress Series 264: 197-212.

McCay, D. P. F., Peterson, C. H., DeAlteris, J. T. & Catena, J. 2003b. Restoration that targets function as opposed to structure: replacing lost bivalve production and filtration. – Marine Ecology Progress Series 264: 177-196.

Mehlum, F. 1989. Summer distribution of seabirds in northern Greenland and Barents Seas. – Norsk Polarinstitutt Skrifter Nr. 191.

Melle, W., Serigstad, B. & Ellertsen, B. 2001. Environmental risk of deep water oil drilling – A preliminary analysis. – Rapport nr. 1/2001. Senter for marint miljø, Havforskningsinstituttet, Bergen.

Melling, H., Gratton, Y. & Ingram, G. 2001 Ocean circulation within the North Water Polynya of Baffin Bay. – Atmosphere-Ocean, 39(3): 301-325

Mellinger, D. K., Stafford, K. M., Moore, S. E., Dziak, R. P. & Matsumoto, H. 2007. An overview of fixed passive acoustic observation methods for cetaceans. – Oceanography. 20(4):36-45

Meltofte, H. 1975. Ornithological observations in Northeast Greenland between 76° 00'and 78° 00' N. lat. 1969-71. – Meddr Grønland 191, 9: 72 pp.

Meltofte, H. 1976. Ornithological observations from the Scoresby Sund area, East Greenland, 1974. – Dansk Orn. Foren. Tidsskr. 70: 107-122. (Danish, with English summary).

Meltofte, H. 1978. A breeding association between Eiders and tethered huskies in North-east Greenland. – Wildfowl 29: 45-54.

Meltofte, H., Elander, M. & Hjort, C. 1981a. Ornithological observations in Northeast Greenland between 74°30' and 76°00'N. lat., 1976. – Meddr Grønland, Biosci. 3: 53 pp.

Menard, H. W. & Smith, S. M. 1966. Hypsometry of the ocean basin provinces. – J. Geophys. Res. 71: 4305-4325.

Mendes, S., Newton, J., Reid, R. J., Zuur, A. F. & Pierce, G. J. 2007. Stable carbon and nitrogen isotope ratio profiling of sperm whale teeth reveals ontogenetic movements and trophic ecology. – Oecologia. 151:605–615.

Merkel, F. R. 2008. Bestandsstatus for ederfuglen i Ilulissat, Uummannaq og Upernavik, 2001 – 2007. Resultater fra overvågning gennemført af lokale optællere i samarbejde med Grønlands Naturinstitut. – Teknisk Rapport nr. 72, Pinngortitaleriffik, Grønlands Naturinstitut.

Merkel, F. R., A.L. Labansen & L. Witting 2007. Monitering af lomvier or rider i Qaanaaq kommune, 2006. – Pinngortitaleriffik, Grønlands Naturinstitut, teknisk rapport 69, 82 pp..

Michaud, J., Fortier, L., Rowe, P. & Ramseier, R. 1996. Feeding success and survivorship of Arctic cod larvae, *Boreogadus saida*, in the Northeast Water polynya (Greenland Sea). – Fish Oceanogr 5:120–135.

Mikkelsen, P. S. 1994. Nordøstgrønland 1908 – 60. Fangstmandsperioden – Dansk Polarcenter.

Mikkelsen, B., Bloch, D. and Heide-Jørgensen, M.P. 2007 A note on movements of two fin whales (*Balaenoptera physalus*) tracked by satellite telemetry from the Faroe Islands in 2001. – J. Cetacean Res. Manage. 9(2):115–120.

Miller, G. W., Moulton, V. D., Davis, R. A., Holst, M., Millman, P., MacGillivray, A. & Hannay, D. 2005a. Monitoring seismic effects on marine mammals – Southeastern Beaufort Sea 2001-2002. Pp. 511-542 in Armsworthy *et al*. (eds.): Offshore oil and gas environmental effects monitoring. Approaches and technologies. – Batelle Press, Columbus, Ohio.

Miller, P. J. O., Johnson, M.P., Tyack, P.L., Madsen, P.T. & Watwood, S. L. 2005b. Controlled seismic airgun exposures: effects on the movement and foraging behavior of sperm whales. In McKay, M. & Nides, J. eds. – Proceedings: Twenty-third Gulf of Mexico information transfer meeting, January 2005. U.S. Dept. of the Interior, Minerals Management Service, Gulf of Mexico OCS Region, New Orleans, LA. OCS Study MMS 2005-066. Pp. 284-288.

Moline, M. A., Karnovsky, N. J., Brown, Z., Divoky, G. J., Frazer, T. K., Jacoby, C. A., Torres, J. J. & Fraser. W. R. 2008. High Latitude changes in ice dynamics and their impact on polar marine ecosystems. – Ann. N.Y. Acad. Sci. 1134. 267-319

Molnar, J., Gamboa, R., Revenga, C and Spalding, M. 2008. Assessing the global threat of invasive species to marine biodiversity. – Frontiers in Ecology and the Environment.DOI: 10.1890/070064

Moore, S. E. & Huntington, H. P. 2008. Arctic marine mammals and climate change: impacts and resilience. – Applications, 18, Supplement, 2008, pp. S157–S165.

Mosbech, A. (ed.) 2002. Potential environmental impacts of oil spills in Greenland. An assessment of information status and research needs. – National Environmental Research Institute, Denmark. NERI Technical report No.415. 106 pp.

Mosbech, A. & Boertmann, D. 1999. Distribution, abundance and reaction to aerial surveys of post-breeding king eiders (*Somateria spectabilis*) in western Greenland. – Arctic 52: 188-203.

Mosbech, A. & Glahder, C. 1991. Assessment of the impact of helicopter disturbance on moulting pink-footed geese *Anser brachyrhynchus* and barnacle geese *Branta leucopsis* in Jameson Land, Greenland. – Ardea 79: 233-238.

Mosbech, A., Dietz, R. & Nymand, J. 2000. Preliminary Environmental Impact Assessment of Regional Offshore Sesimic surveys in Greenland. 2nd edition. – Research Note from NERI NO. 132. http://www.bmp.gl/petroleum/NERI%20Rapport%20132_sec_dmu.pdf

Mosbech, A., Boertmann, D. & Jespersen, M. 2007a. Strategic Environmental Impact Assessment of hydrocarbon activities in the Disko West area. National Environmental Research Institute, University of Aarhus. 188 pp. – NERI technical report no. 618: 188 pp.Web page: http://www.dmu.dk/Pub/FR618.pdf

Mosbech, A., Hansen, A. B., Asmund, G., Dahllöf, I., Petersen, D. G. & Strand, J. 2007b. A chemical and biological study of the impact of a suspected oil seep at the coast of Marraat, Nuussuaq, Greenland. With a summary of other environmental studies of hydrocarbons in Greenland. National Environmental Research Institute, University of Aarhus. - NERI Technical Report 629: 56 pp. http://www2.dmu.dk/Pub/FR629.pdf

Mumm, N. 1993. Composition and distribution of mesozooplankton in the Nansen Basin. Arctic Ocean, during summer. – Polar Biology 13: 451- 461.

Mumm, N., Auel, H., Hanssen, H., Hagen, W., Richter, C. & Hirche, H. J. 1998. Breaking the ice: large-scale distribution of mesozooplankton after a decade of Arctic and transpolar cruises. – Polar Biology 20: 189 -197

Munk, P., Hansen, B. W., Nielsen, T. G. & Thomsen, H. A. 2003. Changes in plankton and fish larvae communities across hydrographic fronts off West Greenland. – Journal of Plankton Research 25: 815 - 830

Muus, B. 1990. Fisk pp. 23-153 in Muus, B, Salomonsen, F & Vibe V. (ed.) Grønlands Fauna. – Gyldendal, Copenhagen.

Møhl, B., Wahlberg, M., Madsen, P. T., Heerfordt, A. & Lund, A. 2003. The monopulsed nature of sperm whale clicks. – J Acoust Soc Am 114: 1143–1154.

Møller, E. F., Nielsen, T. G. & Richardson, K. 2006. The zooplankton community in the Greenland Sea: Composition and role in carbon turnover. – Deep-Sea Research I 53, 76–93.

Nakken, O. 1992. Scientific basis for management of fish resources with regard to seismic exploration. – Proceedings of Petropiscis II, Bergen Norway.

NAMMCO 1995a. Report of the ad hoc working group on Atlantic walrus, Pp. 101-119 in NAMMCO (North Atlantic Marine Mammal Commission) Annual Report 1995. – NAMCO.

NAMMCO 1995b. Report of the Joint Meeting of the Scientific Committee Working Groups on Northern Bottlenose and Killer Whales and Management Procedures. Pp: 71–126 in: Report of the third meeting of the scientific committee. – Annual Report of the North Atlantic Marine Mammal Commission, Tromsø, Norway.

NAMMCO 2001. NAMMCO Annual Report 2001. North Atlantic Marine Mammal Commission. – Tromsø, Norway, 335 pp.

NAMMCO 2005. NAMMCO scientific committee working group on the stock status of walruses in the North Atlantic and adjacent seas. Pp. 279-3008 in NAMMCO (North Atlantic Marine Mammal Commission) Annual Report 2005. – NAMCO.

NAMMCO 2008a. Web page visited 10.4.2008. http://www.nammco.no/webcronize/images/Nammco/667.pdf

NAMMCO 2008b. Web page visited 10.4.2008. http://www.nammco.no/webcronize/images/Nammco/725.pdf

NAMMCO-IWC 2006. Report of the Joint NAMMCO/IWC Scientific Workshop on the Catch History, Stock Structure and Abundance of North Atlantic Fin Whales. – Reykjavík, Iceland, 23-26 March 2006. http://www.iwcoffice.org/conservation/estimate.htm. Web site visited 20080918.

National Research Council 2003. Cumulative Environmental Effects of Oil and Gas Activities on Alaska's North Slope. – The National Academy Press. Washington D.C. Web page visited 09042008: http://books.nap.edu/openbook.php?record_id=10639&page=R1

National Research Council 2005. Marine mammal populations and ocean noise. determining when noise causes biologically significant effects. – The National Academy Press, Washington DC.

Neff, J. M. 1987. Biological effects of drilling fluids, drill cuttings and produced water. Pp 469-538 in Boesch, D.F. & Rabalais, N.N. (eds), Long-term Environmental Effects of Offshore Oil and Gas Development. – Elsevier Applied Science, London and New York.

Nettleship, D. N. & Evans, P.G.H. 1985. Distribution and status of the Atlantic Alcidae. Pp. 53-154 in Nettleship, D.N, & T.R. Birkhead (eds). The Atlantic Alcidae. – Academic Press, London: 573 pp.

Nielsen, J. 1961 Contributions to the biology of the salmonidae in Greenland I-IV. – Medd om Grønland 159 (8): 1-77.

Nielsen, J. G. & Fosså, S. 1993. *Lycodes adolfi*, a new species of eelpout (Zoarcidae) from Greenland. – Cybium 17, 39-44.

Nielsen, J. W., Kliem, N., Jespersen, M., & Christiansen, B. M. 2006. Oil drift and fate modelling at Disko Bay. – Technical Report 06-06, Danish Meteorological Institute, Denmark.

Nielsen, T. G., Ottosen, L. D. & Hansen, B. W. 2007. Structure and function of the pelagic ecosystem in Young Sound, NE Greenland. – Meddelelser om Grønland, Bioscience 58: 88-107

Nielsen, J. W., Murawski, J. & Kliem, N. 2008. Oil drift and fate modelling off NE and NW Greenland. – DMI technical report 08-12.

NMFS (National Marine Fisheries Service). 2002. Biological Opinion, Endangered Species Act-Section 7 Consultation and Operation of the Liberty Oil Production Island. Consultation No. F/AKR/2001/00889. National Marine Fisheries Service, Anchorage, AK. 51 pp. [Online]. Available: http://www.fakr.noaa.gov/protectedresources/whales/bowhead/biop.pdf [accessed Dec. 11, 2002].

NMFS (National Marine Fisheries Service) 2003. Taking marine mammals incidental to conducting oil and gas exploration activities in the Gulf of Mexico. – Fedl Register 68: 9991–9996.

Nowacek, D. P., Thorne, L. H., Johnston, D. W. & Tyack, P. L. 2007: Responses of cetaceans to anthropogenic noise. – Mammal Rev. Vol. 37, No. 2, 81–115.

Nygård, L. A. & Topp-Jørgensen, E. 2007. Paper on significant trade review: Beluga, narwhal, Atlantic walrus and polar bear. – Unpublished report Greenland Home Rule.

Odate, T., Hirawake, T., Kudoh, S., Klein, B., LeBlanc, B. & Fukuchi, M. 2002. Temporal and spatial patterns in the surface-water biomass of phytoplankton in the North Water. – Deep-Sea Research II 49: 4947-4958.

OED 2006. Sameksistens mellom fiskerinæringen og oljevirksomheten i området Lofoten-Barentshavet innenfor rammen af en bærekraftig utvikling. – Olje- og enenergidepartementet, Oslo.

OLF 2005. Environmental Report 2004. – The Norwegian Oil industry Association, Stavanger. http://www.olf.no/miljo/miljorapporter/?27221.pdf

Olsen, E. & Quillfeldt, C. H. V. 2003. Idenificering av særlig verdifulle områder i Lofoten-Barentshavet. – Havforskningsinstituttet og Norsk Polarinstitutt. http://www.imr.no/__data/page/3859/Identifisering_av_saerlig_verdifulle_omraader_i_Lofoten_-_Barentshavet.pdf

Olsen, G. H., Sva, E., Carroll, J., Camus, L., De Coen, W., Smolders, R., Øveraas, H. & Hylland, K. 2007. Alterations in the energy budget of Arctic benthic species exposed to oil-related compounds. – Aquatic Toxicology 83: 85–92.

Olsen, G. H., Carroll, J., Sva, E., & Camus, L. 2008. Cellular energy allocation in the Arctic sea ice amphipod *Gammarus wilkitzkii* exposed to the water soluble fractions of oil. – Marine Environmental Research 66: 213-214.

Olsgaard, F. & Gray, J. 1995. A comprehensive analysis of the effects of offshore oil and gas exploration and production on the benthic communities of the Norwegian continental shelf. – Mar Ecol Prog Ser 122:.277–306.

Olsson, K. A., Jeansson, E., Tanhua, T. & Gascar, J. C. 2005. The East Greenland Current studied with CFCs and released sulphur hexafluoride. – Journal of Marine Systems 55 (1-2), 77-95.

Outridge, P. M. R. W., Macdonald, R.W., Wang, F., Stern, G.A. & Dastoor, A. P. 2008. A mass balance inventory of mercury in the Arctic Ocean. – Environ. Chem. 2008, 5, 89–111.

Overrein, Ø. 2002. Virkninger av motorferdsel på fauna og vegetasjon. – Rapportserie nr. 119. Norsk Polarinstitutt, Tromsø.

Øien, N. 1988.The distribution of killer whale (*Orcinus orca*) in the North Atlantic based on Norwegian catches, 1938-1981 and incidental sightings, 1967-1987. – Rit Fiskideildar, 11:65-78.

Øien, N. 2000. Bestandsforhold og fangst. – Ottar. 230(2): 3-10.

Øigård, T. A., Haug, T., Nilssen, K. T. & Salberg, B. 2008. Pup production estimates of Hooded and Harp Seals in the Greenland sea during the 2007 whelping season. – Joint ICES/NAFO Working Group on Harp and Hooded Seals, WP SEA 166.

Øritsland, N. A., Engelhardt, F.R., Juck, F. A., Hurst, R. J. & Watts, P. D. 1981. Effect of crude oil on polar bears. – Env Stud 24: 268 pp.

Østby, C., Nordstrøm, L. & Moe, K. A. 2003. Konsekvenser av seismisk aktivitet. ULB delutredning 18. – Alpha Miljørådgivning, Oslo.

Paetkau, D., Amstrup, S. C., Born, E. W., Calvert, W., Derocher, A. E., Garner, G. W., Messier, F., Stirling, I., Taylor, M. K., Wiig, Ø. & Strobeck, C. 1999. Genetic structure of the world's polar bear populations. – Mol Ecol 8: 1571–84.

Palsbøll, P., Heide-Jørgensen, M. P. & Dietz, R. 1997. Genetic studies of narwhals, *Monodon monoceros*, from West and East Greenland. – Heredity 78(1997): 284-292.

PAME 2002. Arctic offshore oil and gas guidelines. – Arctic Council.

Pampoulie, C., Danielsdóttir, A. K., Bérubé, M., Palsbøll, P. J., Árnason, A., Gunnlaugsson, T. H., Ólafsdóttur, D., Øien, N., Witting, L. & Víkingsson, G. A. 2008. Lack of genetic divergence among samples of the North Atlantic Fin Whale collected at feeding grounds: congruence among microsatellite loci and mtDNA in the new Icelandic dataset. – International Whaling commission/scientific commitee/60/PFI11.

Panasenko, L. D. & Sobolova, M. S. 1980. Food interrelations between the Barents Sea capelin and polar cod. – ICES Council Meeting 1980:G:23. 15 pp.

Parkinson C. L., & Cavalieri, D. J. 2008. Arctic sea ice variability and trends, 1979-2006. – J. Geophys. Res., 113, C07003.

Parry G. D. & Gason, A. 2006. The effect of seismic surveys on catch rates of rock lobsters in western Victoria, Australia. – Fisheries Research 79: 272–284.

Pars, T., Osler, M. & Bjerregaard, P. 2001. Contemporary use of traditional and imported food among Greenlandic inuit. – Arctic 54: 22-31.

Parsons, E. C. M., Wright A. J. & Gore, M. A. 2008. The Nature of Humpback Whale (*Megaptera novaeangliae*) Song. – Journal of Marine Animals and Their Ecology 1(1): 22-31.

Patenaude, N. J., Richardson, W. J., Smultea, M. A., Koski, W. R., Miller, G. W., Wuersig, B. & Greene, C. R. Jr. 2002. Aircraft sound and disturbance to bowhead and beluga whales during spring migration in the Alaskan Beaufort Sea. – Marine Mammal Science, 18, 309–355.

Pedersen, A. 1926. Beiträge zur Kenntnis der Säugetier- und Vogelfauna der Ostküste Grönlands. – Meddr Grønland 68, 3: 151-249.

Pedersen, A. 1930. Forgesetzte Beitrage zur kenntnis der Säugetiere- und Vogelfauna der Ostküste Grönlands. – Meddr Grønland 77, 5: 343-507.

Pedersen, A. 1934. Die Ornis des Mittleren Teiles der Nordostküste Grönlands. – Meddr Grønland 100, 11: 35 pp.

Pedersen, A. 1942. Säugetiere und Vögel. – Meddr Grønland 128, 2: 119 pp.

Pedersen, A. 1945. Der Eisbär. Verbreitung und Lebenswise. – E. Bruun & Co., Copenhagen 166 pp.

Pedersen, S. A. 2005. Nordatlantiske havøkosystemer under forandring - effekter af klima, avstrømme og fiskeri. – DFU-rapport 157/05.

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

Perez, C., Velando, A., Munilla, I., Lopez-Alonso, M. & Oro, D. 2008. Monitoring Polycyclic Aromatic Hydrocarbon Pollution in the Marine Environment after the Prestige Oil Spill by Means of Seabird Blood Analysis. – Environ. Sci. Techn. 2008: 707-713.

Pesant, S., Legendre, L., Gosselin, M., Smith, R. E. H., Kattner, G. & Ramseier, R. O. 1996. Size-differential regimes of phytoplankton production in the Northeast Water Polynya (77° - 81° N). – Marine Ecology Progress Series 142: 75-86.

Pesant, S., Legendre, L., Gosselin, M., Ashjian, C., Booth, B., Daly, K., Fortier, L., Hirche, H. J., Michaud, J., Smith, R. E. H., Smith, S. & Smith, W. O. 1998. Pathways of carbon cycling in the euphotic zone: the fate of large-sized phytoplankton in the Northeast Water Polynya. – Journal of Plankton Research 20: 1267-1291.

Pesant, S., Legendre, L., Gosselin, M., Bjornsen, P. K., Fortier, L., Michaud, J. & Nielsen, T. G. 2000. Pathways of carbon cycling in marine surface waters: the fate of small-sized phytoplankton in the Northeast Water Polynya. – Journal of Plankton Research 22: 779-801.

Petersen, H. C. 1993. Registrering af de levende naturværdier i Grønland. Scoresbysund Kommune. – Rapport nr. 17. Grønlands Hjemmestyre, Direktoratet for Miljø.

Petersen, I. K. 1995. Alkefuglenes antal og fordeling i forhold til hydrografi og produktionsforhold i havet mellem Island, Jan Mayen og Østgrønland efterårene 1987 til 1991. – Unpublished Master Thesis report, University of Copenhagen.

Petersen, D. G., Dahllöf, I. 2007. Combined effects of pyrene and UV-light on algae and bacteria in an arctic sediment. – Ecotoxicology 16: 371-377.

Petersen, G. H. & Smidt, E. 1981. Havbundens invertebratfauna. Pp. 241-252 in Nørrevang, A. & Lundø, J. (Red.) Danmarks Natur 11, Grønland. – Politikens Forlag.

Petersen, D. G., Reichenberg, F. & Dahllöf, I. 2008. Phototoxicity of pyrene affects benthic algae and bacteria from the Arctic. – Environmental Science & Technology 42: 1371-1376.

Peterson, C. H., Rice, S. D., Short, J. W., Esler, D., Bodkin, J. D., Ballachey, B. E. & Irons, D. B. 2003. Long-term ecosystem response to the Exxon Valdez oil spill. - Science 302: 2082–2086.

Picado, A., Bebianno, M. J., Costa, M. H., Ferreira, A. & Vale, A. 2007. Biomarkers: a strategic tool in the assessment of environmental quality of coastal waters. – Hydrobiologica 587: 79-87

Piepenburg, D. 1988. On the composition of the benthic fauna of the Western Fram Strait. – Ber. Polarforsch. 52, pp 118 - ISSN 0176-5027

Piepenburg, D. 2005. Recent research on Arctic benthos: common notions need to be revised. – Polar Biology 28: 733-755

Piepenburg. D., Ambrose, W. G. Jr., Brandt, A., Renaud., P. E., Ahrens, M. J. & Jensen, P. 1997. Benthic community patterns reflect water column processes in the Northeast Water polynya (Greenland). – J. Mar. Sys. 10: 467-482.

Pike, D. G., Gunnlaugsson, Víkingsson, G. A. & Mikkelsen, B. 2008. Estimates of the abundance of fin whales (*Balaenoptera physalus*) from the T-NASS Icelandic and Faroese ship surveys conducted in 2007. – International Whaling Commision/Scientific Committee/60/PFI13

Pitman, R. L & Enzor P. 2003. Three forms of killer whales (*Orcinus orca*) in Antarctic waters. – J. Cetacean Res. Manage. 5(2):131–139.

Popper, A. N., Fewtrell, J., Smith, M.E. & McCauley, R.D. 2004. Anthropogenic sound: Effects on the behavior and physiology of fishes. – Marine Technology Soc. J. 37(4):35-40.

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

Ramsay, M. A & Stirling, I. 1990. Fidelity of female polar bears to winter-den sites. – J Mammal 71: 233-236.

Rankin, S. & Barlow, J. 2005. Source of the North Pacific "boing" sound attributed to minke whales. – J. Acoust. Soc. Am. 118(5):3346–3351.

Rasmussen, M. H. 1999. Sound production, behaviour and distribution of the White Beaked Dolphin. In Danish: Hvidnæsens lydproduktion, adfærd samt udbredelse. – Master Thesis. Odense University. Nov. 1999. Pp 85.

Rasmussen, R. O. 2005. Analyse af fangererhvervet i Grønland. – no publisher. http://dk.nanoq.gl/Emner/Landsstyre/Departementer/Departement_for_fiskeri/~/media/95CEC05EEA7D40E6873BFDFF459E3AD2.ashx

Ray, J. P. & Engelhardt, F. R. 1992, Produced water. Technological/Environmental Isues and Solutions. – Plenum Press, New York and London, 616 pp.

Reeves, R. R. & Heide-Jørgensen, M. P. 1994: Commercial aspects of the exploitation of narwhals (*Monodon monoceros*) in Greenland, with emphasis on tusk exports. – Meddelelser om Grønland. Bioscience 39, 1994: 199-134.

Reeves, R. R., Ljungblad, D.K. & Clarke, J.T. 1984. Bowhead whales and acoustic seismic surveys in the Beaufort Sea. – Polar Record, 22, 271–280.

Reeves, R. R., Smeenk, C., Kinze, C. C., Brownell, R. L. & Lien, J. 1999. White-beaked dolphin - *Lagenorhynchus albirostris* (Gray, 1846). Pp 1-30 in Ridgway, S.H. & Harrison, S.R. eds), Handbook of Marine Mammals, Vol. 6. – Academic Press, London.

Regehr, E. V., Amstrup, S. C. & Stirling, I. 2006. Polar bear population status in the southern Beaufort Sea. – Open-File Report 2006-1337. U.S. Department of the Interior & U.S. Geological Survey: 30 pp.

Renaud, W. E. & Bradstreet, M.S.W. 1980. Late winter distribution of Black Guillemots in northern Baffin Bay and the Canadian high arctic. – Canadian Field-Naturalist. 94(4):421-425.

Renaud, W. E., McLaren, P. L. & Johnson, S. R. 1982. The dovekie, *Alle alle*, as a spring migrant in Eastern Lancaster Sound and Western Baffin Bay. – Arctic 35: 118-125.

Ribergaard, M. H. & Kliem, N. 2006. HYCOM for the North Atlantic, with special emphasis on West Greenland Waters. – Techn. Rep. 06-07, Danish Meteorological Institute, Denmark.

Rice, D. W. 1989. Sperm whale. *Physeter macrocephalus* Linnaeus, 1758. Pp 177-233 in Ridgway, S.H. & Harrison, S.R. (eds), Handbook of Marine Mammals, vol. 4. – Academic Press, London.

Rice, S. D., Spies, R. B., Wolfe, D. A. & Wright, B. A. 1996. Proceedings of the Exxon valdez Oil Spill Symposium. – American Fisheries Society, Maryland.

Richardson, W. J. & Malme, C. 1993. Man-made noise and behavioural responses. Pp 631-700 in: The bowhead whale (J.J. Burns, J.J. Montague and C.J. Cowles (eds). – The Society for Marine Mammalogy.

Richardson, W. J., Wursig, B. & Greene, C. R. J. 1986. Reactions of bowhead whales, *Balaena mysticetus*, to seismic exploration in the Canadian Beaufort Sea. – Journal of the Acoustical Society of America, 79, 1117–1128.

Richardson, W. J., Würsig, B. & Greene, C. R. 1990. Reactions of bowhead whales, *Balaena mysticetus*, to drilling and dredging noise in the Canadian Beaufort Sea. – Mar. Environ. Res. 29: 135-160.

Richardson, W. J. & Greene, C. R. Jr., Malme, C. I. & Thomson, D. H. 1995. Marine mammals and noise. – Academic Press, San Diego. 576 pp.

Richardson, K., Markager, S., Buch, E., Lassen, M. F. & Kristensen, A. S. 2005. Seasonal distribution of primary production, phytoplankton biomass and size distribution in the Greenland Sea. – Deep-Sea Research I 52: 979-999.

Richman, S. E. & Lovvorn, S. R. 2003. Effects of clam species dominance on nutrients and energy acquisition by spectacled eiders in the Bering Sea. – Mar. Ecol. Prog. Ser. 261: 283-297.

Richter, C. 1994. Regional and Seasonal Variability in the Vertical Distribution of Mesozooplankton in the Greenland Sea. – PhD thesis. University of Kiel (Germany), 101 pp.

Riget, F. F. 2006a .Tidsmæssig udvikling af kontaminanter i grønlandske dyr – en status raport. – Arbejdsrapport fra DMU nr. 228.

Riget, F. & Boje, J. 1989: Fishery and some biological aspects of Greenland Halibut (*Reinhardtius hippoglossoides*) in West Greenland Waters. – NAFO Sci. Coun. Studies, 13: 41-52.

Riget, F. & Böcher, J. 1998. The fresh water environment. Pp. 221-236 in Born, E. & Böcher, J. (ed) The ecology of Greenland. – Ilinniusiorfik, Nuuk.

Riget, F., Johansen, P., Dahlgaard, H., Mosbech, A., Dietz, R. & Asmund, G. 2000. The Seas Around Greenland. Pp 5-16 in: Sheppard, C.R.C. (ed.): Seas at the Millennium: an Environmental Evaluation. Volume I Regional Chapters: Europe, The Americas and West Africa. – Pergamon.

Riget, F. F., Dietz, R., Vorkamp, K., Johansen, P. & Muir, D. 2004. Levels and spatial and temporal trends of contaminants in Greenland biota: an updated review. – Science of the Total Environment 331 (1-3): 29-52.

Riget, F. F., Muir, D., Kwan, M., Savinova, T., Nyman, M., Woshner, V. & O'Hara, T. 2005. Circumpolar pattern of mercury and cadmium in ringed seals. – Science of the Total Environment 351-352: 312-322.

Rigét, F., Vorkamp, K., Dietz, R. & Rastogi S. C. 2006. Temporal trends studies on polybrominated diphenyl ethers (PBDEs) and polychlorinated biphenyls (PCBs) in ringed seals from East Greenland. – J. Environ. Monit. 8, 1000-1005.

Riget, F., Dietz, R., Born, E.W., Sonne, C. & Hobson, K.A. 2007a. Temporal trends of mercury in marine biota of west and northwest Greenland. – Marine Pollution Bulletin 54: 72–80.

Riget, F., Møller, O., Dietz, R., Nielsen, T. G., Asmund, G., Strand, J., Larsen, M. M. & Hobson, K. A. 2007b. Transfer of mercury in the marine food web of West Greenland. – J. Environ. Monit. 9: 877–883

Ringuette, M., Fortier, L., Fortier, M., Runge, J. A., Bélanger, S., Larouche. P., Weslawski, J.M. & Kwasniewski, S. 2002. Advanced recruitment and accelerated population development in Arctic calanoid copepods of the North Water. – Deep-Sea Research II 49: 5081–5099

Roche, C. & Guinet, C. 2007. Marine mammals and demersal longline fishery interactions in Crozet and Kerguelen exclusive economic zones: an assessment of depredation levels. – CCAMLR Science. 14:67-82

Roe, H. S. J. 1969. The food and feeding habits of sperm whales (*Physeter catodon* L.) taken off the west coast of Iceland. – J. Cons. Int. Explor. Mer. 33(1):03-102.

Rosing-Asvid, A. 2002. The polar bear hunt in Greenland. – Technical report No. 45, Greenland Institute of natural Resources.

Rosing-Asvid, A. 2006. The influence of climate variability on polar bear (*Ursus maritimus*) and ringed seal (Pusa hispida) population dynamics. – Can J Zool 84: 357-364.

Ross, S. L. 1992: Evaluation of the behaviour and cleanup of offshore oil-well blowout spills in west Greenland. – S.L. Ross Ltd. 87 pp. + app.

Ross, W. G. 1993. Commercial whaling in the north Atlantic sector. Pp. 511-561 in Burns, J.J., Montague, J.J. & Cowles C.J. (eds.) The Bowhead Whale. – Special publication No. 2 of the Society for Marine Mammology.

Rudels, B., Fahrbach, E., Meincke, J., Budeus, G. & Eriksson, P. 2002. The East Greenland Current and its contribution to the Denmark Strait overflow. – ICES J Mar Science 59: 1133-1154

Rye, H., Nordtug, T. & Skognes, K. 2003. Spredning og deponering av kaks og slam. Spredning av producert vann med doser på organismer. Spredning av radioaktivitet. OED studie 5a og 5b – udredning Lofoten-Barentsghavet. – Sintef Kjemi, Sintef.

Rysgaard, S. & Glud, R. N. (eds). 2007. Carbon cycling in Arctic marine ecosystems: case study Young Sound. – Meddr. Grønland, Bioscience Vol 58.

Rysgaard, S. & Nielsen, T. G. 2006. Carbon cycling in a high-arctic marine ecosystem – Young Sound, NE Greenland. – Progress in Oceanography 71: 426-445.

Rysgaard, S., Christensen, P. B., Borum, J., Carl, J.D., Ehlmé G. & Elander, M. 1998. 5.2. Nutrient dynamics in Northeast Greenland waters and sediments. Pp. 48-53 in Meltofte, H. & Rasch, M. (eds) ZERO Zackenberg Ecological Research Operations, 3rd annual report 1997. – Danish Polar Centre.

Rysgaard, S., Sejr, M. K., Frederiksen, M., Arendt, K. & Frandsen, E. R. 2007. Zackenberg Basic. The MarineBasis programme. Pp. 66-77 in: Klitgaard, A. B., Rasch, M. & Caning, K. (eds.), Zackenberg Ecological Research Operations, 12th annual report, 2006. – Danish Polar Center.

Røe Utvik, T. I. & Johnsen, S. 1999. Bioavailability of polycyclic aromatic hydrocarbons in the North Sea. – Environ. Sci. Technol. 33: 1963–1969.

Sameoto, D.D. 1984. Vertical distribution of zooplankton biomass and species in Northeastern Baffin Bay related to temperature and salinity. – Polar Biology 2: 213-224.

Sandell, H. T. & Sandell, B. 1991. Archaeology and environment in the Scoresby Sund fjord. – Meddelelser om Grønland, Man & Society 15, 150 pp.

Sandell, H. T., Sandell, B., Born, E. W., Dietz, R. & Sonne-Hansen, C. 2001. Isbjørne i Østgrønland: Fangst og forekomst – en interviewundersøgelse. – Teknisk Rapport Nr. 40. Grønlands Naturinstitut. Nuuk: 1-94.

Santos, M. B., Pierce G. J., Boyle P. R., Reid R. J., Ross H. M., Patterson I. A. P., Kinze C. C., Tougaard S., Lick, R., Piatkowski U. & Hernández-García V. 1999. Stomach contents of sperm whales *Physeter macrocephalus* stranded in the North Sea 1990–1996. – Marine Ecology Progress Serie.s183:218–294.

Saunders, P. A., Deibel, D., Stevens, C. J., Rivkin, R. B., Lee, S. H. & Klein, B. 2003. Copepod herbivory rate in a large arctic Polynya and its relationship to the seasonal and spatial variation in copepod and phytoplankton biomass. – Mar Ecol Prog Ser 261: 183-199.

Scheifele, P. M., Andrew, S, Cooper, R.A., Darre, M., Musiek, F.E. & Max, L. 2005. Indication of a Lombard vocal response in the St. Lawrence River beluga. – J. Acoust. Soc. Am. 117 (3): 1486–1492.

Schick, R. S. & Urban, D. L. 2000. Spatial components of bowhead whale (*Balaena mysticetus*) distribution in the Alaskan Beaufort Sea. – Canadian Journal of Fisheries and Aquatic Sciences, 57, 2193–2200.

Schiedek, D., Sundelin, B., Readman, J. W. & Macdonald, R. W. 2007. Interactions between climate change and contaminants (review). – Mar Pollut Bull 54, 1845-1856.

Schreiber, E. A. & Burger, J. 2002. Biology of marine Birds. – CRC Press.

Schaanning, M. T., Trannum, H. C., Øxnevad, S., Carroll, J. L., Bakke, T. 2008. Effects of drilling cuttings on biogeochemical fluxes and macrobenthos of marine sediments. – J. Exp. Mar. Biol. Ecol 361, 49-57.

Sejr, M. K. & Christensen, P. B. 2007. Growth, production and carbon demand of macrofauna in Young Sound, with special emphasis on the bivalves *Hiatella arctica* and *Mya truncata* In: Rysgaard S & Glud RN (Eds.) Carbon cycling in Arctic marine ecosystems: Case study Young Sound. – Meddelelser om Grønland, Bioscience 58.

Sejr, M. K., Jensen, K.T. & Rysgaard S. 2000 Macrozoobenthic community structure in a high-arctic East Greenland fjord. – Polar Biol. 23:792-801.

Sergeant, D. E. 1991. Harp seals man and ice. – Special Publication of Fisheries and Aquatic Science. 114.

Short, J. W. & Harris, P. M. 1996. Chemical sampling and analysis of petroleum hydrocarbons in near-surface seawater of Prince William Sound after the Exxon Valdez oil spill. Pp 17-28 in Rice, D.S. *et al*. (eds) Proceedings of the Exxon Valdez oil spill symposium. – American Fisheries Society, Bethesda, Maryland.

Short, J. W., Lindeberg, M. R., Harris, P. M., Maselko, J. M., Pella, J. J. & Rice, S. D. 2004. Estimate of oil persisting on the beaches of Prince William Sound 12 years after the Exxon Valdez oil spill. – Envion. Sci. Technol 38: 19-25.

Siegstad, H., Neve, P. B., Heide-Jørgensen, M. P. & Härkönen, T. 1998. Diet of the Ringed Seal (*Phoca hispida*) in Greenland. Pp. 229-241 in Heide-Jørgensen, M.P. & Lydersen, C. (eds) Ringed Seals in the North Atlantic. – NAMMCO scientific publications vol. 1.

Sigurjonsson, J. & Gunnlaugsson, T. 1990. Recent trends in the abundance of blue (*Balaenoptera musculus*) and humpback whales (*Megaptera novaeanglia*) off west and southwest Iceland with a note on the occurrence of other cetacean species. – Rep. int. Whal. Commn. 40:537–551.

Sigurjónsson, J. & Leatherwood, S. 1988. The Icelandic live-capture fishery for killer whales, 1976-1988. – Rit Fiskideildar, 11, 307-316.

Similä, T. & Ugarte, F. 1997. Social organisation of north Norwegian killer whales. In: Similä, T. PhD thesis. – NFH, University of Tromsø.

Similä, T., Holst, J. C. & Christensen, I. 1996. Occurrence and diet of killer whales in northern Norway: seasonal patterns relative to the distribution and abundance of Norwegian spring-spawning herring. – Can. J. Fish. Aquat. Sci. 53:769-779.

Simon, M. J., Kristensen, T. K., Tendal, O. S., Kinze, C. C. & Tougaard, S. 2003. *Gonatus fabricii* (Mollusca, Theuthida) as an important food source for sperm whales (*Physeter macrocephalus*) in the northeast Atlantic. – Sarsia 88:244–246.

Simon, M., Kinglsey, M., Ugarthe, F. & Witting, L. submitted. Biological Parameters and Distribution of Fin and Minke Whale Catches off West Greenland. – Journal of Marine Mammals Science.

Simon, M., McGregor, P. K. & Ugarte, F. 2007. The acoustic behaviour of herring-eating killer whales (*Orcinus orca*). – Acta Ethologica. 10:47-53

Simonsen, S. C, Munk, P., Folkvord, A. & Pedersen, S.A. 2006. Feeding ecology of Greenland halibut and sandeel larvae off West Greenland. – Marine Biology 149: 937–952.

Širovi, A., Hildebrand J. A. & Wiggins S. M. 2007. Blue and fin whale call source levels and propagation range in the Southern Ocean. – J. Acoust. Soc. Am. 122 (2): 1208-1215.

Sjare, B. & Stirling, I. 1996. The breeding behavior of Atlantic walruses, *Odobenus rosmarus rosmarus*, in the Canadian High Arctic. – Canadian Journal of Zoology 74: 897-911.

Sjare, B., Stirling, I. & Spencer, C. 2003. Structural variation in the songs of Atlantic walruses breeding in the Canadian High Arctic. – Aquatic Mammals 29: 297-318.

Skaug, H. J., Øien, N., Schweder, T. & Bøthun G. 2004. Abundance of minke whales (*Balaenoptera acutorostrata*) in the Northeast Atlantic: variability in time and space. – Can. J. Fish. Aquat. Sci. 61: 870–886.

Skjoldal, H. R., Thurston, D., Baffrey, M., Crandall, B., Dahle, ., Gilman, A., Hunington, H. P., Klungsør, J., Lockhart, L., Macdonald, C. l., Mosbech, A. & Thomas, D. 2007. Chapter 7. Scientific Findings and Recommendations. – Arctic Council, AMAP Oil and Gas Assessment. http://www.amap.no/oga/

Slotte, A., Hansen, K., Dalen, J. & Ona, E. 2004. Acoustic mapping of pelagic fish distribution and abundance in relation to a seismic shooting area off the Norwegian west coast. – Fisheries Research 67: 143-150.

Smith, S. L. & Schnack-Schiel, S. B. 1990. Polar zooplankton. Pp 527–598 in Smith, W.L. (ed.): Polar oceanography part B: chemistry biology and geology. – Academic Press, London.

Smith, S. L., Smith, W. O., Codispoti, L.A., Wilson, D. L. 1985. Biological observations in the marginal ice zone of the East Greenland Sea. – Journal of Marine Research. Vol. 443, 693-717.

Smultea, M. A. & Wursig, B. 1995. Behavioral reactions of bottlenose dolphins to the Mega Borg oil spill, Gulf of Mexico 1990. – Aquatic Mammals 21: 171–181.

Sonne, C., Dietz, R., Leifsson, P. S., Born, E.W., Kirkegaard, M., Letcher, R. J., Muir, D. C. G., Riget, F. F. & Hyldstrup, L. 2006. Are organohalogen contaminants a cofactor in the development of renal lesions in East Greenland polar bears (*Ursus maritimus*)? – Environmental Toxicology and Chemistry 25: 1551-1557.

Sonne, C., Dietz, R., Born, E. W., Riget, F. F., Kirkegaard, M., Hyldstrup, L., Letcher,R. J. & Muir, C.G. 2004. Is Bone Mineral Composition Disrupted by Organochlorines in East Greenland Polar Bears (*Ursus maritimus*)? – Environ Health Perspect: 112: 1711–1716.

Sonne, C., Dietz, R., Leifsson, P. S., Born, E. W., Letcher, R. J., Kirkegaard, M., Muir, D. C. G., Riget, F. F. & Hyldstrup, L. 2005. Do Organohalogen Contaminants Contribute to Histopathology in Liver from East Greenland Polar Bears (*Ursus maritimus*)? – Environmental Health Perspectives 113: 1569-1574.

Sonne, C., Dietz, R., Leifsson, P. S., Asmund, G., Born, E. W. & Kirkegaard, M. 2007. Are liver and renal lesions in East Greenland polar bears (*Ursus maritimus*) associated with high mercury levels? – Environmental Health 6: 11.

Spraker, T.R., Lowry, L.F. & Frost, K.J. 1994. Gross necropsy and histopathological lesions found in harbor seals. Pp. 281-312 in: Loughlin, T.R. (ed.), Marine mammals and the 'Exxon Valdez'. – Academic Press, San Diego, CA.

St. Aubin, D. J., Stinson, R. H. & Geraci, J. R. 1984. Aspects of the structure and composition of baleen, and some effects of exposure to petroleum hydrocarbons. – Can. J. Zool. 62(2): 193–198.

St. Aubin, D. J. 1990. Phyisiologic and toxic effects on pinnipeds. In: Geraci, J.R & St. Aubin, D.J. (eds). Sea Mammals and Oil. Confronting the Risks. – Academic Press.

Statistics of Greenland 2008. Kalaallit Ninaat/Grønland 2007. – Naatsorsueqqissartarfik/ Grønlands Statistik.

Stein, M. 2007. Warming periods off Greenland during 1800–2005: their potential influence on the abundance of cod (*Gadus morhua*) and Haddock (*Melanogrammus aeglefinus*) in Greenlandic waters. – J. Northw. Atl. Fish. Sci. 39: 1-20.

Stemmerik, L. 1990. Hvalrosø – a new breeding site for Fulmar *Fulmarus glacialis* and possibly for Little Auk *Alle alle* in East Greenland. – Dansk Orn. Foren. Tidsskr. 84: 161. (Danish, with English summary).

Stendel, M., Christensen, N. H. & Petersen, D. 2008. Arctic Climate and Climate Change with a Focus on Greenland. – Advances in Ecological Research 40, 13-43.

Stenseth, N. C., Mysterud, A., Ottersen, G., Hurrell, J. W., Chan, K. S. & Lima, M. 2002. Ecological effects of climate fluctuations. – Science 297: 1292-1296.

Stenson, G. B., Myers, R. A., Ni, H. I. & Warren, W. G. 1996. Pup production of hooded seals (*Cystophora cristata*) in the Northwest Atlantic. – NAFO Sci.Coun. Studies 26:105-114.

Stevick P. T., Allen J., Clapham P. J., Katona S. K., Larsen F., Lien J., Mattila D. K., Palsbøll P. J., Sears R., Sigurjonsson J., Smith T.D., Vikingsson G., Øien N. & Hammond P.S. 2006. Population spatial structuring on the feeding grounds in North Atlantic humpback whales (*Megaptera novaeangliae*). – Journal of Zoology 270: 244–255.

STF 2000. Utslipp på norsk kontinentalsokkel 1999. Olje, kemikalier og utslip til luft. – STF-rapport 1762/2000. – Statens forureningstilsyn, Oslo. http://www.sft.no/publikasjoner/vann/1762/ta1762.htm

Stimpert, A. K., Wiley, D. N., Whitlow W. L. A., Johnson, M. P. & Arsenault, R. 2007. 'Megapclicks': acoustic click trains and buzzes produced during night-time foraging of humpback whales (*Megaptera novaeangliae*). – Biol. Lett. 3, 467–470.

Stirling, I. 2002. Polar bears and seals in the eastern Beaufort Sea and Amundsen Gulf: A synthesis of population trends and ecological relationships over three decades. – Arctic 55 Supp.: 59-76.

Stirling, I. & Parkinson, C. L. 2006. Possible effects of climate warming on selected populations of polar bears (*Ursus maritimus*) in the Canadian Arctic. – Arctic 59: 261-275.

Strand, J. & Asmund, G. 2003. Tributyl accumulation and effects in marine molluscs from West Greenland. – Environmental Pollution 123: 31-37.

Söderkvist, J., Nielsen, T. G. & Jespersen, M. 2006. Physical and biological oceanography in West Greenland waters with emphasis on shrimp and fish larvae distribution. NERI Technical Report, No. 581. – National Environmental Research Institute. 54 pp.

Søreide, J. E., Hop, H., Carroll, M. L., Falk-Petersen, S. & Hegseth, E. N. 2006. Seasonal food web structures and sympagic-pelagic coupling in the European Arctic revealed by stable isotopes and a two-source food web model. – Progress in Oceanography 71: 59-87.

Taylor, M. K., Akeeagok, S., Andriashek, D., Barbour, W., Born, E.W., Calvert, W., Cluff, H.D., Ferguson, S., Laake, J., Rosing-Asvid, A., Stirling, I. & Messier, F. 2001. Delineating Canadian and Greenland polar bear (*Ursus maritimus*) populations by cluster analysis of movements. – Can J Zool 79: 690–709.

Taylor, M. K., Laake, J., McLoughlin, P. D., Born, E, W., Cluff, H. D., Ferguson, S. H., Rosing-Asvid, A., Schweinsburg, A. R. & Messier, F. 2005.Demography and Viability of a Hunted Population of Polar Bears. – Arctic 58(2): 203– 214.

Teloni, V., Johnson P. M., Miller J. O. P., & Madsen T. P. 2008. Shallow food for deep divers: Dynamic foraging behavior of male sperm whales in a high latitude habitat. – Journal of Experimental Marine Biology and Ecology 354:119-131

Theisen, B. F. 1973. The growth of *Mytilus edulis* L. (Bivalvia) from Disko and Thule Districts. Greenland. – Ophelia 12: 59-77.

Thibault, D., Head, E. J. H. & Wheeler, P. A. 1999. Mesozooplankton in the Arctic Ocean in summer. – Deep-Sea Res 46:1391–1415.

Thompson, D. A. W. 1928. On whales landed at the Scottish whaling stations during the years 1908-1914 and 1920-1927. – Rep. Fish. Bd Scot. Sci. Invest. 1928(3), 40pp.

Thompson, P. O., Cummings, W. C. & Ha, S. J. 1986 Sounds, source levels, and associated behaviour of humpback whales, Southeast Alaska. – J. Acoust. Soc. Am. 80: 735–740. (doi:10.1121/1.393947).

Thomsen, F., Franck, D. & Ford, J. K. B. 2002. On the communicative significance of whistles in wild killer whales (*Orcinus orca*). – Naturwissenshaften 89: 404–407.

Thorson, G. 1933. Investigations on shallow water animal communities in the Franz Joseph Fjord (East Greenland) and adjacent waters. – Meddr. Grønland 100(2): 1-68.

Thorson, G. 1934. Contributions to the animal ecology of the Scoresby Sound Fjord complex (East Greenland). – Meddr. Grønland 100(3): 1-67.

Tremblay, J. E., Hattori, H., Michel, C., Ringue, M., Mei, Z. P., Lovejoy, L., Hobsen, K. A., Amiel, D. & Cockran, K. 2006. Trophic structure and pathways of biogenic carbon flow in the eastern North Water Polynya. – Progress in Oceanography 71: 402-425.

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

Tremblay, J. E., Hattori, H., Michel, C., Ringuette, M., Mei, Z. P., Lovejoy, C., Fortier, L., Hobson, K. A., 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, J. E., Michel, C., Hobson, K. A., Gosselin, M. & Price, N. M. 2006b. Bloom dynamics in early opening waters of the Arctic Ocean. – Limnology and Oceanography 51: 900-912.

Tåning, Å. V. 1949, On changes in the marine fauna of the north-western Atlantic. – Rapports et Proces-Verbaux des Reunions du Conseil International pour l'Exploration de la Mer 125: 26–29.

Ugarte, F. 2007. White Paper on Hunting of Large Whales in Greenland. – IWC/59/ASW/8rev.

Urick, R. J. 1983. Principles of underwater sound. – Peninsula publishing, Los Altos.

Ussing, H. H. 1938. The biology of some important plankton animals in the fjords of East Greenland. – Meddelelser om Grønland 100(1), 108 pp.

Valeur, H. V., Hansen, C., Hansen, K. Q., Rasmussen, L. & Thingvad, N. 1996. Weather, sea and ice conditions in eastern Baffin Bay, offshore Northwest Greenland. A review. – DMI Technical Report No. 96-12. http://www.bmp.gl/petroleum/EB3_50ba_10na_baffinsec.pdf

Van der Oost, R., Beyer, J. & Vermeulen, N. P. E. 2003. Fish bioaccumulation and biomarkers in environmental risk assessment: A review. – Environ Toxicol Pharmacol 13:57–149

Vibe, C. 1950. The marine mammals and the marine fauna in the Thule District (Northwest Greenland) with observations on the ice conditions in 1939-41. – Meddelelser om Grønland 150: 1-115.

Vibe, C. 1967. Arctic animals in relation to climatic fluctuations. – Meddelelser om Grønland 170:1–226.

Vibe, C. 1976a. Preliminary report on the First Danish Polar Bear Expedition in North East Greenland, 1973, Pp. 74-76 in Polar Bears. Proceedings of the 5th Working Meeting of the Polar Bear Specialist Group, Le Manoir St-Prex, Switzerland, 3-5 December 1974. – IUCN Publications New Series Supplementary Paper No. 42

Vibe, C. 1976b. Preliminary report on the Second Danish Polar Bear Expedition in North East Greenland, 1974, Pp. 91-97 in Polar Bears. Proceedings of the 5th Working Meeting of the Polar Bear Specialist Group, Le Manoir St-Prex, Switzerland, 3-5 December 1974. – IUCN Publications New Series Supplementary Paper No. 42.

Vilhjálmsson, H. 1994. The Icelandic capelin stock. – Journal of the Marine Research Institute Reykjavik 13(1), 281 pp.

Visser, I. N. 2001 Orca (*Orcinus orca*) in New Zealand waters. – PhD thesis, The University of Canterbury, New Zealand.

Visser, I. N. 2005. First Observations of Feeding on Thresher (*Alopias vulpinus*) and Hammerhead (*Sphyrna zygaena*) Sharks by Killer Whales (*Orcinus orca*), which Specialise on Elasmobranchs as Prey. – Aquatic Mammals. 31(1), 83-88.

Vorkamp, K., Dam, M., Riget, F., Fauser, P., Bossi, R. & Hansen, A. B. 2007. Screening of "new" contaminants in the marine environment of Greenland and the Faroe Islands. – NERI Technical Report No. 525.

Vorkamp K., Rigét, F. F. Glasius, M., Muir, D. C. G. & Dietz, R. 2008. Levels and trends of persistent organic pollutants in ringed seals (Phoca hispida) from Central West Greenland, with particular focus on polybrominated diphenyl ethers (PBDEs). – Environmental International 34: 499-508.

Walsh, J. E. 2008. Climate of the Arctic marine environment. – Ecological Applications, 18 Supplement, 2008, pp. S3-S22.

Wardle, C. S., Carter, T. J., Urquhart, G. G., Johnstone, A. D. F., Ziolkowski, A. M., Hampson, G. & Mackie, D. 2001. Effects of seismic air guns on marine fish. – Continental shelf research. 21(8-10): 1005-1027.

Welch, H. E., Bergmann, M. A., Siferd, T. D., Martin, K. A., Curtis, M. F., Crawford, R. E., Conover, R. J. & Hop, H. 1992. Energy flow through the marine ecosystem of the Lancaster Sound region, Arctic Canada. – Arctic 45: 343-357.

Werner, I. & Gradinger, R. 2002. Under-ice amphipods in the Greenland Sea and Fram Strait (Arctic): environmental controls and seasonal patterns below the pack ice. – Marine Biology 140: 317-326.

Werth, A. J. 2001. How do mysticetes remove prey trapped in baleen? – Bulletin Museum of Comparative Zoology. 156(1): 189-203.

Whitehead, H. & Weilgart, L. 2000. The sperm whale: social females and roving males. Pp. 154–172 in: Mann, J., Connor, R.C., Tyack, P.L., Whitehead, H. (eds) Cetacean societies: field studies of whales and dolphins. – University of Chicago Press, Chicago, IL.

Whitehead, H. 2003. Sperm whales social evolution in the ocean. – The University of Chicago Press. 431 pp.

Whitehead, H. & Wimmer, T. 2005. Heterogeneity and the mark recapture assessment of the Scotian Shelf population of northern bottlenose whales (*Hyperoodon ampullatus*). – Canadian Journal of Fisheries and Aquatic Sciences, 62: 2573–2585.

Wiese, F. K., Robertson, G. J. & Gaston, A. J. 2004. Impacts of chronic marine oil pollution and the murre hunt in Newfoundland on Thick-billed Murre populations in the Eastern Canadian Arctic. – Biological Conservation 116: 205–216.

Wiig, Ø. 1995. Distribution of polar bears (*Ursus maritimus*) in the Svalbard area. – J Zool (London) 237: 515-529.

Wiig, Ø., Belikov, S. E., Bultonov, A.N. & Garner, G.W. 1996. Selection of marine mammal Valued Ecosystem Components and description of impact hypotheses in the Northern Sea Route Area. – INSOP Working paper, NO. 40 – 1996, II.4.3.

Wiig, Ø., Derocher, A. E., Gjertz, I. & Scheide, J. O. 2000. Kunnskapsstatus for isbjørn ved Svalbard og fremtidige behov for kartlegging, overvåkning og forskning. – Nor Polarinst Medd Nr. 160: 34 pp.

Wiig, Ø., Born, E. W & Toudal Pedersen, L. 2003. Movement of female polar bears (*Ursus maritimus*) in the East Greenland pack ice. – Polar Biol 26: 509-516.

Wimmer, T. & Whitehead, H. 2004. Movements and distribution of northern bottlenose whales, *Hyperoodon ampullatus*, on the Scotian Slope and in adjacent waters. – Canadian Journal of Zoology 82: 1782–1794.

Witting, L. 2008. Assessment update for West Greenland fin whales. – International Whaling Commission/Scientific/60/AWMP4. http://www.iwcoffice.org/ Web site visited 20080918.

Witting, L. & Born, E. W. 2005. An assessment of Greenland walrus populations. – ICES Journal of Marine Science 62: 266-284.

**NERI** **National Environmental Research Institute**

**DMU** **Danmarks Miljøundersøgelser**

National Environmental Research Institute, NERI, is a part of Aarhus University.

NERI undertakes research, monitoring and consultancy within environment and nature.

At NERI's website www.neri.dk you'll find information regarding ongoing research and development projects.

Furthermore the website contains a database of publications including scientific articles, reports, conference contributions etc. produced by NERI staff members.

Further information: www.neri.dk

National Environmental Research Institute
Frederiksborgvej 399
PO Box 358
DK-4000 Roskilde
Denmark
Tel: +45 4630 1200
Fax: +45 4630 1114

Management
Department of Arctic Environment
Department of Atmospheric Environment
Department of Environmental Chemistry and Microbiology
Department of Marine Ecology
Department of Policy Analysis

National Environmental Research Institute
Vejlsøvej 25
PO Box 314
DK-8600 Silkeborg
Denmark
Tel: +45 8920 1400
Fax: +45 8920 1414

Department of Freshwater Ecology
Department of Marine Ecology
Department of Terrestrial Ecology

National Environmental Research Institute
Grenåvej 14, Kalø
DK-8410 Rønde
Denmark
Tel: +45 8920 1700
Fax: +45 8920 1514

Department of Policy Analysis
Department of Wildlife Ecology and Biodiversity

## NERI Technical Reports

NERI's website www.neri.dk contains a list of all published technical reports along with other NERI publications. All recent reports can be downloaded in electronic format (pdf) without charge. Some of the Danish reports include an English summary.

**Nr./No.** **2009**

716 Annual Danish informative inventory report to UNECE. Emission inventories from the base year of the protocols to year 2007.
By Nielsen, O-K., Winther, M., Mikkelsen, M.H., Hoffmann, L., Nielsen, M., Gyldenkærne, S., Fauser, P., Plejdrup, M.S., Albrektsen, R. & Hjelgaard, K. 498 pp.

714 Vandmiljø og Natur 2007. NOVANA. Tilstand og udvikling – faglig sammenfatning.
Af Nordemann Jensen, P., Boutrup, S., Bijl, L. van der, Svendsen, L.M., Grant, R., Bøgestrand, J., Jørgensen, T.B., Ellermann, T., Dahl, K., Josefson, A.B., Ejrnæs, R., Søgaard, B., Thorling, L. & Dahlgren, K. 118 s.

713 Arter 2007. NOVANA.
Af Søgaard, B. & Asferg T. (red.). 140 s.

712 Terrestriske Naturtyper 2007. NOVANA.
Af Ejrnæs, R., Nygaard, B., Fredshavn, J.R., Nielsen, K.E. & Damgaard, C. 150 s.

711 Vandløb 2007. NOVANA.
Af Bøgestrand, J. (red.). 108 s.

710 Søer 2007. NOVANA.
Af Jørgensen, T.B., Clausen, J., Bjerring Hansen, R., Søndergaard, M., Sortkjær, L. & Jeppesen, E. 68 s.

709 Landovervågningsoplande 2007. NOVANA.
Af Grant, R., Pedersen, L.E., Blicher-Mathiesen, G., Jensen, P.G., Hansen, B. & Thorling, L. 128 s.

708 Atmosfærisk deposition 2007. NOVANA.
Af Ellermann, T., Andersen, H.V., Bossi, R., Christensen, J., Geels, C., Kemp, K., Løfstrøm, P., Mogensen, B.B. & Monies, C. 97 s.

707 Marine områder 2007 – Tilstand og udvikling i miljø- og naturkvaliteten. NOVANA.
Af Dahl, K. & Josefson, A.B. (red.) 113 s.

706 Beregning af naturtilstand for vandhuller og mindre søer. Tilstandsvurdering af Habitatdirektivets søtyper.
Af Fredshavn, J.F., Jørgensen, T.B. & Moeslund. B. 38 s.

705 Hazardous substances and heavy metals in the aquatic environment. State and trend, 1998-2003.
By Boutrup, S. (ed.), Fauser, P., Thomsen, M., Dahllöff, I., Larsen M.M., Strand, J., Sortkjær, O., Ellermann, T., Rasmussen, P., Jørgensen, L.F., Pedersen, M.W. & Munk, L.M. 44 pp.

704 Contaminants in the traditional Greenland diet – Supplementary data.
By Johansen, P., Muir, D., Asmund, G. & Riget, F. 22 pp.

703 Projection of Greenhouse Gas Emissions 2007 to 2025.
By Nielsen, O-K., Winther, M., Mikkelsen, M.H., Gyldenkærne, S., Lyck, E., Plejdrup, M., Hoffmann, L., Thomsen, M., Fauser, P. 211 pp.

702 Rastende vandfugle i Margrethe Kog og på forlandet vest for Tøndermarsken, 1984-2007.
Af Laursen, K., Hounisen, J.P., Rasmussen, L.M., Frikke, J., Pihl, S., Kahlert, J., Bak, M. & Amstrup, O. 78 s.

700 Drivhusgasopgørelse på kommuneniveau. Beskrivelse af beregningsmetoder.
Af Nielsen, O.-K., Winther, M., Gyldenkærne, S., Lyck, E., Thomsen, M., Hoffmann, L. & Fauser, P. 104 s.

699 Omsætning af formalin i danske dambrug.
Af Sortkjær, O., Pedersen, L-F. & Ovesen, N.B. 126 s. (2008)

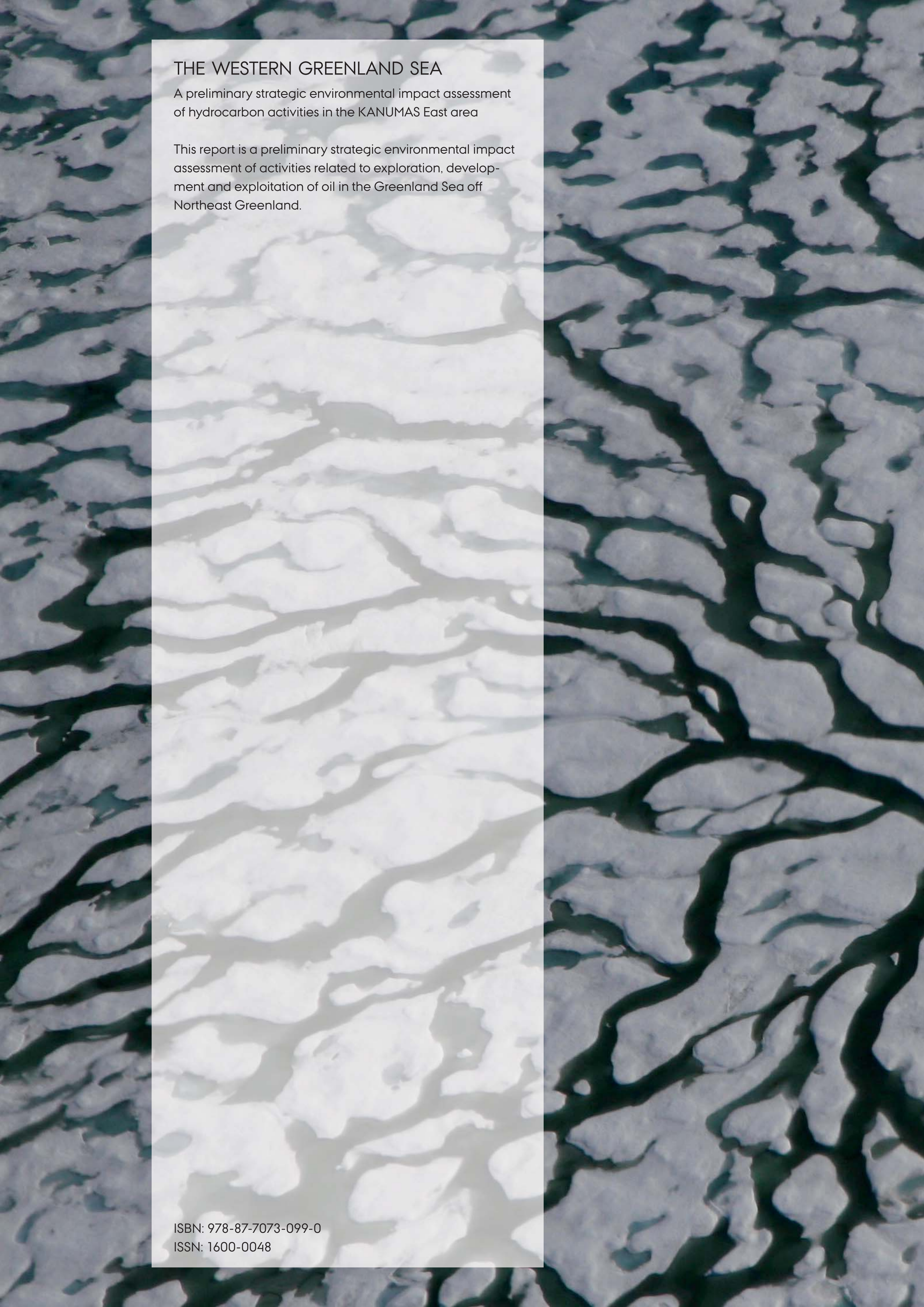
698 Environmental monitoring at the Nalunaq Gold Mine, South Greenland, 2008.
By Glahder, C.M., Asmund, G. & Riget, F. 30 pp.

**2008**

697 OML-spredningsberegninger på basis af 10 års meteorologi i relation til Luftvejledningen.
Af Løfstrøm, P. & Olesen, H.R. 35 s.

696 Beregning af skovtilstand – tilstandsvurdering af Habitatdirektivets skovtyper.
Af Fredshavn, J.R., Johannsen, V.K., Ejrnæs, R., Nielsen, K.E. & Rune, F. 48 s.

695 Værdisætning af natur- og kulturgoder. Et metodestudie af betydningen for ændringer i skala og betalingsformat. Af Hasler B., Jacobsen, J.B., Lundhede, T.H., Martinsen, L., Thorsen, B.J. 78 s.



# THE WESTERN GREENLAND SEA

A preliminary strategic environmental impact assessment of hydrocarbon activities in the KANUMAS East area

This report is a preliminary strategic environmental impact assessment of activities related to exploration, development and exploitation of oil in the Greenland Sea off Northeast Greenland.

ISBN: 978-87-7073-099-0
ISSN: 1600-0048