THE EASTERN BAFFIN BAY

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

NERI Technical Report no. 720 2009

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Aqqalu Rosing-Asvid (GINR): Seals
Frank Riget (NERI): Arctic char
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Abstract: This report is a preliminary strategic environmental impact assessment of activities related to exploration, development and exploitation of oil in the Baffin Bay off northwest Greenland.

Keywords: Strategic environmental impact assessment, SEIA, oil exploration, oil exploitation, oil spill, Baffin Bay, northwest Greenland, fauna.

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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 forms part of this process and deals with the KANUMAS area in Northwest Greenland: the KANUMAS West 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 licencing 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.

Acknowledgement

Malene H. Petersen and Marie Frandsen compiled the reference list. Kristin Laidre and Mads Peter Heide-Jørgensen (GINR) supplied data and information on whales. Flemming Getreuer Christiansen (GEUS) supplied the potential drill sites for oil spill modelling.

The sections on weather, oceanography and ice conditions are modified from a DMI contribution to the oil spill sensitivity map covering the West Greenland region between 68° and 72° N (Mosbech *et al*. 2004).

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 Northwest Greenland between 71° and 78° N. The KANUMAS West 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 Greenland Sea – the KANUMAS East area.

The prospecting licence did not include any exclusive rights to the licensee. The licence implied a considerable obligation of exploration. This was balanced by granting the companies a special preferential position for the KANUMAS group. 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 a large oil spill deriving from activities within the expected licence areas, although drift modelling indicates that oil 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 conditions of the study area are briefly described with focus on oceanography and ice conditions. Sea ice and icebergs are present throughout the year, with the lightest conditions in the period July-October. One of the most important physical features of the biological environment is the polynyas (ice-free or almots ice-free areas surrounded by sea ice), of which the most important is the North Water between the Qaanaaq area and Ellesmere Island in Canada. Polynyas become free of ice very early in spring (April) and also have ice-free parts throughout the winter, and particularly the North Water is an important winter habitat for marine mammals. Another important feature is the shear zone along the fast ice. Here open water often occurs in winter.

An updated account of some of the physical conditions is under preparation by the Danish Meteorological Institute (DMI).

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 and with a few species playing a key role in the ecology of the region (Figure 10). In the marine environment the most significant event is the spring bloom of planktonic algae, the primary producers in the food web. These are grazed upon by zooplankton, including the important copepods *Calanus*, which is one of the key species groups in the marine ecosystem (Figure 10).

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.

Northern shrimp is found in the southern part of the assessment area and a commercial fishery takes place here.

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 again 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.

The 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 locally Arctic char.

Seabirds are locally abundant with several species present in the study area in summer and spring. Many species breed in dense 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 breeding sites in Northwest Greenland and Arctic Canada and winter grounds in Southwest Greenland and Newfoundland. Some of the most important species are northern fulmar, common eider, thick-billed murre, little auk, black-legged kittiwake and ivory gull (Table 1). Almost all the marine birds leave the area for the winter to return in April and May. Thick-billed murre, common eider, black-legged kittiwake and ivory gull are all red-listed in Greenland due to declining populations. Other red-listed bird species which occur in the marine part of the assessment area include Sabines gull, Arctic tern and Atlantic puffin.

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, as an estimated 80 % of the global population breed on the coasts of the former Qaanaaq municipality. Other national responsibility species are black guillemot and light-bellied brent goose.

Marine mammals are significant components of the marine 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 is narwhal, white whale, bowhead whale, walrus, ringed seal and polar bear (Table 2). They are often associated with ice edges, polynyas or shear zones, where open water is present.

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

Human use of natural resources occurs throughout the assessment area, except for the most offshore parts. Subsistence hunting (marine mammals and seabirds) and subsistence fishery takes place near the towns and settlements. Commercial fishery takes place in the southern part of the assessment area and is aimed at Greenland halibut and northern shrimp. Greenland halibut and northern shrimp catches in offshore waters constitute a small proportion of the total Greenlandic catch, while the inshore fishery of Greenland halibut in the former Uummannaq and Upernavik municipalities is significant.

Tourism is a relatively new and growing industry in Greenland and this is also the case in the assessment area, where activities take place from early spring (April) and throughout the summer.

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 (June–October). 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 in affected areas.

Marine mammals, particularly whales, may also be displaced from critical areas such 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 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 producued 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. This will probably only be a problem in the offshore areas where a relatively limited fishery for Greenland halibut and northern shrimp takes place.

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, white whale 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 probably the most sensitive species in this respect, because the population is dependent on relatively few, localised and shallow 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, in some shallow areas, a risk 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 of 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 reduce the importance of traditional hunting grounds used by local people.

Finally, placement of structures and installations 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 sensitve 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 (Skjoldal *et al*. 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 the species level. Furthermore, the lack of adequate response methods in ice-covered waters and the remoteness and lack of infrastructure in large parts of the assessment area will 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 KANUMAS West 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, three of the 24 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 West, which is dominated by sea ice during 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, spawning capelin 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 of the assessment area intensively.

Long-term impacts may occur if oil is buried in sediments, among boulders, in mussel beds or is imbedded in crevices in rocks. From such sites oil may seep and cause a 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 West assessment area is very limited.

Bird populations particularly at risk of being impacted by an oil spill in the KANUMAS West area include the large breeding colonies of little auk and the many thick-billed murre colonies. Many other seabird breeding colonies will also be exposed. Pre-breeding eiders and murres in polynyas and the shear zone will be very exposed. Moulting aggregations of king and common eiders are also very sensitive.

Several populations of red-listed seabird species (e.g. thick-billed murre, common eider, Atlantic puffin, Sabines gull and 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 now is slowly recovering from heavy exploitation. This recovery may be halted by even a slight increase in mortality. The population of narwhal and white whale have both decreased in the assessment area, so they may also be sensitive to additional mortality from an oil spill.

There are special problems related to oil spills in ice. The spread of an oil spill will, at least in the beginning, tend to be contained and limited by the presence of sea ice, unlilke in the open sea. 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, white whales and bowhead whales, which often occur in densely ice-covered waters. In the case of a large oil spill in densely ice-covered waters the limited open waters will be covered by oil, and whales could surface here because they have no other option. Walruses and other seals living in the ice may also be vulnerable to this scenario.

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 distribution and habits of quarry species.

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 West 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 to be issued in 2010. See section 13 for a review of the projects.

However 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. On the other hand, a number of knowledge gaps are specific to the assessment area.

Dansk resumé

Foreløbig, strategisk miljøvurdering af olieaktiviteter i KANUMAS West-området

Denne rapport er en foreløbig, strategisk miljøvurdering af aktiviteter forbundet med olieefterforskning og -udvinding i den grønlandske del af Baffin Bugt i Nordvestgrønland. Nærmere bestemt farvandet mellem 71° og 77° N (Figur 1). Dette område betegnes KANUMAS West-området.

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 Grønlandshavet – KANUMAS East.

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

Forundersøgelsestilladelsen indebar ikke nogen eneret for licenshaverne. 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 West-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 meget rigt i biologisk/økologisk forstand. Primærproduktionen om foråret er visse steder meget 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, ederfugl, ride, havterne og lunde. Blandt havpattedyrene er der vigtige (både nationalt og internationalt) arter som isbjørn, hvalros, narhval, hvidhval og grønlandshval.

Et meget væsentligt biologisk område er det store polynie, Nordvandet, beliggende mellem Qaanaaq Kommune og Ellesmere Island. Her er mere eller mindre isfrit om vinteren og om foråret starter primær-produktionen meget tidligere end i de omkringliggende isdækkede områder. Dette medfører koncentrationer af havpattedyr og fugle, som bl.a. har gjort det muligt for mennesker at etablere sig permanent i området. Langs de grønlandske kyster af dette polynie yngler for eksempel mere end 80 % af den globale bestand af den meget talrige søkonge; vurderet til mere end 30 millioner par. De vigtige arter af fugle og havpattedyr som er nævnt ovenfor forekommer særligt talrigt i polyniet.

Hellefisk og rejer udnyttes kommercielt i den sydlige del af vurderingsområdet og fangst og fiskeri til lokalt brug er vigtige aktiviteter langs de beboede kyster.

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 til ind i 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.

Vinterperioden er særligt følsom overfor støjende aktiviteter bl.a. på grund af forekomster af hvidhval, narhval, grønlandshval, hvalros og remmesæl, men efterforskningsaktiviteter forventes ikke i de perioder, hvor de fleste af disse arter er til stede. Narhvaler har dog et vigtigt sommerområde i Melville Bugt, og der er tillige vigtige trækruter for både nar- og hvidhvaler gennem Melville Bugt og langs kysten af Upernavik og Uummannaq Kommuner, som benyttes endnu inden vinteren sætter en stopper for olieefterforskningsaktiviteter.

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. Men 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.

Seismiske undersøgelser forventes ikke at påvirke rejebestandene eller deres fordeling i området.

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. Denne kan skræmme havpattedyr og særligt hvaler angives at være følsomme. Der er derfor risiko for at særligt narhvaler, hvidhvaler, grønlandshvaler og hvalros kan blive bortskræmt fra vigtige opholdsområder. For hvidhval, grønlandshval og hvalros er risikoen dog lille, da deres tidsmæssige overlap med en prøveboring bliver begrænset til en kort periode i det sene efterår. Der er også risiko for midlertidig bortskræmning af fin-, våge og pukkehval i sommermånederne. Dette kan tænkes at påvirke fangstmulighederne i den periode aktiviteterne står på.

Den væsentligste risiko for miljøpåvirkninger under en efterforskningsboring opstår i forbindelse med uheld (”blow-out”), 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 West-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 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.

Energiforbruget ved udvikling og produktion er meget stort, og anlægget af et stort oliefelt i KANUMAS West-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 bortskræmmes permanent fra vigtige fourageringsområder eller således at de ændrer trækruter. I KANUMAS West-området er det især narhval, hvidhval, 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 landskablige 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 grønlandske 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 (Skjolddal *et al.*2007) vurderer at risikoen for oliespild i Arktis er størst i forbindelse med transport af olie.

DMI har modelleret drivbanerne for oliespild i KANUMAS West-området med udgangspunkt i fire spildsteder. De viser at oliespild med oprindelse langt til havs som regel ikke vil nå kysterne, men ved visse forhold kan kyster op til flere 100 km fra spildstedet blive påvirket. 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 West 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. gydende lodde (ammassat), 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, i strande med rullesten og i muslingebanker, 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 West-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 bestandene af rejer og hellefisk, de vigtige arter for det grønlandske fiskeri.

Fugle er særligt sårbare overfor oliespild på havoverfladen, og i KANUMAS West-området er der talrige meget udsatte fugleforekomster. Ynglefuglene omfatter ofte store kolonier af polarlomvie, søkonge, ederfugl, havterne og lunde, ligesom der er vigtige forekomster af fældende kongeederfugle.

Havpattedyr kan også påvirkes af oliespild på havoverfladen. Indenfor KANUMAS West-området forekommer bestande som er særligt sårbare, fordi de i forvejen påvirkes af andre menneskelige aktiviteter – primært fangst. Det gælder hvidhval, narhval og hvalros, hvis bestande alle er for nedadgående. Hvalros og remmesæl lever desuden af bunddyr, og kan blive udsat for at indtage olie med deres føde. 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 bestand, som først for nyligt er begyndt at vise tegn på fremgang, efter at have været næsten udryddet i begyndelsen af 1900-tallet. Bestanden er stadig lille, og 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 og 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 West-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.

Der er allerede igangsat supplerende regionale strategiske studier i Disko West-området, som ligger umiddelbart syd for området behandlet i denne rapport. Resultaterne fra disse vil være meget relevante i KANUMAS West-sammenhæng.

Imaqarniliaq kalaallisooq

Utaaqqiisaagallartumik KANUMAS WEST-imi uuliasiornikkut ingerlatanut tunngatillugu siumut isigaluni avatangiisinik naliliineq

Nalunaarusiaq una utaqqiisaagallartumik Kalaallit Nunaata kitaata avannaani uuliamik ujarlernermut piiaanermullu tunngatillugu ingerlatanut siumut isigaluni avatangiisinik naliliineruvoq. Erseqqissumik oqaatigalugu imartami allorniusat 71° aamma 77° N-ip akornanniittumi (Titartagaq 1). Tamanna taaneqarpoq KANUMAS West-områdemik.

KANUMAS tassaavoq tamaani sajuppillatitsisarluni ujarlernissamik pilersaarut 1989-ip naalernerani aallartinneqartoq. Ingerlatseqatigiiffiit ataatsimoorussisut – KANUMAS gruppen – taamanikkut KANUMAS-eqarfinni, aamma Grønlandshavet-p kalaallinut atasortaanittumi – Kanumas East-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 West-ip ingerlatsivissaanit annertunerusoq (takuuk titartagaq 1). Tamatumunnga pissutaavoq uuliaarluernerup neqeroorutigineqartussamiit sumorujussuaq siaruaassinnaanerata ilanngunneqartussaanera. Nalunaarusiami naatsorsuutigineqartoq tamanna ”the assessment area”-mik (nalilersuiffigineqartumik), taagorneqarpoq.

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

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

Biologiip tungaatigut pingaaruteqartorujussuaq tassaavoq Aakkarnersuaq, Nordvandet, Qaanaap kommuniata Ellesmere Islandillu akornannittoq. Tamanna ukiuugaluartoq ammaannangajattuusarpoq upernaakkullu uumasuaqqanik pinngorartitsineq tamaani eqqaaniittunut suli sikkuusunut naleqqiullugu piaarnerujussuarmik aallartittarluni. Taamaanera pissutigalugu immaq tamanna miluumasut imarmiorpassuit timmiarpassuillu katersuuffigisarpaat, ilaatigullumi tamaani inuit nunassivissinnaanerannik tunngavissaliisimalluni. Assersuutigalugu Aakkarnersuup tamatuma Kalaallit Nunaannut sineriai atuarlugit silarsuarmi appaliarsuit tamarmiusut 80 %-ii sinnerlugit piaqqisarput; nalilerneqarsimallutillu aappariikkuutaat tamaaniittut 30 millionit sinneqassasut. Uumasut pingaarnerit tassaapput timmissat assigiinngisitaartut miluumasullu imarmiut qulaani oqaatigineqartutut aakkarnersuarmi ingasavittartut.

Qalerallit kinguppaallu nalilersuiffiup kujasinnersssortaani iluanaarniutigalugit aalisarneqarput aammalu nammineq atugassanik piniarneq aalisarnerlu inoqarfinni sinerissamiittuni ingerlataapput pingaaruteqartut.

Uuliasiorfimmi ukioq kaajallallugu inuuneq ingerlasartoq sapinngisamik ingerlatat pisartullu misilittakkat tunngavigalugit avatangiisinut sunniuteqarnerusartut pingaarnerutillugit nalilersorniarneqarsimapput. Kalaallit Nunaannili uuliamik piiaanermik misilittagaqartoqanngimmat tassunga tunngatillugu ingerlatanik nalilersuinerit aalajangersumut tunngatinneqanngillat, allamili, sapinngisamik maani pissutsinut assersuunneqarsinnaasumiittuni misilittakkanik tunnavilersorniarneqarsimallutik. Pingaartumik Prince William Sound-imi, Alaskamiittumi 1989-imi uuliaarluerujussuarnermut tunngatillugu naqitigarpassuit, norskit Barentshavet-mi (2003) uuliasiornikkut ingerlatanut tunngatillugu avatangiisinik naliliinerat aamma Arktisk Råd-ip nalunaarusiaa saqqummerlaavik ”Arctic Oil and Gas Assessment”, suli manna tikillugu ilaanakortumik internet-ikkut takuneqarsinnaasoq, isumassarsiorfigineqarsimapput (Link).

Ingerlatanik naliliinerit

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

Ujarlerneq

Uulliamik ujarlernikkut ingerlatat utaqqiisaannaagallarput, tammannalu ukiualunnik sivisussuseqarajuppoq, tamakkualu amerlanertigut akuersissuteqarfimmi sumi tamaani simmarsimallutik ingerlanneqartarlutik. Aammalu tamakkua imarorsimanerinnaani, tassa aasaanerani ukiakkut oktoberip ingerlalerneranut ingerlanneqartarput. Uuliamik iluaqutigineqarsinnaasumik nassaartoqanngikkaangat ingerlatat unitsivinneqartarput. Uuliamilli nassaartoqaraangat ingerlatat piiaaninngorlutik uuliaqarfimmik iluaquteqarninngortarput, (ataaniittoq takuuk).

Ujarlernikkut ingerlatat sunniineri pingaarnerit tassaasarput nipiliornikkut akornusersuinerit (soorlu sajuppillatitsisarluni misissuinertigut, immap naqqani qillerinikkut helikopterimillu ingerlasoqartarneratigut). Ilimagineqarpoq sulliviginegartorpiami annertoorsuunngitsumik qaangiukkumaartumillu tammakua sunniuteqarumaartut, tassami sunniutissat pikkunarnerusut pinngitsoorneqarsinnaammata mianersortumik iliuuseqarnikkut, soorlu ingerlatat sumiiffinni piffissanilu sunniuteqarnerluffiusinnaasuniitsinnaveersaarnerisigut.

Pingartumik ukiuunera ingerlatanik nipiliortunik misikkariffiusarpoq, pingaartumik ilaatigut qilalukkat qaqortat qernertallu, arfiviit, aarrit ussuillu tamaaniittarmata, ujarlernikkulli ingerlatat ukiup taamaalinerani, uumasut taagorneqartut tamaaniinnerata nalaani, ingerlanneqartarnissaat naatsorsuutigineqanngilaq. Qilalukkalli qernertat aasaanerani Qimusseriarsuarmiittarnerat pingaartorujussuuvoq, aammalumi qilalukkat qaqortat qernertallu sineriak Upernaviup Uummannallu kommuuniiniit, uuliasiornikkut ingerlatat ukiunerani unitsinneqartinnagit atorneqartartut, aqqusaarlugit Qimusseriarsuakkoortumik ingerlaartarfeqarput.

Annertuumik sajuppillatitsisarluni misissuinerit qalerallit tamaaniittut qimagukkallartissinnaagunarpaat, tamannalu aalisarfinni pingaaruteqartuni pissappat misissuinerit aalisarnermut ajortumik sunniuteqarsinnaassapput. Aalisakkanilli allanik misissuinerit taamattut sunniuteqarneq sivisunavianngitsutut isigaat. Suffisarfiit nalinginnaasumik sajuppillatitsisarluni misissuinernit ajoquseruminartutut isigineqartarput, qalerallilli nalilersuiffimmi suffineq ajorput taamaattumillu tamaani taanna ajornartorsiutaanngilaq.

Sajuppillatitsisarluni misissuinernit kinguppannut tamaaniittunut imaluunniit tamaani sumiiffinnut assigiinngitsunut agguataarsimanerannut sunniuteqarnissaat ilimagineqanngilaq.

Miluumasut imarmiut neriniarfimminni ingerlaartarfimminnilu misissuinerit akornusersuinerat pissutigalugu qimagussinnaanerat aarleqqutigineqarsinnaavoq. Kisiannili taamatut sunniuteqarnera sivikitsuinnaajumaartoq naatsorsuutigineqarpoq (immaqa sapaatip akunnialuinik qaammatinilluunniit), tamatumani ingerlatat unittussaanerat tunngavigineqarpoq.

Uppernarsineqarnikuuvoq qamutillit silaannarmik imaqartut sajuppillatitsisarnikkut misissuinermi atorneqartartut aalisakkat suaannik aalisagaaqqanillu tukerlaanik toqutsisinnaammata taakkua 5 m sinnernagu ungasissuseqarsimagaangata. Aalisakkat piaqqiverujussuini annertuumik sajuppillatitsisarluni misissuinerit aalisagaaqqanik tukerlaanik amerlasuunik toqoraasinnaanerat aalisakkat inersimasut amerlassusiannut sunniuteqarsinnaanera Norgime aarleqqutigineqarpoq. Taamatut aalisagaaqqat amerlasoorsuuffiinik kalaallit imartaanni ilisimasaqartoqanngilaq, amerlasuullu taamatut ataatsimoortarnerat upernaakkut pisarpoq sajuppillatitsisarluni misissuinerit nalinginnaasumik aallartittarnerat sioqqullugu. Sajuppillatitsisarluni misissuinerit annertunerusumik aalisagaqatigiinnut sunniuteqarnissaat aarlerigisariaqanngitsoq naliliineqarpoq.

Ujarlerluni qillerisarnerit ingerlatanut nipiliortunut ilaapput. Qillerineq namminneq, aammalu maskiinat sarpiillu qilleriviusumik illikarnaveersaartitsisut (qilleriviusussani tamani imaq qilleriviit naqqanut tunngatillugit qajannaakkat atornissaannut itivallaarpoq) sakkortuumik nipiliortuupput. Taamatut nipiliornermut miluumasut imarmiut, minnerunngitsumillu arferit, misikkarissuunerarneqartarput. Taamaattumik qilalukkat qaqortat qernertallu, arfiviit aarrillu najortakkaminnit pingaaruteqartuniit qimaatinneqarnissaat aarleqqutigineqarsinnaavoq. Qilalukkanulli qaqortanut, aarfivinnut aavernullu tunngatillugu aarlerianartoq anikitsuinnaavoq, tassami misiligaalluni qillerinerit ukiarluarneranik naleruisimasarnerat sivikitsuinnaasarmat. Aammali tikaagulliusaat, tikaagulliit qipoqqaallu aasap qaammataani qimaatinneqarsinnaanerat aarleqqutissaavoq. Tamatumalu tamakkua piniarneqarnerannut periarfissanik sunniisinnaanera ilimanarsinnaavoq taamaalineranimi piniarneq ingerlanneqartarmat.

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

Qillerinikkut qillernerlukut 450 m^3 missiliortut pilersinneqartaput aammalu qilleriffiup sulluanut maralluk 2000 m^3 missaanik annertussusilik atorneqartarluni. Qillernerlukut taakkua salinneqareeraangata immap naqqanut igiinnarneqarajupput. Taakkualu immap naqqata uumasui qanituminniittut sunnertarpai. Sunniutilli suli erseqqinnerusarput maralluk qillerinermut atorneqartoq uuliamik tunngaveqartoq atugaagallarmat, ullumikkummi taanna avatangiisinut naleqqunnerusunik imermik tunngaveqartunik taarserneqarsimavoq.

Maralluup qillerinermut atorneqartup qillernerlukullu KANUMAS West-imi sunniutissaat nalileruminaatsuupput, tassami immap naqqani uumasuusunut tunngatillugu ilisimasat annertunngeqimmata. Ilimagineqarporli ujarlernermut ataatsimut atatillugu qillerinerup sunniutigiumaagai annikitsuinnaajumaartut maralluk qillerinermut atorneqartartoq avatangiisinut sallaannerusoq atorneqarsimappata. Sunniutissat pinngitsoorneqarsinnaapput maralluk qillerinermut atugaq qillernerlukullu nunamut qallorneqartuuppata imaluunniit pumpi atorlugu qillerinerup naammassineratigut qilleriffikumut immiunneqartartuuppata.

Ineriartortitsineq tunisassiornerlu

Ujarlernermi ingerlatanut naleqqiullugu uuliaqarfiup ineriartortinneranut uuliamillu tunisassiornissamut atatillugu ingerlatat sivisoorujussuarmik (ukiuni qulikkuutaanni arlalinni) ingerlanneqarsinnaapput, ingerlatallu tamakkua ilarpassui avatangiisinut annertuumik ajoqusiisinnaasuupput. Tamakkua sunniutaasinaasut sukumiisumik pilersaarusiornikkut, periaatsinillu ”Health, Safety and Environment” (HSE)-imi, ”Best Available Technique” (BAT)-imi aamma ”Best Environmental Practice” (BEP)-imi akuerisaasunik atuinikkut sillimaffigineqarluarsinnaapput. 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 imermik 30.000 m^3 tikillugu annertussusilimmik aniatitsisinnaavoq, ukiorlu kaajallallugu norskit uuliasiorfiini imeq 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 erngup taamaattup immamut akuleruttarnera annikillisinneqartarmat erngup tunisassiornermi atukkap aniatinneqarneranut atatillugu aamma allanik ajornartorsiuteqarpoq. Avatangiisinut tunngatillugu erngup tunisassiornermut atorneqartup aniatinneqarneratigut avatangiisitigut ajornartorsiuteqalernissaq pinngitsoorneqarsinnaavoq imeq taamaattoq norskit Barentshavet-mut tunngatillugu ”zero-discharge” –imik politikkianni nassuiarneqartutuut imeq taanna uuliap aniavianut pumperlugu uterartinneqarneratigut.

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

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

Sanaartukkat sumiinnerata akornusersuutillu taakkuninngaanniit pisut miluumasut imarmiut sunniuteqarnerluffigisinnaavaat neriniarfinnaaminnit qimagutivitinneqarsinnaammata ingerlaartarfimminnillu allanngortitsisariaqalersinnaagamik. KANUMAS West-imi qilalukkat qernertat, qaqortat, arfiviit aarrillu pingaartumik aarleqqunnarnerupput. Taamaalisappallu aamma tamatuma uumasunik piniagarineqartunik taakkuninnga piniarniarneq ajornarnerulersissinnaavaa.

Sanaartugassat nunamut inissinneqarneratigut taamaattut nunap ilusaanut sunniutissaat nalilersorneqarlutillu annikillilerniarneqartariaqarput, tassami nunap tamatut atorneqartup takornarianit soqutiginannginnerulerneranik kinguneqarsinnaammat.

Annertuumik helikopterinik angallanneq timmissat miluumasullu imarmiut najugannaaviniit pingaarutilinniit tatamisillugit qimaatinneqarnerannik aamma kinguneqarsinnaavoq.

Ineriartortitsiviusumi tunisassiorfiusumilu immap naqqatigut atortulersuutit (piiaaviup milluaavii ruujorillu) qilleriveqarfiillu assigiinngitsut allat ivertissorneqarnerisigut aalisarneq periarfissamigut annikillileriffigineqassaaq. Sanaartukkammi taammaattut isumannaallisaaneq pissutigalugu nalinginnaasumik 500 m-init qaninneruleqqusaaneq ajorput.

Uulia tunisassiarineqartoq umiarsuarnik uuliamik usilersulersinnatik imermik ballasterisimasaminnik igitseqqaartartussanit, assartorllugu aallarussorneqartussaavoq. Taamatut igitsisarneq uumasut kissaatigineqanngitsut (imaappoq tamaani uumasooreersunik tatisillutik siaruariartortarsinnaasut) kalaallit imartaanni takornartaagaluartut eqqunegartalernissaannut aqqutaasinnaavoq. Ajornartorsiut taanna Issittumi imatorsuaq ajornartorsiortitsisimanngilaq, kisiannili klimap allanngoriartornerata kinguneranik annertusiartorsinnaasorineqarpoq. Aarlerinartuali annikillisinneqarsinnaavoq erngup ballasterineqarsimasup igitsinnagu saleqqaarneqartarneratigut.

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

Uuliaarluerneq

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

Ullutsinni uuliamik aniasoorujussuarnerit qaqutigoortorujussuanngornikuupput isumannaallisaanikkut iliuusaasartut pitsanngorsarneqartuarmata. Aarlerinartuali taannaajuarpoq, pingaartumik ”frontier”-områdini, kalaalit imaartaasut ittuni, iluliaqartarnerarta ajutoorsinnaaneq ajunaarsinnanerluunniit annertunerulersittarmagu. AMAP (2007)-imi naliliivoq Issittumi uuliaarluertoqarnissaanut aarlerinartup annersaa uuliamik assartuinermiittoq.

DMI-p KANUMAS West-imi uuliaarluernikkut uuliap siammariartorfissaa assersuusiorsimavaa uuliaarluerfinnut assigiinngitsunut sisamanut tunngatillugu. Taassuma takutippaa avasissorsuarmi uuliaarluerneq sinerissamut tipigajunngitsoq, pissutsilli assigiinngitsut pissutaallutik sineriak mingutitsiviusumiit 100 km ungasissusilik uuliaarluernermit eqqorneqarsinnaasoq.

Sinerissap qanittuani uuliaarluernerit avasissumi uuliaarluernernit ajorqusiinerujussuusartutut isigineqarput. KANUMAS West-itulli ittumut tunngatillugu taamatut oqaneq allanngortittariaqarpoq. Tamatumunnga pissutaavoq sikoqartarnera sikullu uuliamik tigusisarnera aammalu sikup uuliamik allanngortitsinngingajavilluni ungasissorujussuaq tikillugu 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 ammassanik suffisunik, natermiunik ikkannersuarni 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 West-imili eqqaanilu isiginngitsuusaarneqarsinnaanngilaq avasissumi uuliaarluernerugaluartoq ulorianartorsiortitsilluinnarsinnaammat. Taamaattulli sorpiamiinnersut tikkuarnissaannut ilisimasat naammanngillat. Taamaattut tassaasinnaapput frontzonit, ”up-welling”-ngeqarfiit (sarfap samannga pikialaarfii) upernaakkut uumasuaqqat pinngorarfigilluartagaat aammalu quajaatit naasuusut uumasuaqqallu tappiorarnartut imartani taamaattuni immap qaavata tungaa eqiterusimaffigilluinnartagaat.

Uuliamilli aniasoornerup kinguppannut qaleralinnullu, kalaallit aalisarneranni pingaarnerpaajusunut, sunniuteqarnissaa ilimananngilaq.

Timmissat immap qaavata uuliaarluerfigineqarneranut misikkarissorujussuupput, KANUMAS West-imilu taamaalisoqarneratigut navianartorsiortunneqarsinnaasut timmiaqatigiippassuupput. Timmissanut tamakkununnga ilaapput apparpassuit, appaliarsuit, mitit, imeqqutaallat qilanngallu piaqqiortut, aammalumi mitit siorakitsut tamaani isaasartut.

Miluumasut imarmiut immap qaavata uuliaarluerfigineqarneratigut sunnerneqarsinnaapput. KANUMAS West-illu iluaniipput uumasut tamakkua taama pisoqarneratigut eqqornerlukkuminarnerpaat, tassami inuit ingerlataannit allanit sunnersimaneqareeramik – pingaartumik piniarneqarnermikkut. Taakkua tassaapput qilalukkat qaqortat qernertallu, aaveq, kinguliimmi taakkua ikkiliartoreersuupput. Aaveq ussullu aamma natermiunik nerisaqartuupput, taamaattumillu nerisamik uuliaarluerfigineqarneratigut eqqornerlunneqarsinnaallutik. Misissuinerittaaq nutaat pasinarsisippaat aarluit (immaqalumi aamma arferit allat) uuliap aniasoortup aalarneranik najuussuinermikkut ajoquserneqarsinnaasut.

Nannut aamma ajoquseruminartorujussuupput meqquminnimi uuliaarluernernik aluttuillutik saliisarneq ileqqorigamikku taamaalillutillu uuliakkut iijorakkamikkut toqunartortorsinnaallutik. Arfiviit tamaaniittartut arfeqatigiiupput 1900-ikkut aallartinneranni nungutaangajaluinnariarlutik aatsaat qanittukkut amerliartornerannik malunnarsisinut ilaasut. 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.

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

Misissueqqinnerit

Avatangiisinik nalilersuilluni suliaq aallartimmat erseqqissivoq KANUMAS West-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 avatangiisinik 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. Disko West-imi, misissuiffiup uani sammineqartup kujatinnguaniittumi, taamatut ilassutaasunik sumiifimmut aalajangersumut tunngatillugu misissuinerit aallartinneqareerput. Taakunani inernerit anguneqartut KANUMAS West-imut atussallugit naleqquttorujussuussapput.

1 Introduction

This document comprises a preliminary strategic environmental impact assessment (SEIA) of expected activities in the KANUMAS West area. It was prepared by the National Environmental Research Institute (NERI) and the Greenland Institute of Natural Resources (GINR) in cooperation 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 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) (Skjoldal *et al.*2007). 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 context is climate change. This affects both the physical and the biological environment; for example, the ice cover of the Baffin Bay area is expected to be reduced, which again will impact the ecology and particularly wildlife dependent the on 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 then may be very different from those at present.

1.1 Coverage of the SEIA

The offshore waters and coastal areas between 71° N to 78° N (from Uummannaq Fjord northwards to central part of the former Qaanaaq municipality) are in focus, as this is the region which potentially can be most affected by the activities, particularly from accidental oil spills originating from oil activities in the KANUMAS West area (Figure 1). This focus area will be referred to as the 'assessment area'. However, the oil spill trajectory model developed by DMI indicates that oil may drift further, outside

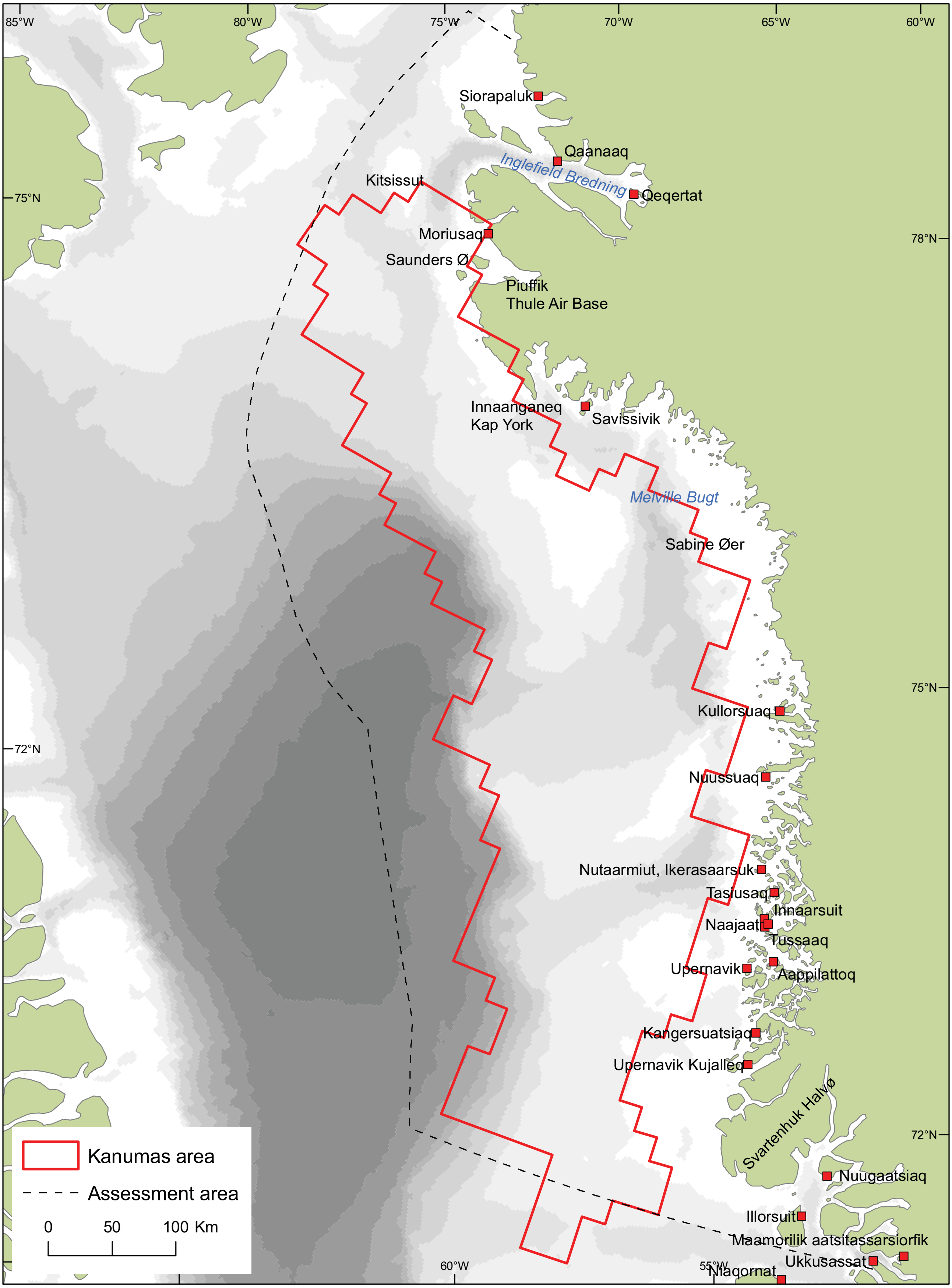


Figure 1. The KANUMAS West area and the surrounding assessment area. The most important place names are shown. Red dots indicate inhabited sites: Mainly towns and settlements. See also text. The southernmost part of the KANUMAS West area (outside the assessment area) is included by the SEIA covering the Disko West area (Mosbech *et al*. 2007).

the boundaries of this area (Nielsen *et al.* 2008). The region to the south of the assessment area was dealt with in a separate assessment of the 'Disko West Area' (Mosbech *et al.* 2007a).

The present assessment area extends over waters of three of the former municipalities: the northern part of Ummannaq, the entire area of Upernavik and the southern part of Qaanaaq (now part of one single municipality, Qaasuitsup Kommunia). In the Uummannaq area, only three settlements are found, with altogether 358 inhabitants; Upernavik has one town and 11 settlements with a total of 1,796 inhabitants, and in the Qaanaaq there is one small town and four settlements with a total of 846 inhabitants (Greenland Statistics 2008, population data from 2007).

1.2 Abbreviations and acronyms

BAT = Best Available Technique
bbl = barrel of oil
BEP = Best Environmental Practice
BMP = Bureau of Mineral and Petroleum, Greenland Homerule 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
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.
NOW = North Water polynya
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
SEIA = Strategic Environmental Impact Assessment
TPH = Total Petroleum Hydrocarbons

TTS = temporary elevation in hearing threshold
USCG = United States Coast Guard
VEC = Valued Ecosystem Components
VOC = Volatile Organic Compounds
WGC = West Greenland Current
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 which 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 previoulsly oil-based (OBM), but due to the toxicity, they have now been replaced mainly 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 associated with strong noise 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 the 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 bio-accumulate. The produced water moreover contributes to the major part of the oil pollution during normal operations, 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 concerning, for example, the hormone-disrupting alkylphenols and radioactive components with respect to toxic concentrations, 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 emmissions

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 gasses (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 transshipment.

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 off Disko. Something similar could be expected for the KANUMAS West 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 (Skjoldal *et al.*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 animal populations and even to species.

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), which has previously reviewed weather, sea and ice conditions (Valeur *et al.* 1996, Link).

The assessment area lies within the Arctic climate zone, which means that the average July temperature does not exceed 10° C. The Arctic zone is divided into the low Arctic (average July temperature higher than 5° C) and the High Arctic (average July temperature below 5° C). The major part of the assessment area is within the High Arctic zone. 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 a large part of the year (section 3.4.4), and permafrost is widespread in the inland areas.

The offshore part of the assessment area is the Baffin Bay. The shelf is represented by the rather shallow waters (depths less than 200 m) near the coast. This shelf is generally rather narrow, usually less than 50 km, compared to further south in West Greenland. Outside the shelf depths reach more than 2,000 m in central parts of the bay.

3.1 Weather

The weather conditions in the area are influenced by the North American continent and the North Atlantic Ocean, but also the Greenland Inland Ice and the steep coasts of Greenland have a significant impact on the local weather. Many Atlantic depressions develop and pass near the southern tip of Greenland and frequently cause very strong winds off West Greenland. Also more local phenomena such as fog or polar lows are common features near the West Greenland shores. The probability of strong winds increases close to the Greenland coast and towards the Atlantic Ocean. Detailed descriptions can be found in the sensitivity atlas for West Greenland south of the assessment area, previously prepared by NERI (Mosbech *et al.* 2004. Link to sensitivity map).

3.2 Oceanography

3.2.1 Currents

Along West Greenland the West Greenland Current (WGC) flows with two principal components. Closest to the shore, cold polar water from East Greenland moves northward. On its way, this is diluted by run-off waters from the various fjord systems. The other component is from the North Atlantic, deriving from the Irminger Sea. This relatively warm and high saline water can be traced all the way along West Greenland from Cape Farewell to Qaanaaq (Figure 2). The East Greenland Current compo-

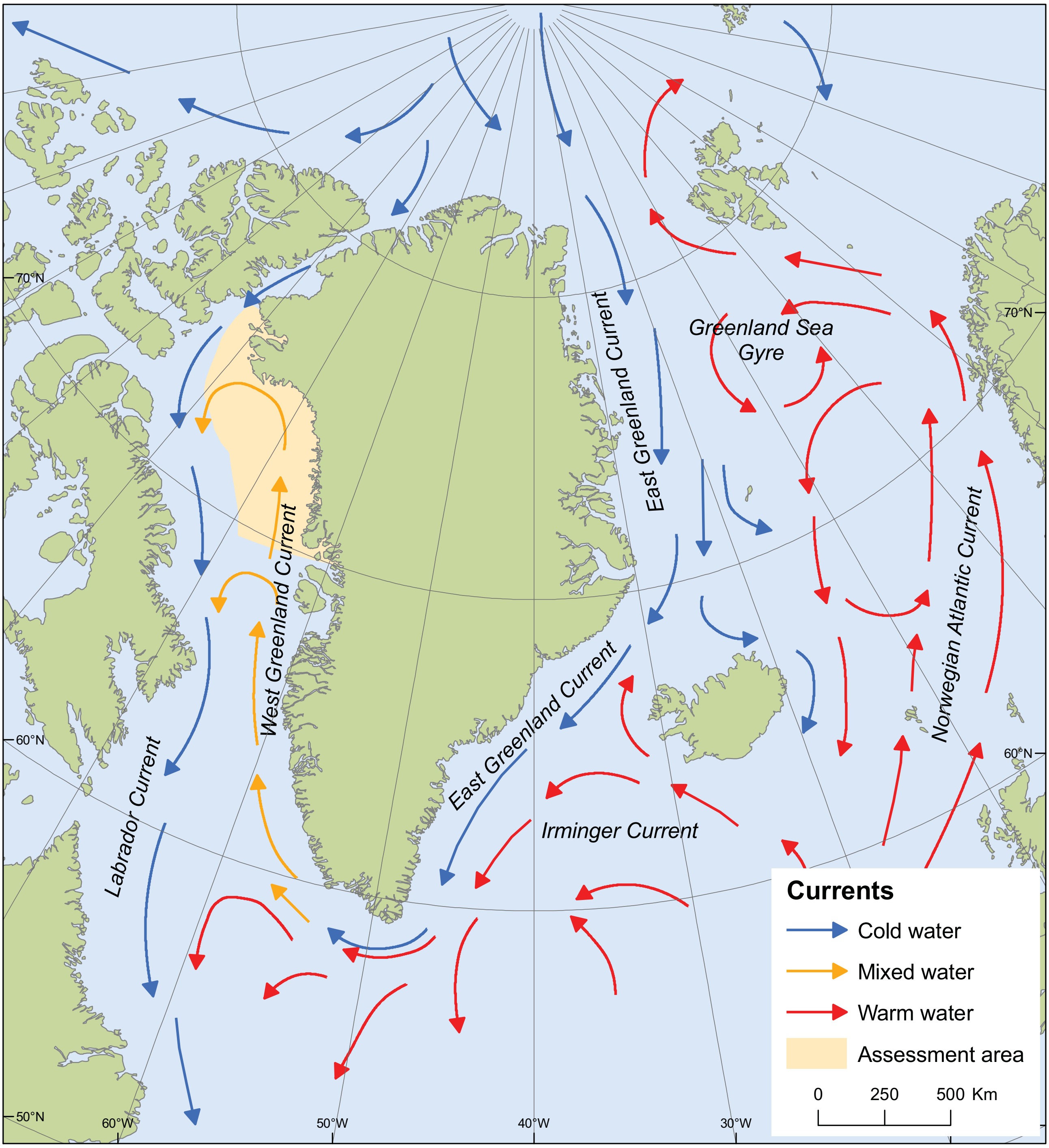


Figure 2. Major sea surface currents in the northern Atlantic.

nent loses its momentum on the way northward, and does not enter the waters of the assessment area.

The currents in the northern part of the assessment area where the North Water Polynya is situated, is dominated by a strong southward flow of cold water and ice from the Arctic Ocean (Figure 3). Although most of the warm West Greenland Current crosses Baffin Bay to the south of the polynya, a branch provides a modest northward flow of warm water up the eastern side. When the inflow of ice from the north is blocked in Smith Sound, the continued drift out of northern Baffin Bay is sufficient to create the North Water, without oceanic heating. Cold Arctic waters of lower salinity flow over the remnant of the warm flow that continues northward. However, upwelling near the Greenland coast forced by Ekman transport

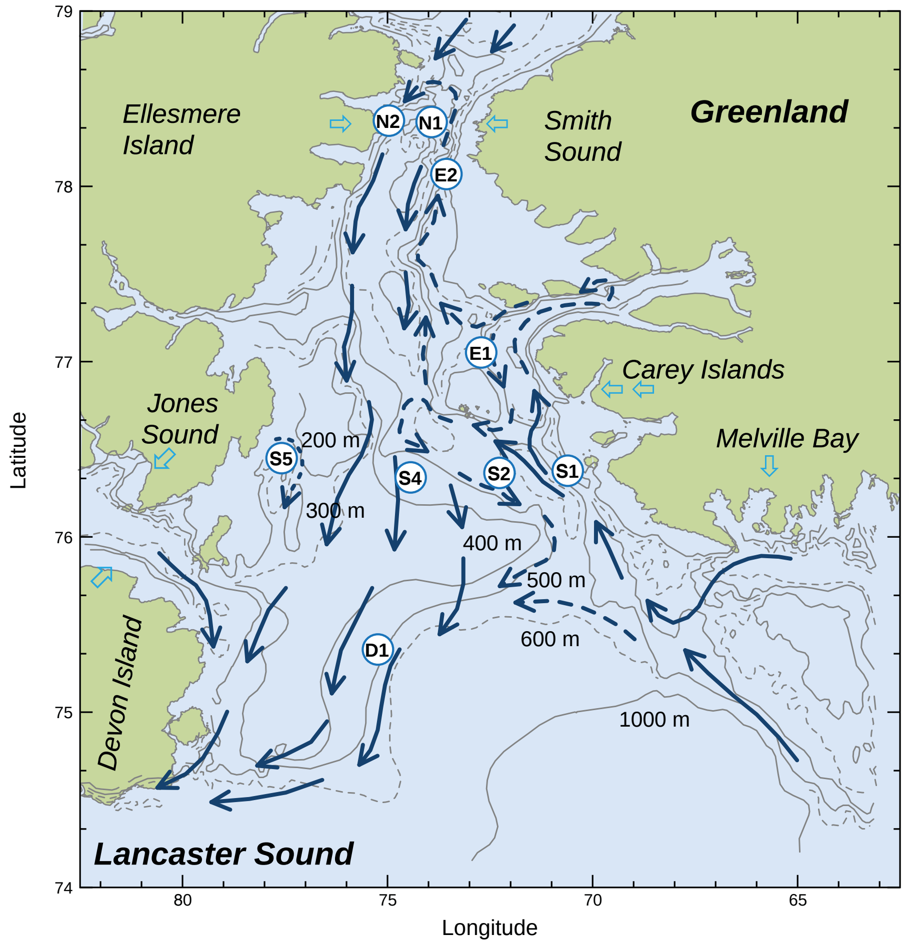


Figure 3. Schematic plan view of ocean circulation in northern Baffin Bay. Solid arrows represent the direction of motion throughout the water column, except in areas where dashed arrows indicate counter-flow at depth (from Melling *et al.* 2001).

brings the warm water to the base of the turbulent surface layer where it is entrained (Melling *et al.* 2001).

The polar water inflow to the assessment area through the narrow Nares Strait north of the assessment area is strongest during spring and early summer (May–July). The inflow of Atlantic water masses from the south is strongest during autumn and winter.

A fifty-year long time series of temperature and salinity measurements from West Greenland oceanographic observation points reveals strong inter-annual variability in the oceanographic conditions off West Greenland. However, in recent years there has been a tendency towards increased water temperatures and reduced ice cover in winter (Hansen *et al.* 2006, Stirling & Parkinson 2006).

3.2.2 Hydrodynamic discontinuities

Hydrodynamic discontinuities are areas where different water masses meet with sharp boundaries and steep gradients between them (Figure 4). They can be 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 (just to the south of the assessment area) revealed some significant upwelling areas and some of the model results also included the major part of the present assessment area (Figure 5).

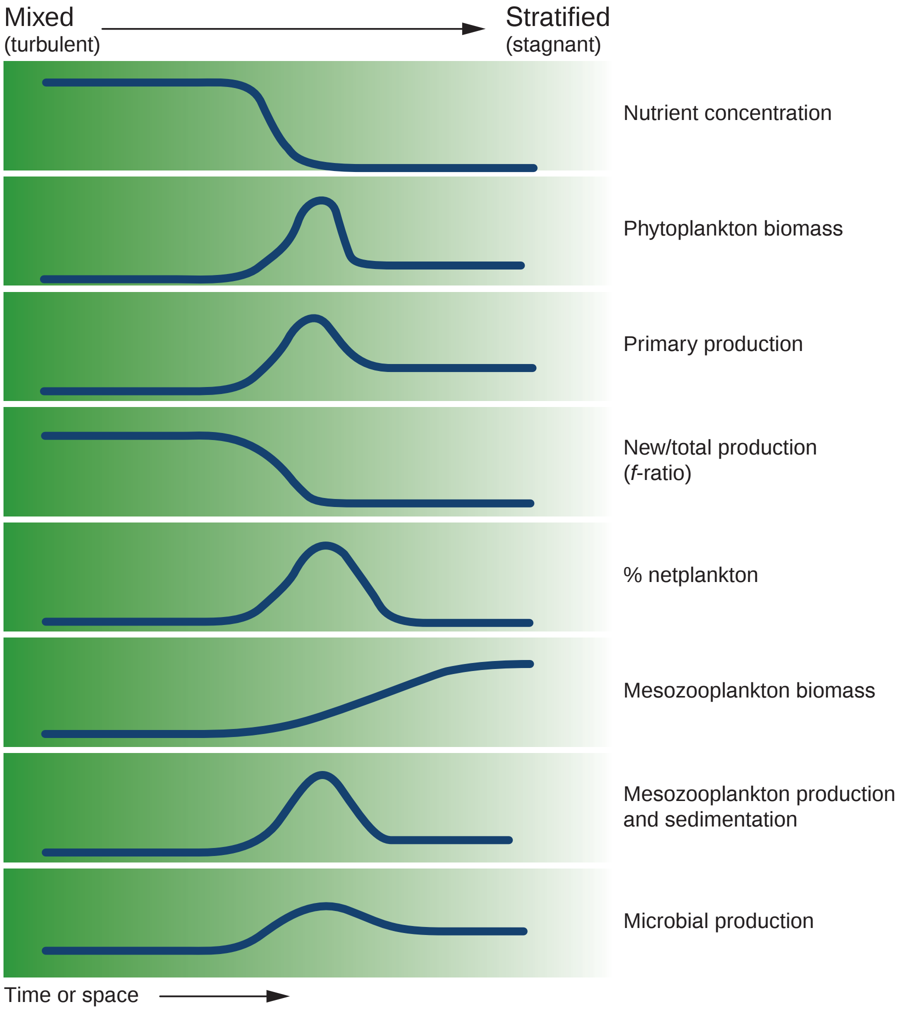


Figure 4. Hydrographic discontinuities are often sites of enhanced biological activity. This can be defined in time, e.g. the shift from mixed water in the winter to stratified water in the spring or in space when two water masses meet or at the marginal ice zone where the frontal zone will provide better growth conditions for plankton and the succeeding links in the food web (Legendre & Demers 1984).

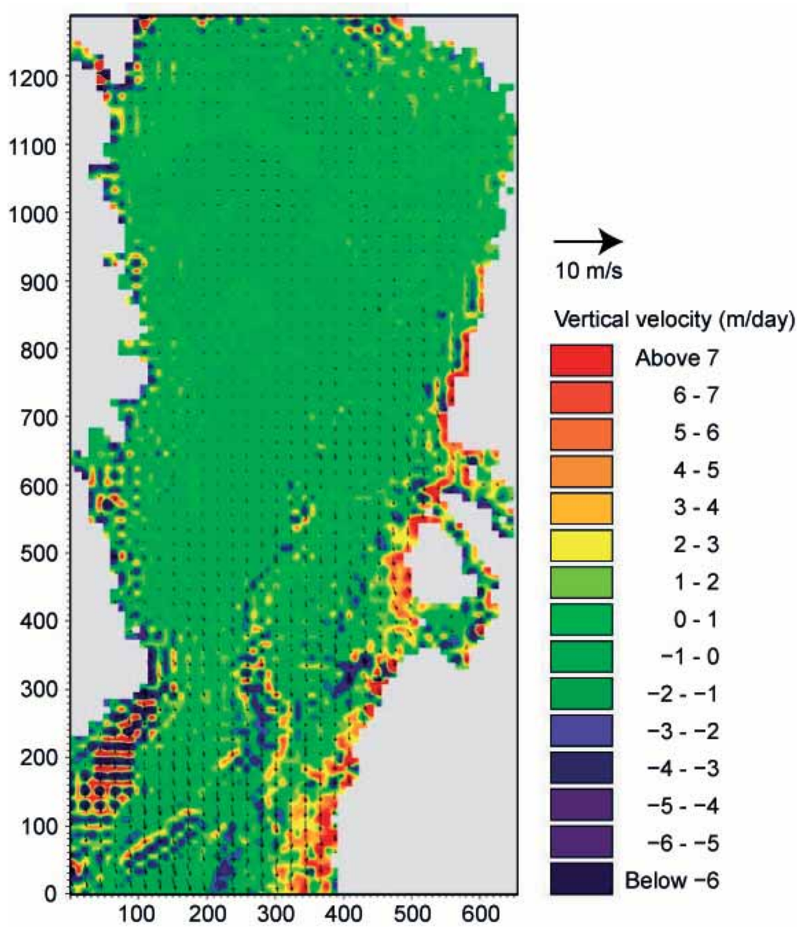


Figure 5. Model results, when using a Hybrid Coordinate Ocean Model (HYCOM), showing the daily mean value of vertical velocity at 20 m depth, and wind speed in Baffin Bay. The present figure show daily mean value on the 24th of April, 2005, but it shows a frequent model feature during spring. The colour scale shows the daily mean value of upwelling velocity (m day-1), and the arrows show wind speed. Large vertical velocity suggests up/down-welling or large mixing at 20 m. depth. For this specific date there is strong upwelling along the Greenland west coast, especially near the Store Hellefiskebanke, which has an approximate coordinate on the map at (300,300). Large vertical velocities as presented here is a very common model feature during late winter and spring 2005. Within the assessment area the vertical currents are found only along the coats. The present model set up is described in detail in Ribergaard *et al.* (2006).

The upwelling described in section 3.2.1 differs in the fact that it is relatively warm water which is forced to the surface, but it still carries the nutrients essential for the primary productivity (Melling *et al.* 2001).

3.3 The coasts

The coasts of the assessment area are dominated by bedrock shorelines with many skerries and archipelagos. But there are also extensive areas dominated by basals and sedimentary rocks as well as low shores with loose sediments. In the Melville Bay glaciers reach the coast over very long stretches.

3.4 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. The drift ice is often referred to as 'The West Ice' because it is formed to the west of Greenland. In addition to sea ice, icebergs originating from calving glaciers are very frequent. The description of ice conditions given here is based on a DMI contribution to the Oil Spill Sensitivity Atlas covering the coasts south of 72° N (Mosbech *et al.* 2004). As part of the preparations for oil activities in the assessment area, BMP has initiated a new sea ice study by DMI, where the information on ice condition presented in this section will be updated.

3.4.1 The drift ice

The eastern sector of Baffin Bay is influenced by the warm West Greenland current, which is an offshoot of the Gulf Stream (*cf.* section 3.2.1). This creates open water in winter along the southwest Greenland coast, usually to Disko Island. The western side of Baffin Bay is influenced by the cold Labrador Current. Due to its colder waters, the winter ice is considerably more persistent in the western side of Baffin Bay. Because of the currents and prevailing winds, the spring break-up of the Baffin Bay pack ice commences along the West Greenland coastal ice and moves progressively north along the West Greenland coast and west towards the eastern coast of Baffin Island, where the ice remains longest and for some years – fields of pack ice may prevail throughout summer (Taylor *et al.* 2001).

The predominant sea-ice type in Baffin Bay is first-year ice. Small amounts of multi-year ice of Arctic Ocean origin drift to the western parts of the bay from Lancaster Sound or Nares Strait; however, the multi-year ice from these waters does not usually reach the West Greenland shores. At the end of the freeze-up season, first-year ice in the thin and medium categories dominates in eastern parts (up to about 100 km from the Greenland coast). Western and central parts of Baffin Bay are dominated by medium and thick first-year ice categories, mixed locally with small amounts (1–3 tenths) of multi-year ice (Figure 6, 7). The thickness of the drift ice at end of freeze-up increases towards the north, from approx. 75 cm off Disko Island to 120–150 cm in the northern Baffin Bay (in a severe winter), and the land fast ice in Melville Bay is probably event thicker 130–180 cm (Valeur *et al.* 1996).

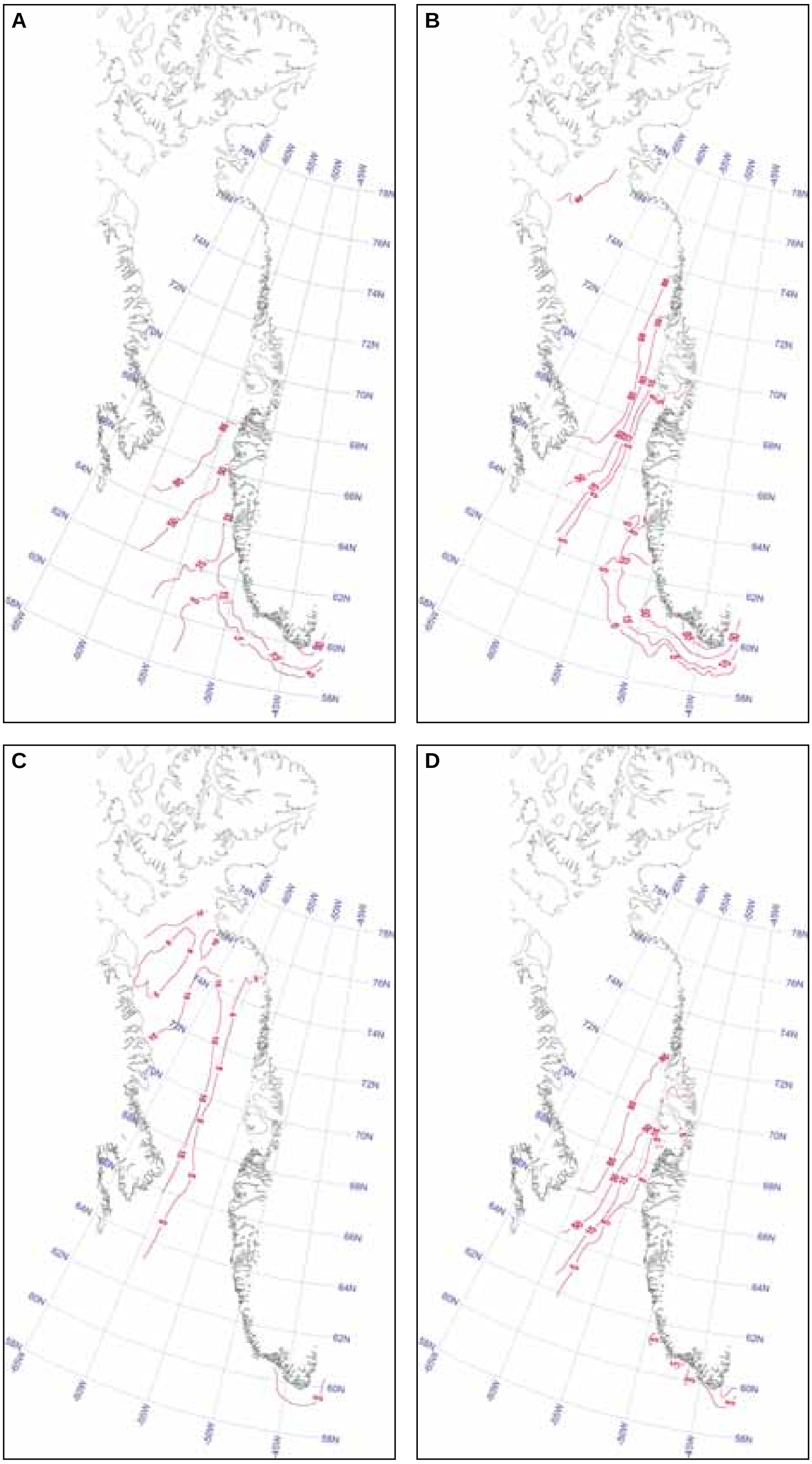
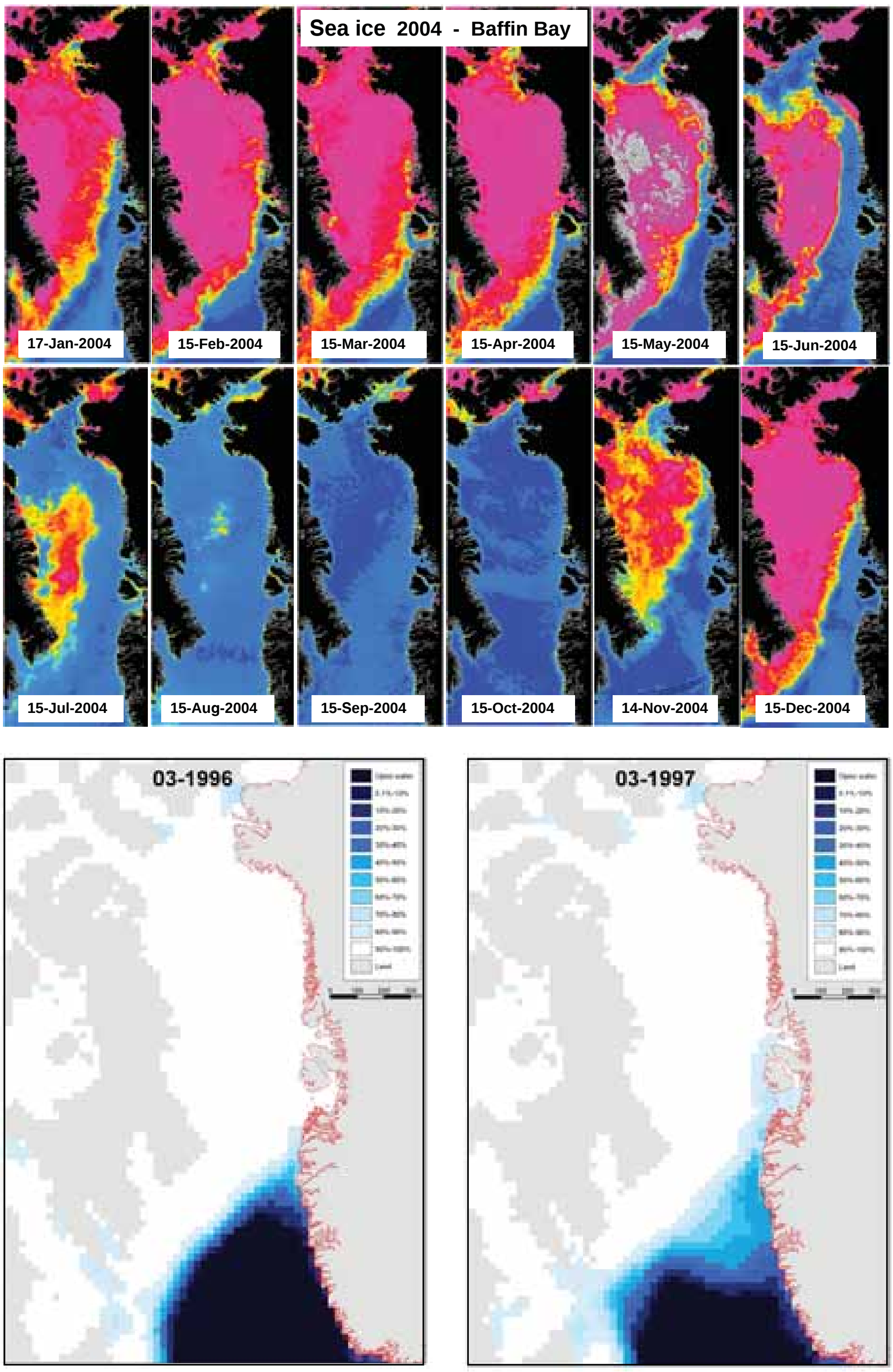


Figure 6. Probability of sea ice in West Greenland offshore waters based on data from the period 1960-96. (A) March the 1st , (B) June the 4th , (C) September the 3rd , (D) December the 3rd.

The dominant size of ice floes ranges from less than 100 m wide to vast floes larger than 50 km. These floes are often made up of consolidated lesser floes and they continuously break apart and freeze together. In recent years both the extension of the winter ice and the ice cover period has been reduced (Stirling & Parkinson 2006).

Figure 7. Distribution of ice in the Baffin Bay area. Images based on Multichannel Microwave Radiometer (AMSR and SMMR. Red and magenta in the maps in upper two rows indicate the very dense ice (8-10/10); while yellow indicate somewhat looser ice. The loosest ice (1-3/10) is not recorded. (Data sources: DMI and Canadian Ice Service).



3.4.2 Sea-ice drift

The drift pattern of the sea ice off West Greenland is not very well known. The local drift is to some extent controlled by the major surface current systems, the West Greenland Current and Baffin Island Current; however, the strength and direction of the surface winds also affect the local drift of sea ice, especially in the southern waters. The drift pattern was studied in the southernmost part of the assessment area in April 2006 (Figure 8) and an earlier study is presented in the DMI review (Valeur *et al.* 1996).

Isolated from the offshore ice conditions, sea ice forms locally throughout the winter in most of the fjords and coastal waters of the region. Generally freeze-up begins at the inner parts of the fjords in October or November, but very low temperatures can significantly affect the ice formation.

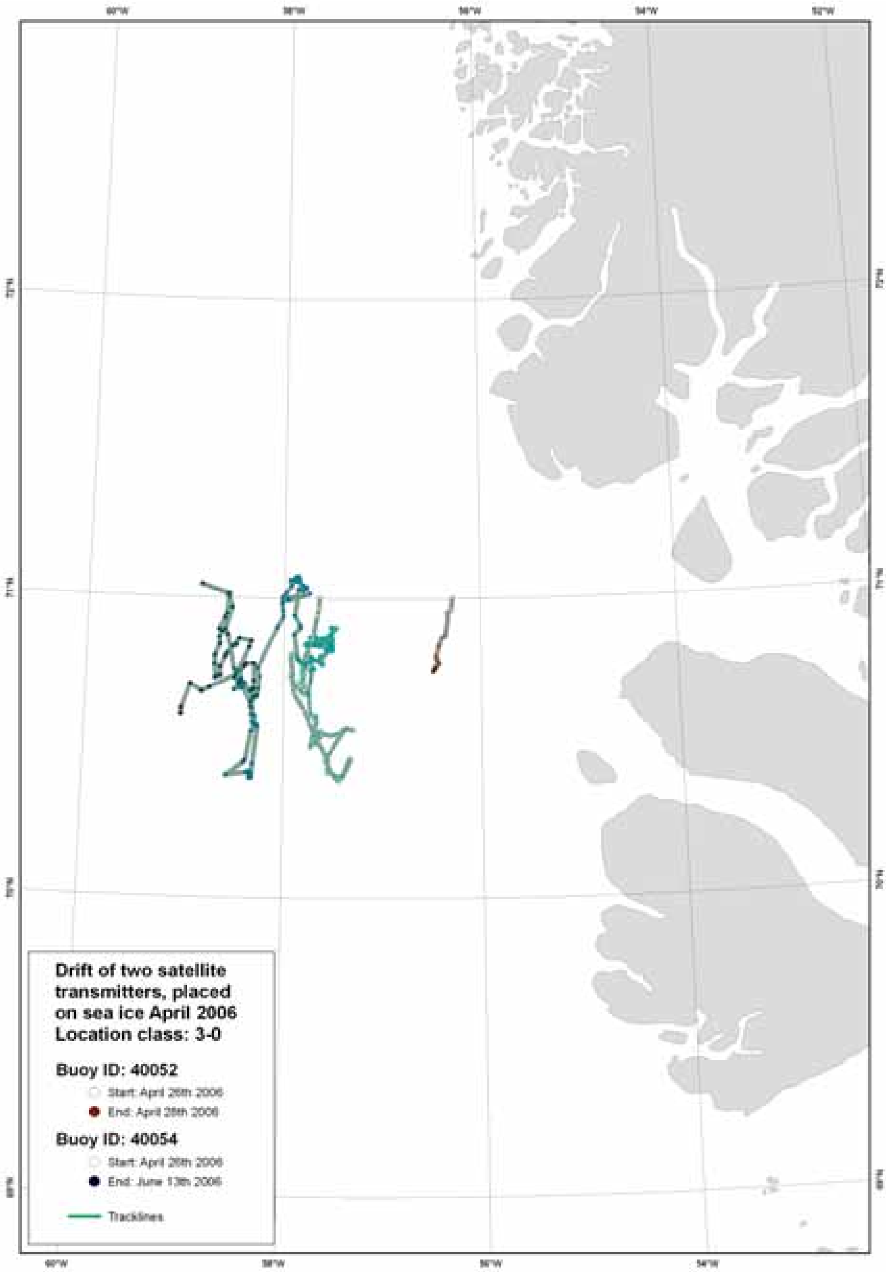


Figure 8. Drift of two buoys equipped with satellite transmitters deployed in the drift ice just south of the assessment area on 27th April 2006. One stopped transmitting after only two days, when it had moved 21 km to the south. The other was tracked until June 13th. The track of this buoy is approx. 500 km long, but overall it only moved 66 km towards southwest. Source DMI (study carried out at the request of BMP and GEUS).

3.4.3 Polynyas and shear zone

Polynyas are open waters in otherwise ice-covered areas. They are predictable in time and space, and are of a high ecological significance. The most important polynya of the assessment area is the North Water (NOW) in the entrance to Smith Sound, *viz.* off former Qaanaaq Municipality – and during the International North Water Polynya Study in 1997–1999 this was shown to be the most productive area in the Arctic (Deming *et al.* 2002).

The North Water evolves seasonally from a relatively small area in winter, where ice is thinner than elsewhere, to a large area of ice-free water in June and ultimately in summer ceases to exist as a distinct ice-bounded region within Baffin Bay. Although the area often has 95 % ice cover in January, this ice is mobile and criss-crossed by open leads (Melling *et al.* 2001).

Smaller polynyas are found at several sites along the Greenland coast. Moreover, a shear zone occurs (with open cracks and leads) between the land fast ice and the drift ice, and this is also very important to marine mammals and seabirds, particularly in spring when populations are migrating northwards. In this shear zone, open water gradually extends northwards during the spring.

3.4.4 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 navigation and offshore activity

The production of icebergs on a volumetric basis varies only slightly from year to year. Once calving is accomplished, meteorological and oceanographic factors begin to affect the icebergs. Icebergs are carried by sea currents directed by the integrated average of the water motion over the whole draft of the iceberg. However, wind also plays an important role, either directly or indirectly.

Iceberg sources

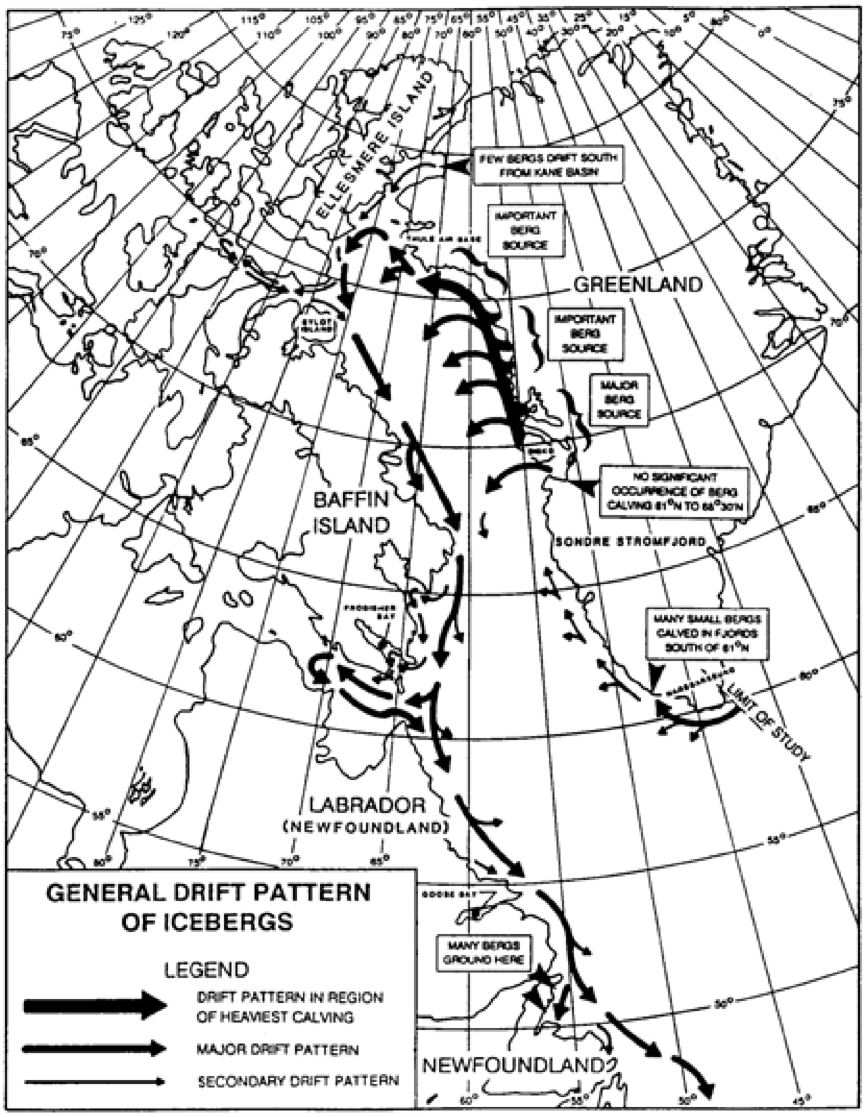
Glaciers are numerous in the coastal parts of the assessment area, and the most productive glaciers in West Greenland are in fact concentrated between Nares Strait and Disko Bay, including the assessment area.

Melville Bay north of the former Upernavik municipality is a major source of icebergs. Thousands of icebergs are calved from 19 major glaciers each year (Figure 9). The volume produced in this region was estimated at 60 km^3 anually. Some of these glaciers are capable of producing icebergs of about 1 km in diameter. Several active glaciers in Uummannaq Fjord and Disko Bay produce 10–15,000 icebergs per year (95 km^3) creating a significant input of icebergs to Baffin Bay. The total annual production of icebergs calved in the Baffin Bay and the northern Davis Strait was estimated to be about 25–30,000; estimates however vary, up to as high as 40,000 (Valeur *et al.* 1996). Climate change may have rendered these estimates obsolete.

Iceberg drift and distribution

On a large scale the basic water currents and drift of icebergs in Baffin Bay and the northern Davis Strait are fairly simple (Figure 9). There is a north-flowing current along the Greenland coast and a south-flowing current along Baffin Island and the Labrador coast, giving an anti-clockwise drift pattern. However, branching of the general currents causes variations, and these can have a significant impact on the iceberg population and their residence time. Although the majority of icebergs from Disko Bay are carried northward to northeastern Baffin Bay and Melville Bay before heading southward, icebergs have also been observed to be diverted into one of the west-branching eddies without passing north of 70° N. Most of the icebergs from Baffin Bay drift southward in the western Davis Strait, joining the Labrador Current further south, although some may enter the eastern Davis Strait area west of Disko Island instead. Icebergs produced in Disko Bay or Baffin Bay generally will never reach the Greenland shores south of 68° N.

Figure 9. Major iceberg sources and general drift pattern of icebergs in the West Greenland Waters (US National Ice Centre, Washington DC).



Iceberg dimensions

The characteristics of iceberg masses and dimensions off the west coast of Greenland are poorly investigated, and the following is mainly based on a Danish study in the late 1970s (Valeur 1996).

The largest icebergs north of 66° N were found north and west of Store Hellefiskebanke. The average iceberg mass was about 2 million tonnes with a maximum mass of 15 million tonnes. In Disko Bay, the average mass of icebergs was in the range 5–11 million tonnes with a maximum recorded mass of 32 million tonnes. Average draft was 80–125 m and maximum draft was 187 m. It is worth noting that many icebergs are deeply drafted and, due to the bathymetry, large icebergs will not drift into shallow water regions.

The measurements of iceberg drafts north of 62° N indicate that an upper limit of 230 m will only be exceeded very rarely; however, no systematic 'maximum draft measurements' exist and the extremes remain unknown. The large icebergs originating in Baffin Bay are expected to have a maximum draft of about 250– 300 m. The largest icebergs recorded in a study in Baffin Bay in 1997 were characterised by a draft of more than 260 m, a mass of up to 90 million tonnes and a diameter of more than 1,400 m. Icebergs from the productive Ilulissat glacier pass a sill which allows for a maximum draft of 250 m.

4 Biological environment

4.1 Primary productivity

4.1.1 General context

From an Arctic perspective, the shelves around Northwest 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 northern 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 from upwelling leads to locally very high production.

The ice-free period in high Arctic areas around Northwest Greenland is generally 3–4 months, but in polynyas may be > 6 months. Occasionally some areas are dominated by heavy pack 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 produced organic carbon that is recycled through the microbial loop, and the proportion available to pelagic consumers that are 'lost' when sinking to the bottom, 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. The northern part of the area is dominated by the large North Water Polynya, which is one of the most biologically productive marine areas in the Arctic. This area is also relatively well studied. Further south, the ice-free period in Melville Bay and Baffin Bay is much shorter, although the whole region becomes ice free most summers. A number of small polynyas are present along the Greenland coast. The whole region south of the North Water Polynya is very poorly studied. 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 Water Polynya (NOW)

The North Water is one of the largest (~80,000 km^2) and biologically most productive polynyas in the Arctic, and is exceptionally important for consumers at higher trophic levels, including humans. Nevertheless, until fairly recently very little was known about the ecology of the area due to logistical constraints. Preliminary data were collected during a brief cruise in 1991 (Lewis *et al.* 1996). The physical, biological and biogeochemical processes were studied intensively during the international North Water Polynya Study in 1997–99 (Deming *et al.* 2002), leading to a better ecological understanding of this productive region than of any other part of the assessment area. However, more recent *in situ* data are not available. Exceptionally for Arctic areas, phytoplankton biomass and primary productivity were high throughout the ice-free period (April–October), although a clear peak was present in early June (Tremblay *et al.* 2006a). Annual primary production was among the highest recorded in the Arctic (average for the whole polynya: 251 g C m^{-2} yr^{-1}), dominated by large producers such as diatoms (Klein *et al.* 2002), particularly *Thalassiosira* spp. and *Chaetoceros socialis* (Booth *et al.* 2002). Despite the importance of diatoms, total primary production was most likely limited by nitrate rather than silicate (Tremblay *et al.* 2002). Most of this production was channelled through the grazing food chain, and a relatively small proportion (~20 %) was lost through sinking to the benthic system (Tremblay *et al.* 2006a). This implies that most of the local secondary production was available to plankton consumers, including larger zooplankters, fish, marine mammals and planktivorous seabirds. The bloom started in the eastern part of the polynya, where ice break-up and attendant stratification were earliest due to the relatively warm West Greenland Current, and progressed westwards over the season (Odate *et al.* 2002, Tremblay *et al.* 2002). The extremely early start of the bloom (April, similar to in temperate oceans) was likely due to stratification (shallow mixing) in the eastern part of the polynya (Tremblay *et al.* 2006b). The prolonged phytoplankton bloom was likely maintained by storm-driven admixture of nutrients (primarily nitrate) from deeper waters (Lovejoy *et al.* 2002, Tremblay *et al.* 2002, Tremblay *et al.* 2006a), and it is possible that the bloom would be more short-lived in years with fewer storms in spring and summer.

There are many interactions between the mesoplankton (i.e. diatoms-zooplankton) and microbial food web. The microbial food web is complex and its internal and external pathways web change with seasonal development (Berreville *et al.* 2008). In this regard NOW differs from the North East Water polynya in Northeast Greenland (NEW) where the interactions are less complex. This is probably caused by differences in their longevity, i.e. the longer-lived NOW polynya having more time to develop complex trophic interactions.

4.1.3 Baffin Bay and Melville Bay

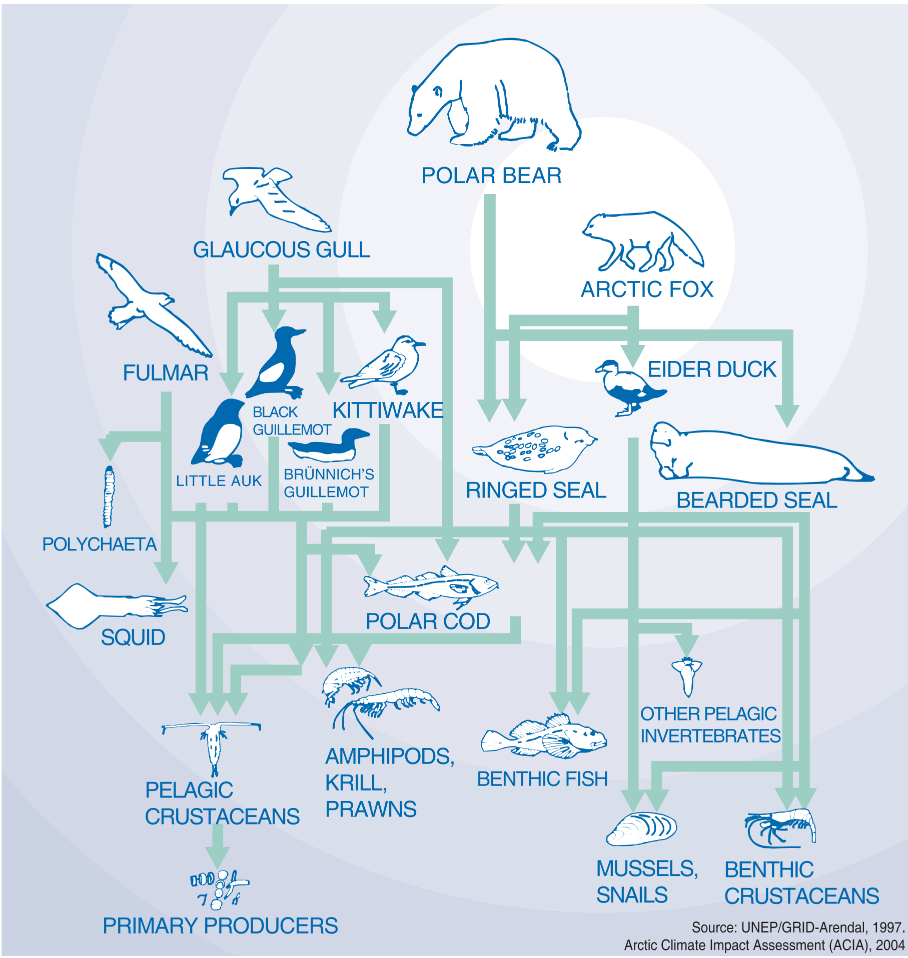
This region, constituting most of the assessment area, is poorly studied in terms of primary production, at least partly because of logistical issues due to high ice concentrations and a short open-water season. During summer, a distinct subsurface chlorophyll maximum was found in northern Baffin Bay (Harrison *et al.* 1982, Herman 1983), and primary production was similar to other Arctic and Antarctic waters (Harrison *et al.* 1982). Jensen *et al.* (1999) measured primary production in the southernmost part of the assessment area during summer and found that it was similar to areas further south along the West Greenland coast (*cf.* Söderkvist *et al.* 2006).

4.1.4 Satellite-derived maps of estimated surface chlorophyll concentration

In Figure 11 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 e.g. sea ice, areas with too little incident light to get 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 example, irregular white areas in central Baffin Bay in August–September are more likely to represent extremely high and persistent cloud concentration.

Figure 10. A schematic description of the interactions in the marine Arctic environment.



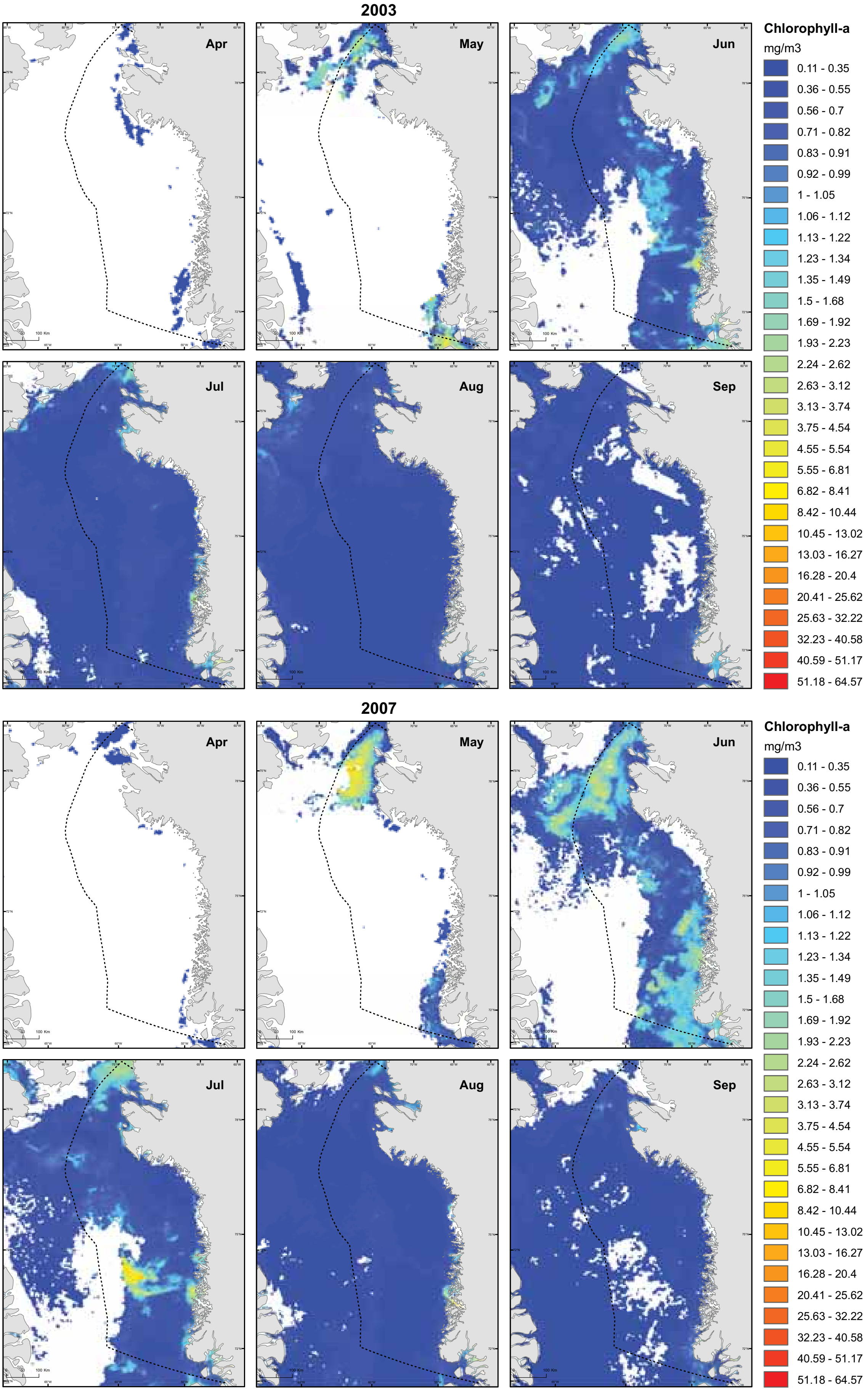


Figure 11. Estimated monthly mean surface chlorophyll concentration in the period April-September 2003 and 2007 in the Baffin Bay area. The map is based on level 3 data from the MODIS Aqua satellite sensor and downloaded from OceanColorWeb (http://oceancolor.gsfc.nasa.gov). The spatial resolution used 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.

Despite the high annual and seasonal variation in ice cover, some spatio-temporal patterns were recurrent between years. For example, the pronounced early bloom in NOW in May–June was apparent in all years, although intensity and spatial extent varied. Widespread surface blooms were also observed in the southeastern part of the assessment area in 2006 and 2007. In addition, a small but highly regular coastal bloom occurred every year in the Upernavik area.

4.1.5 Important and critical habitats

The International North Water Polynya Study (1997–1999) showed the eastern part of the NOW along the Greenland coast was much more productive than the other parts, and therefore will be particularly sensitive to oil spills. However, localised areas were not identified. Outside the NOW, information on primary productivity generally is too sparse and the location of potential hot-spots too irregular to identify localised important and / or critical areas.

4.2 Zooplankton

4.2.1 General considerations

Zooplankton has an important role within marine food webs (Figure 10), 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. 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 bivalves, 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 its nearly continual presence for four months per year has a strong influence on food availability and on the life cycle of the organisms living there. 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 cycles, since these depot lipids not only provide energy during starvation in winter but also the materials for egg production and larval development (Smith & Schnack-Schiel 1990 and references therein).

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 form of lipids which are used for overwintering at depth and to fuel reproduction in the following spring. Their life cycles have been estimated to be 2–4 years (Hopcraft *et al.* 2005).

Meanwhile, general aspects of the life histories of *Calanus* are known. Two species, *Calanus hyperboreus* (Krøyer) and *Calanus glacialis*, have been characterised as Arctic species (Smith & Schnack-Schiel 1990). *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 (a larvae) stage I and exploit the spring bloom and develop into copepodite II and III. Larger copepodites (C IV and CV) and females also ascend to feed during spring after overwintering in the deeper parts (Tremblay *et al.* 2006). This specific reproduction and overwintering strategy is seen as ecological advantage compared to other copepod species.

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 utilise lipid reserves stored during the productive summer (Ashjian *et al.* 2003 and references therein). The third main copepod species, *Calanus finmarchicus*, was first characterised as a boreal species but is now 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 assessment area by the inflow of Atlantic water. The other major species, *Metridia longa*, was classified by several authors as an Arctic deep-water species that overwinters as stage V copepodite and adults (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 (Figure 10) 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.

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 consumer through several trophic levels. For instance, lipids originating from *Calanus* can be found in the blubber of sperm whales, which feed 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 item 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.

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 were closely linked with the prevailing hydrography in the area. The interactions between hydrography, plankton and shrimp and fish larvae indicate that the productive cycle in Disko Bay is highly pulse-like in nature, which is characteristic for Arctic marine ecosystems (Söderkvist *et al.* 2006).

Estimates of plankton vulnerability to anthropogenic impact tailored for the assessment area are not available. However, the vulnerability of plankton to anthropogenic impacts should be linked to local environmental conditions that influence the pelagic food web, such as temperature, water circulation and ice occurrence. The impact of human activity is likely to vary depending on seasonality, location and biological activity. High biological activity in the surface waters can be expected in connection with hydrodynamic discontinuities, i.e. spring blooms, fronts, upwelling areas or at the marginal ice zone. In Arctic marine habitats, the most severe ecological consequences of massive anthropogenic impacts (such as oils spills) 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 would be assumed to be less severe (Söderkvist *et al.* 2006).

4.2.2 Zooplankton in the assessment area

For larger parts of the assessment area, no information is available regarding the distribution and population dynamic of important zooplankton taxa and their role in the food web. Based on studies performed in the vicinity of Melville Bay, north-eastern Baffin Bay (75° to 76° N, 68° to 72° W) in summer 1980, the most dominant copepod species are *Calanus hyperboreus*, *Calanus glacialis* and *Calanus finmarchicus*. Their vertical distribution was linked to food availability as well as to salinity and temperature (Herman 1983, Sameoto 1984, Head *et al.* 1985). The three copepods were most abundant in water masses with temperatures below 0° C whereas at temperatures above 0° C other planktonic species (i.e. pteropod molluscs) showed highest abundance. In addition to *Calanus*, a range of other species and taxonomic groups were present in the plankton (Sameoto 1984).

Zooplankton diversity and its functional role have also been studied in the North Water polynya (NOW) as part of the International North Water Polynya Study. NOW is one of the largest Arctic polynyas and represents a productive region (*cf.* the section on primary productivity) with abundant seabird and marine mammal populations. Several comparisons indicate that NOW is among the most productive ecosystems north of the Polar Circle (Tremblay *et al.* 2006). The extensive ice-free periods in polynyas are associated with increased primary production, resulting in a diverse zooplankton community (Prokopowicz & Fortier 2002, Ringuette *et al.* 2002). By number, copepods represented >80 % of the zooplankton assemblage in the North Water. The copepod assemblage was quite diverse, including taxa typically found in Arctic Ocean waters, such as *C. hyperboreus*, *C. glacialis*, *Pseudocalanus* spp., *Metridia longa*, *Microcalanus pygmaeus*, *Oithona similis*, *Oncaea borealis* and *C. finmarchicus* (Ringuette *et al.* 2002). Their distribution patterns varied and were often directly linked to hydrographical features, i.e. temperature and salinity, but also to duration of ice coverage. Other studies have shown that the copepod biomass in NOW was comparable to that observed in other Arctic polynyas. Nevertheless, dominant diatoms accumulated indicating that copepod abundance was not sufficient to control phytoplankton biomass. It was speculated that planktivory, especially small pelagic birds, limit the abundance of large *Calanus* spp (Saunders *et al.* 2003). The little auk is present in many millions in the NOW region and known to large amounts of *Calanus* spp. Calculations of carbon requirements show a reasonable agreement between auk populations and production rates of *C. hyperboreus* (Saunders *et al.* 2003).

Other studies have revealed that the carbon demand of the little auk amounted to about 2 % of the biomass synthesised by *C. hyperboreus* and that most of the secondary carbon production was therefore available for pelagic carnivores, e.g. polar cod and marine mammals (Tremblay *et al.* 2006). The trophic studies based on stable isotope measurements also documented that a large fraction of the primary production in NOW was already ingested by consumers in the upper 50 m. It was estimated that only about 15 % of the particulate primary production was left to sink directly to the bottom (pelago-benthic coupling) to be used by benthic organisms (Tremblay *et al.* 2006).

The influence of temperature on copepod life history has also been analysed. Depending on the species, reproductive success was improved with increased food availability and higher temperature, resulting from reduced ice cover. It was predicted that a climate-induced reduction in the duration of ice cover will favour the population growth of the predominant large calanoid copepods and *Pseudocalanus* on Arctic shelves (Ringuette *et al.* 2002).

Climate change is likely to change primary production from strongly pulsed to a more prolonged and unpredictable production of diatoms (rich in polyunsaturated 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. A prolonged production period could favour a mixed diatom-dinoflagellate community which could result in a food chain based on *C. finmarchicus – Metridia longa*, which are less valuable as food for Arctic planktivorous species (bowhead whale and little auk).

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.

4.2.3 Important and critical areas

The 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 important components 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 a tight pelago-benthic coupling.

Furthermore, the low temperatures reduce 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 regimes also influence benthic diversity and species composition.

Compared with pelagic organisms, which often display significant seasonal variation in biomass, benthic biomass is far more stable and thus a predictable source of food for the higher trophic levels of the food chain (Hobson *et al.* 2002, Born *et al.* 2003, 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 a number of years and if the community is disturbed it may take decades for the system to recover.

4.3.1 Benthic fauna in the assessment area

Among the very few benthos surveys carried out in the assessment area is that by Vibe (1939), who studied a few locations in the Upernavik area in 1936. Here at approx. 72º N, the total average wet weight of the *Macoma* community, which mainly constituted the bivalves *Macoma*, *Mya* and *Hiatella*, was 160–388 gww / m^2. Average benthic biomasses as high as 1,482 gww / m^2 were found locally in this area, although such levels were considered exceptionally high (Vibe 1939, 1950).

The present knowledge of benthic diversity is therefore very limited and species composition, diversity and spatial variability are largely unknown. The physical environment in the assessment area is very variable, partly because water depth ranges from 0 to approx. 2,000 m. Depth is generally considered as one of the primary factors regulating benthic communities since it is often correlated with other factors such as sediment grain size composition, food availability and disturbance level. Changes in these factors directly affect the structure and diversity of the benthos. Thus the KANUMAS West assessment area can be expected to consist of numerous habitats inhabited by different assemblages of benthic species. Taking into consideration research results from other Arctic areas the following general pattern can be expected.

The shallow coastal region (approximately 10–100 m depth) is the most productive area where the highest benthic biomass occurs. In areas with sea ice the tidal zone is often affected by ice scouring, which destroys flora and fauna and reduce the biomass. In such areas maximum biomass is often found at 10–50 m depth, where a few large species dominate (Figure 12) e.g. bivalves (*Mya truncata*, *Serripes groenlandicus*, *Clinocardium ciliatum*), gastropods (*Buccinum* spp.) or sea urchins (*Strongylocentrosus droebachiensis*). Especially bivalves are an important food source for organisms at the higher trophic levels such as eider and walrus. In the fjords the deposition of sediment from rivers or glaciers can locally reduce benthic diversity and biomass. In such areas bivalves are absent and have been replaced by polychaetes.

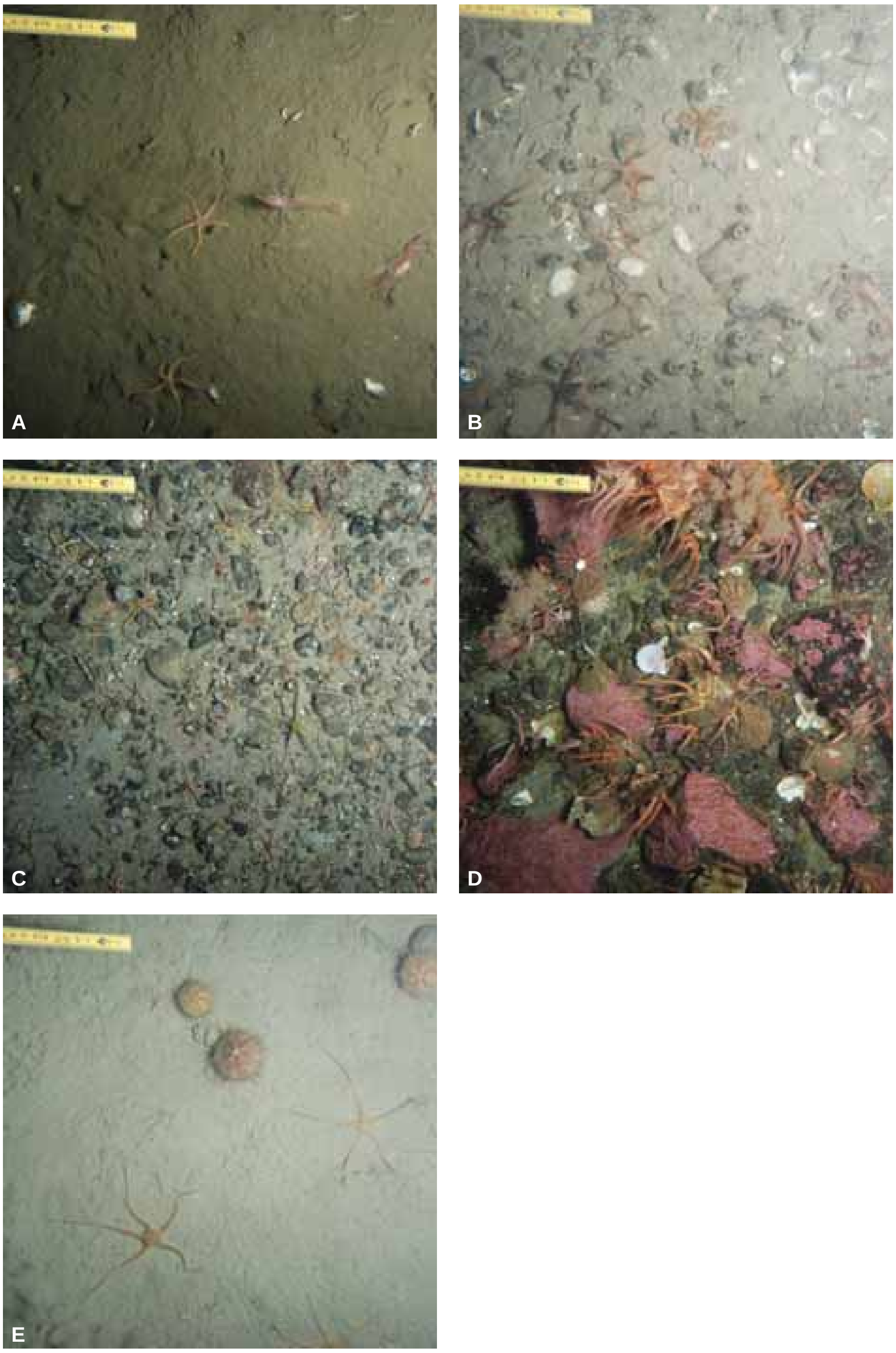
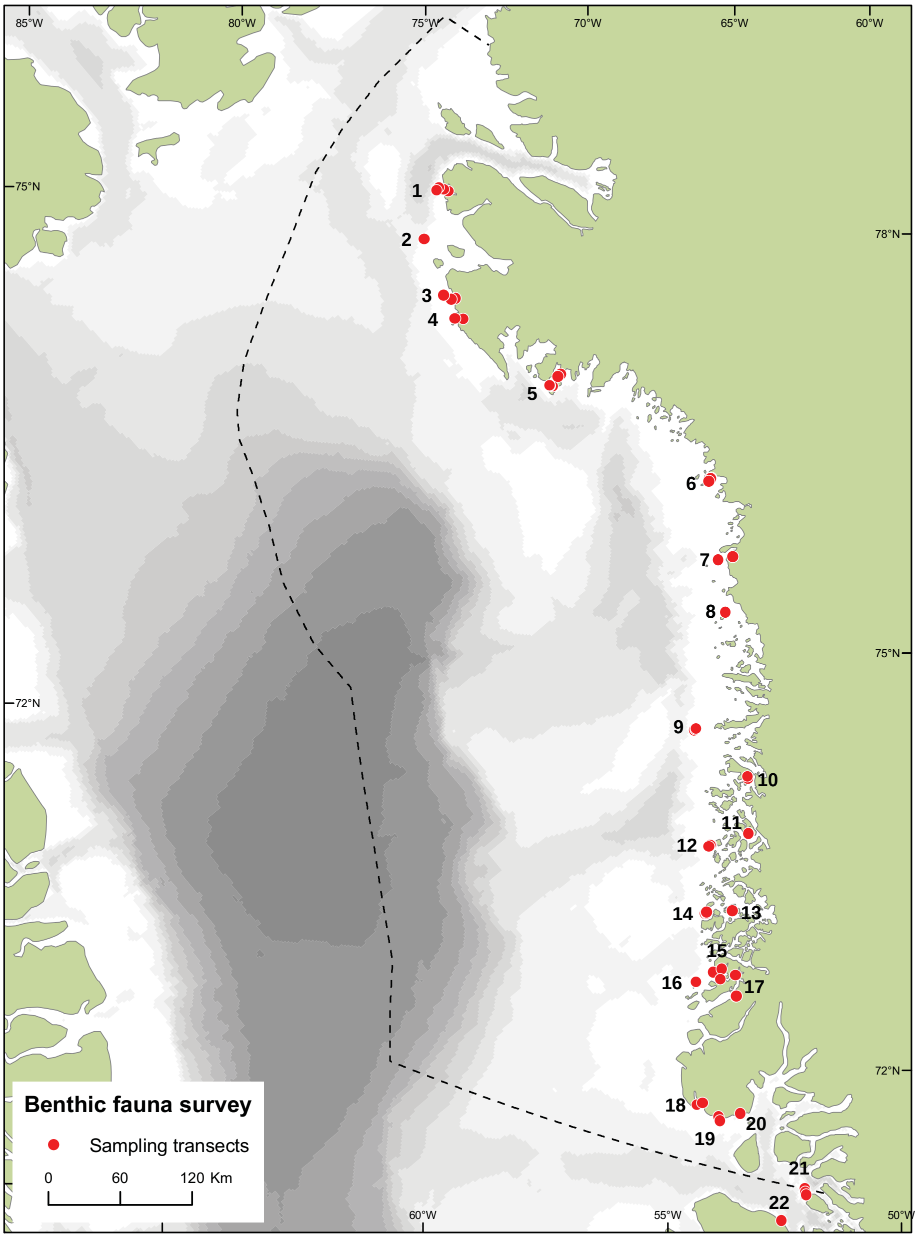


Figure 12. Photos of the seafloor at different stations in the sampling area describing variations in the physical and biological structure. (**A**) St. 15.3, (**B**) St. 8.1, (**C**) St. 9.3, (**D**) 9.1 and (**E**) St. 5.2 (Blicher *et al.* 2008).

At depths of 100–1000 m benthic communities are dominated by polychaetes which can be very numerous, although the total biomass is lower compared with shallow sites (Piepenburg 2005). Diversity of the benthic communities has been found to peak at a depth of approximately 400 m on the continental shelf of Svalbard (Wlodarska *et al.* 2004). In a recent study from the Godthåb Fjord and Fyllas Bank (southwest Greenland) maximum diversity was found at the continental slope at 900 m and in the outer part of the fjord (depth 600 m). Here more than 80 different species were observed per sample of 0.1 m^2. Minimum diversity was found on Fyllas Bank and near the glaciers in the fjord with an average of 20 species per sample (Sejr *et al.* unpublished).

One of the studies initiated in relation to the EIA work in the assessment area includes a survey of the benthic communities. In August 2008 a number of sites were sampled (Figure 13). The study, combined with

Figure 13. Sampling stations (transects along which several samples were made) during the NERI/GINR 2008 survey.



detailed biogeochemical studies, is expected to provide data on benthic biomass, abundance, diversity and species composition as well as the physico-chemical characteristics of the sediment and estimates of the carbon turnover of the sediment.

An underwater camera system was applied to describe seafloor characteristics and the main epi-faunal communities. In addition, a dredge (10 mm mesh size) was used at selected locations to determine characteristic species. When applicable, Van Veen grab samples were taken for quantitative analysis of macrofauna (>1mm) living in the sediment and for sediment characteristics.

The underwater photos revealed a high diversity and variability in regard to sediment structure and benthic habitats. The habitats found varied from soft mud / muddy clay to sandy sediments and large areas were dominated by hard substrates (rock, stones, gravel). The great variability in the sediment structure was also reflected in the composition of the epibenthic fauna (Figure 12). Quantitative sampling of the endobenthos in the vicinity of bird and mammal colonies was in most cases not possible due to the dominance of hard substrate (Blicher *et al.* 2008). Detailed distribution maps of the various benthic communities will be available at the end of 2009, when both determination of the macrofauna and the chemical sediment analyses have been completed.

Northern shrimp *Pandalus borealis*

An important species is the northern shrimp. Although not a true benthos species, at least it lives on and near the sea bed. It occurs on the West Greenland continental shelf more or less continuously distributed from Cape Farewell (60° N) to about 74° N, with the highest densities occurring at depths between 150 and 600 m. Within this area, there is little evidence of stock sub-structure, and the species has been assessed as a single stock. During the day, shrimp stay at the bottom, but may during the night perform vertical movements up in the water column. The eggs are laid in summer and carried by the female until the following spring (April–May), when the females seek shallow water and release the larvae. These are planktonic for three or four months, at which time they drift passively with the currents and subsequently settle on the seafloor far from their release site. Three to six years later they become sexually mature first as males and later, when six to eight years old, as females. Females are larger than males and are therefore the main target for commercial fishery, which in the assessment area only takes place in the southernmost part (section 5.1).

4.3.2 Important and critical area

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 except for the shrimp fishing ground (Figure 39).

4.4 Ice fauna and flora

The drifting ice in the assessment area is 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

Our present knowledge concerning the fish fauna in Northwest Greenland (including the assessment area) is mainly based on information obtained during early Danish expeditions and follow-up analysis (Jensen 1926, 1935, 1939), on more recent studies on single fish species including the description of new species (Nielsen and Fosså 1993, Møller & Jørgensen 2000, Møller 2001) and fisheries related research activities and assessments (Jensen & Fristrup 1950, Pedersen 2005).

4.5.1 Fish assemblages

Based on 263 bottom trawl hauls conducted in the Davis Strait and Baffin Bay (to 74° N) at depths down to 1,500 m in 1999 and 2001, Jørgensen *et al.* (2005) were able to identify seven bottom fish assemblages that differed in respect to species composition, depth distribution and distribution in relation to bottom temperature. Four of these assemblages were unique to Baffin Bay:

1) An assemblage in relatively shallow and warm (mean 302 m, 2.6° C) with low abundance and diversity of fish and with the two small sculpins, *Triglops nybelini* and *Artediellus atlanticus* as 'primary indicator species'. It was also characterised by the daubed shanny (*Leptoclinus maculates*), the checker eelpout (*Lycodes vahlii*), the spotted wolffish (*Anarhichas minor*), the Atlantic sea poacher (*Leptagonus decagonus*) and the thorny skate (*Raja radiata*). Greenland halibut was rare in this assemblage.

2) On the upper slope of Baffin Bay (mean depth 534.6 m and 2.0° C) an assemblage was found dominated by Greenland halibut, but with some shallow water species such as the sculpins, *A. atlanticus* and *T. nybelini* and the American plaice (*Hippoglossoides platessoides*).

3) The slopes facing the central part of Baffin Bay inhabited two assemblages. The shallower one (mean depth 886.1 m and 1.0° C) was also dominated by Greenland halibut and characterised by the presence of the threadfin rockling (*Gaidropsaurus ensis*) and the double-line eelpout (*Lycodes eudipleurostictus*) and by the lack of shallow water species.

4) Greenland halibut was also the dominant species in the deepest assemblage (mean depth 1115.6 m and 0.7° C), which was further characterised by the presence of the Arctic skate, (*Raja hyperborea*), the threadfin seasnail (*Rhodichthys regina*) and the eelpout *Lycodes adolfi*.

The northern part of Baffin Bay (to 73° N–77° N) was surveyed by bottom trawl at depths down to 1,500 in 2004 (Jørgensen 2005), but the results have not been analysed in detail. The bottom temperatures were low and ranged between 1.9° C and –0.7° C. In total, 44 species were identified but Greenland halibut was totally dominant and the only other species caught in notable numbers were pelagic polar cod (*Boreogadus saida)*, Arctic cod (*Actogadus glacialis*) and the Arctic skate (*Raja hyperborea*). The pelagic species were excluded from the analysis of the 1999 and 2001 surveys described above, but especially polar cod was caught in significant numbers in Baffin Bay.

4.5.2 Selected species

Greenland halibut *Reinhardtius hippoglossoides*
The Greenland halibut is a sub-Arctic and 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*

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 eggs, and larvae when they hatch drift with the currents to nursery areas.

The biology of Greenland halibut in the Baffin Bay is poorly known. Neither spawning nor indications of spawning have been observed, either offshore or inshore, but the offshore area has only been surveyed in late autumn. At present it is believed that Greenland halibut recruits arrive as larvae from a spawning area in Davis Strait. The larvae drift from Davis Strait along the coast in the West Greenland Current. They settle as young fish in the southern part of Baffin Bay and later migrate into the assessment area. Preliminary tagging results seem to support this assumption about the connection between the Greenland halibut population in the Davis Strait and Baffin Bay.

Greenland halibut is an important food source for narwhals (*Monodon monoceros*). During five winter months, 50,000 narwhals distributed at two wintering grounds in the central part of Baffin Bay were estimated to consume in the region of 790 tonnes of this fish per day assuming a diet consisting of 50 % of Greenland halibut (Laidre *et al.* 2004). Based on studies of diving depths of narwhals, Laidre *et al.* (2003) concluded that polar and Arctic cod could be more important food sources in the northern wintering ground, and during summer.

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 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 webs (Figure 10) and constitute an important prey for many marine mammals and seabird species, notably ringed seal, harp seal, white whale, thick-billed murre, northern fulmar, black-legged kittiwake, and ivory and Ross's gulls.

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 people of Greenland (Riget & Böcher 1998).

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 at higher latitudes with shorter growing season, lower temperature and variability in food resources will result in a slower growth rate and later maturity than at lower latitudes (Malmquist 2004).

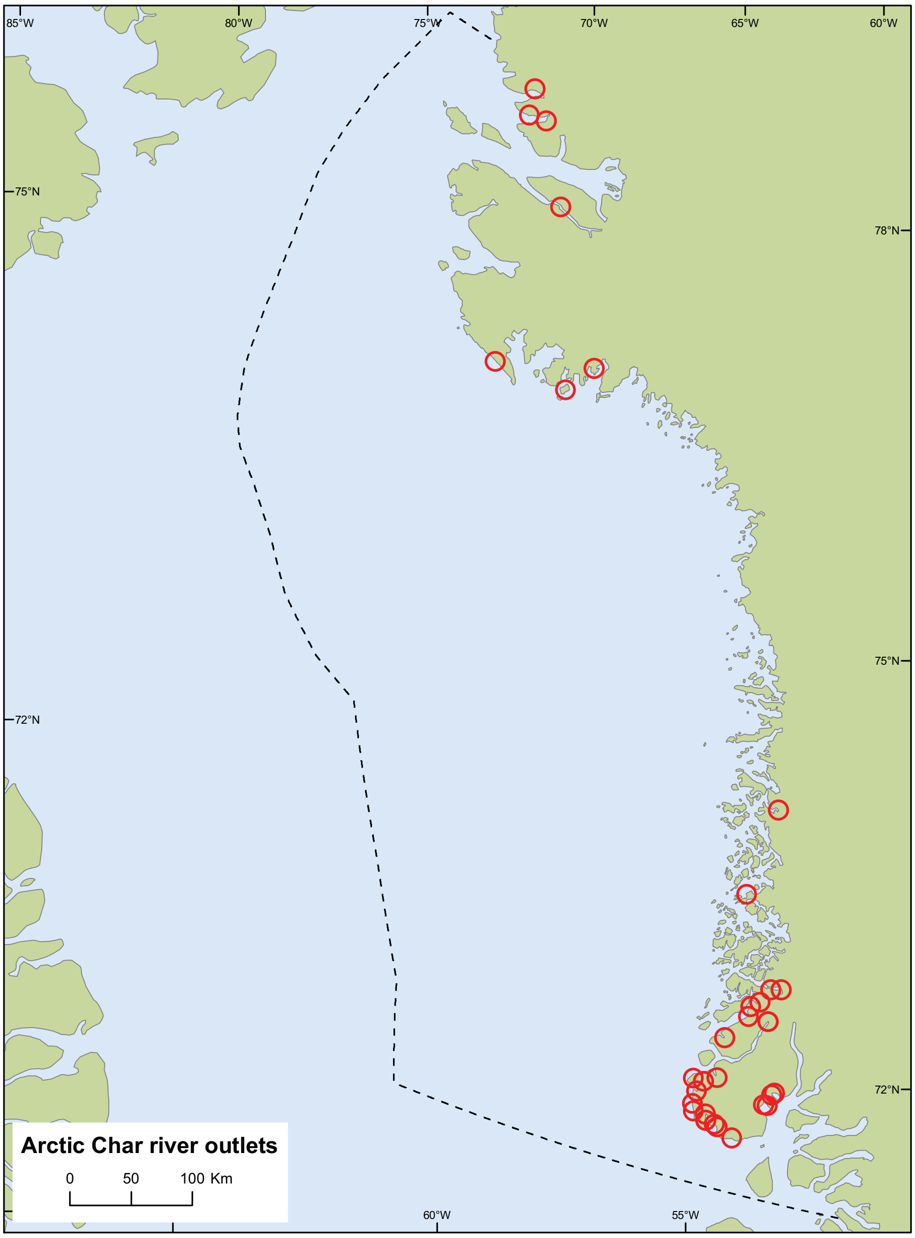
The eggs of the char winter in gravel in deep river pools or in lakes. The fry emerge in April–May and live off their yolk sac for about a month before feeding on small plankton organisms along the margins of rivers or lakes (Muus 1990). The young char called parr remain in freshwater for several years 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 (approx. 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 movements of tagged fish 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 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 Fiskeriundersøgelser 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 rivers 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

Figure 14. River outlets with Arctic char. Red circles indicate position of outlets of rivers with anadromous Arctic char. Based on local knowledge (Petersen 1993, a, b, Olsvig & Mosbech 2003). The information from northern Upernavik and Qaanaaq municipalities is fragmentary and more rivers with Arctic char probably occur.



(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 of the occurrence of anadromous population along the coast of the assessment area is limited. Spawning rivers and fishing grounds were mapped based on local knowledge during an interview investigation in 2002 covering the former Uummannaq municipality and the southernmost parts of former Upernavik municipality north to 72° 30’ N (Olsvig & Mosbech 2003). According to an earlier investigation there are very few char rivers in the northern parts of the former Upernavik municipality and in the former Qaanaaq municipality (Petersen 1993a, b). Figure 14 gives an overview of the known river outlets with spawning Arctic char.

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		Distribution	Red List status in Greenland	Importance of study area to population	VEC
Fulmar	b	Summer	c & o	Least Concern (LC)	high	+
Great cormorant	b	Summer	c	Least Concern (LC)	high	+
White-fronted goose	b	May-September	c	Endangered (EN)	medium	
Snow goose	b	May–September	c	Least Concern (LC)	low	
Brent goose	b, mi	Spring and autumn	c	Least Concern (LC)	high	
Common eider	b/s/m	Summer	c	Vulnerable (VU)	high	+
King eider	s, m, mi,	July–September	c	Least Concern (LC)	high	+
Long-tailed duck	b/m	Summer	c	Least Concern (LC)	medium	+
Red-breasted merganser	b/m	Summer	c	Least Concern (LC)	low	
Red-necked phalarope	mi, (b)	Spring and autumn	o	Least Concern (LC)	low	
Grey phalarope	mi, (b)	Spring and autumn	o	Least Concern (LC)	low	
Arctic skua	b	Summer	c	Least Concern (LC)	low	
Black-legged kittiwake	b, mi	Summer	c & o	Vulnerable (VU)	high	+
Glaucous gull	b	Summer	c & o	Least Concern (LC)	medium	
Iceland gull	b	Summer	c & o	Least Concern (LC)	low	
Great black-backed gull	b	Summer	c & o	Least Concern (LC)	low	
Sabines gull	b, mi	August and May/June	c & o	Near Threatened (NT)	low	
Ivory gull	mi	Spring and autumn	c & o	Vulnerable (VU)	medium	+
Arctic tern	b, mi	May–September	c & o	Near Threatened (NT)	high	+
Thick-billed murre	b/s, mi	Summer	c & o	Vulnerable (VU)	high	+
Razorbill	b	Summer	c & o	Least Concern (LC)	high	
Atlantic puffin	b, mi	Summer	c & o	Near Threatened (NT)	high	+
Black guillemot	b, mi	Summer	c & o	Least Concern (LC)	high	
Little auk	b, mi	Summer	c & o	Least Concern (LC)	high	+

4.6 Seabirds

During the ice-free periods seabirds 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 on land. Many species are primarily fish consumers living from schooling species (capelin, sandeel and polar cod). Some species live on or supplement their fish diet with large zooplankton (copepods, krill), and others feed primarily on benthic invertebrates (e.g. bivalves) (Falk & Durinck 1993, Merkel *et al.* 2007). The species utilise the common resources by means of different feeding methods; for example, some species are deep-diving foragers while others take their food on the surface. Many seabird species tend to aggregate at breeding or foraging sites, and extremely high concentrations may occur. For example, 80 % of the global breeding population (N = 33 million pairs) of little auks (*Alle alle*) are estimated to breed on a 200 km-long shoreline of the former Qaanaaq Municipality of Northwest Greenland (Egevang *et al.* 2003). An overview of seabird species is given in Table 1.

Overall and general knowledge of seabirds in the assessment area is fairly good. However knowledge about offshore distributions in migration seasons is needed most, and several other specific questions remain to be solved in order to conduct project-specific EIAs.

Most seabirds are colonial breeders and numerous seabird breeding colonies are found dispersed along the coast of the assessment area (Figure 15). Colonies vary in size (from a few pairs to millions of pairs) and in species composition, from holding only a single species up to eight different species. In addition to the breeding birds, colonies are also used by many immature birds, which are potential breeders. The breeding seabirds utilise the waters near the breeding site; thick-billed murres (*Uria lomvia*) may fly more than 100 km to find their food, but most feed within a much smaller range (Falk *et al.* 2000, NERI unpublished).

Seaducks arrive from breeding sites in Canada and inland Greenland and assemble to moult in remote bays and fjords (Figure 16). The most numerous is the king eider (*Somateria spectabilis*), but also long-tailed ducks (*Clangula hyemalis*) and red-breasted mergansers (*Mergus serrator*) may occur in shallow fjords and bays (Mosbech & Boertmann 1999, Boertmann & Mosbech 2002). A few species occur only as migrant visitors during spring and autumn, e.g. two species of phalaropes and Sabines gull (*Larus sabini*). The rare and threatened ivory gull (*Pagophila eburnea*) occurs as migrant visitor and as far as is known does not breed within the area; although it is frequent in the North Water area in summer and breeds on southern Ellesmere Island (Boertmann 1994, Gilchrist *et al.* 2008).

There are 16 species of seabirds breeding in the assessment area (Boertmann *et al.* 1996). The most important are described in the following pages.

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: Two breeding colonies are known from the assessment area (Figure 15), and the major part of the Greenland breeding population is found just to the south in Uummannaq Fjord and Disko Bay (Boertmann *et al.* 1996). The breeding numbers in the two colonies are unknown, but at least several thousand pairs breed in each of them.

Offshore distribution: Fulmars occur almost everywhere in the offshore areas as long as open water is present, and they usually only avoid areas with high

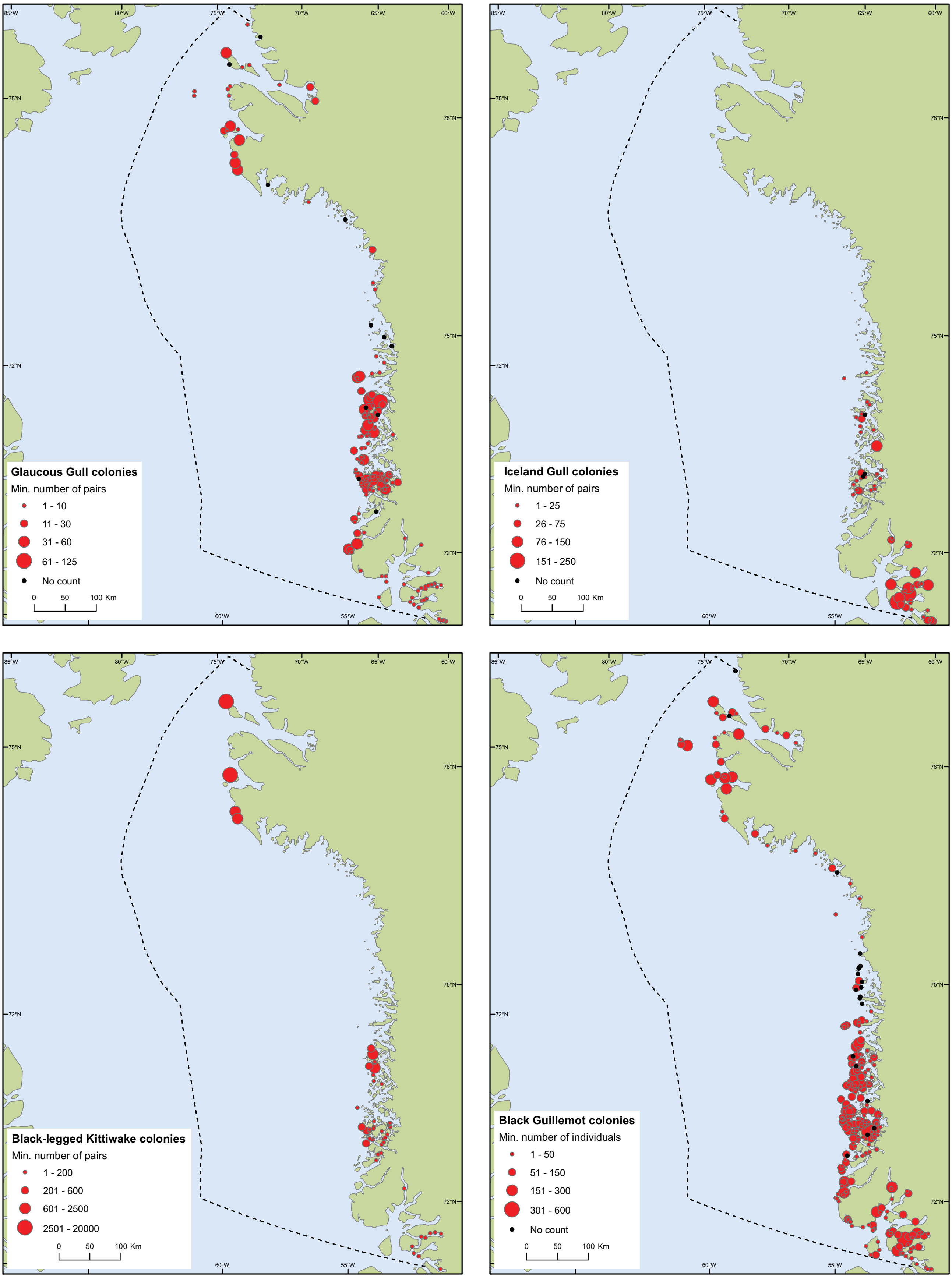


Figure 15A. Distribution and size of seabird breeding colonies in the assessment area. Note that the size of the huge colonies of little auk in Qaanaaq municipality is unknown. However, the total numbers breeding here has been estimated to more than 30 million pairs.

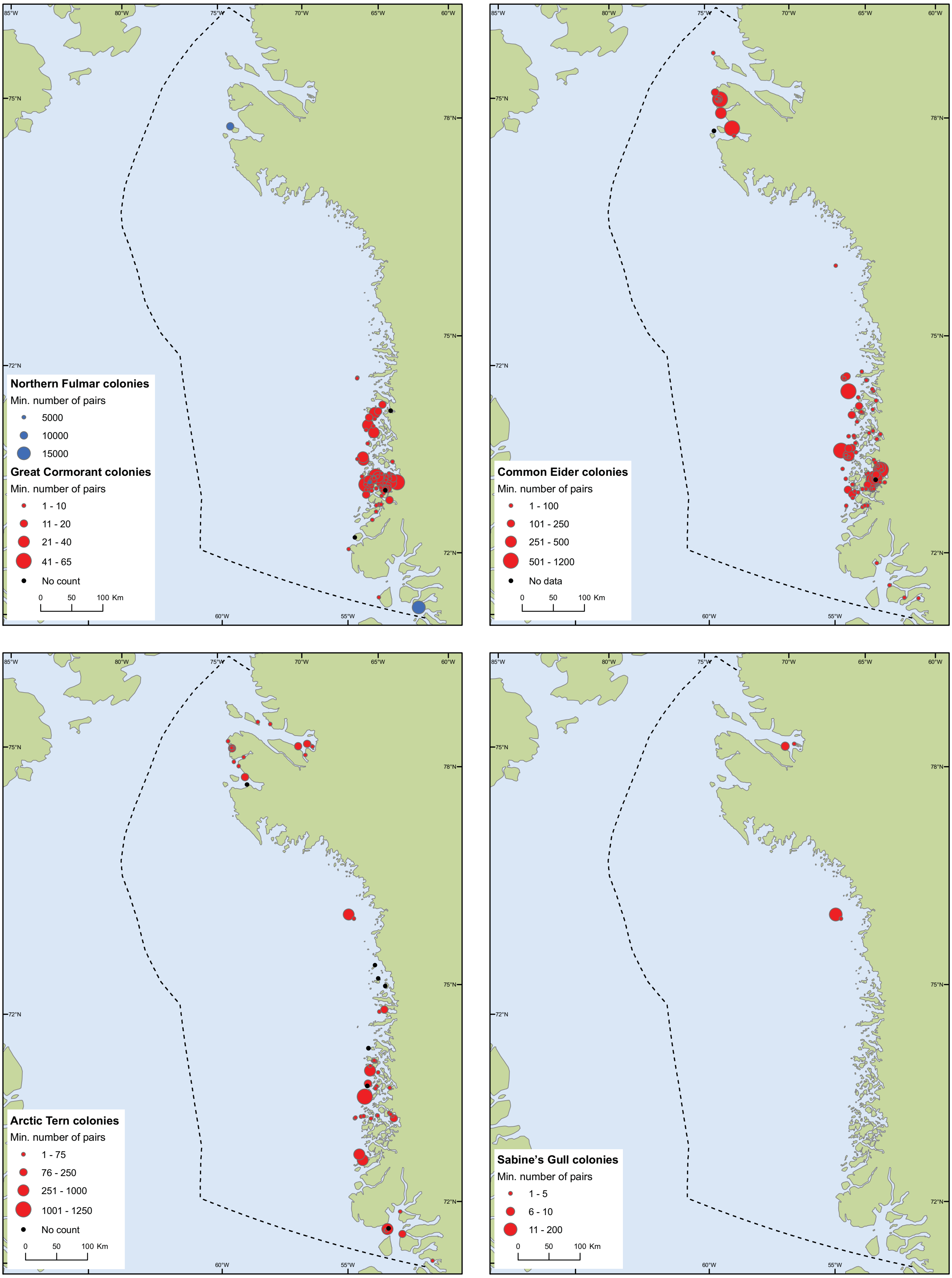


Figure 15B. Distribution and size of seabird breeding colonies in the assessment area. Note that the size of the huge colonies of little auk in Qaanaaq municipality is unknown. However, the total numbers breeding here has been estimated to more than 30 million pairs.

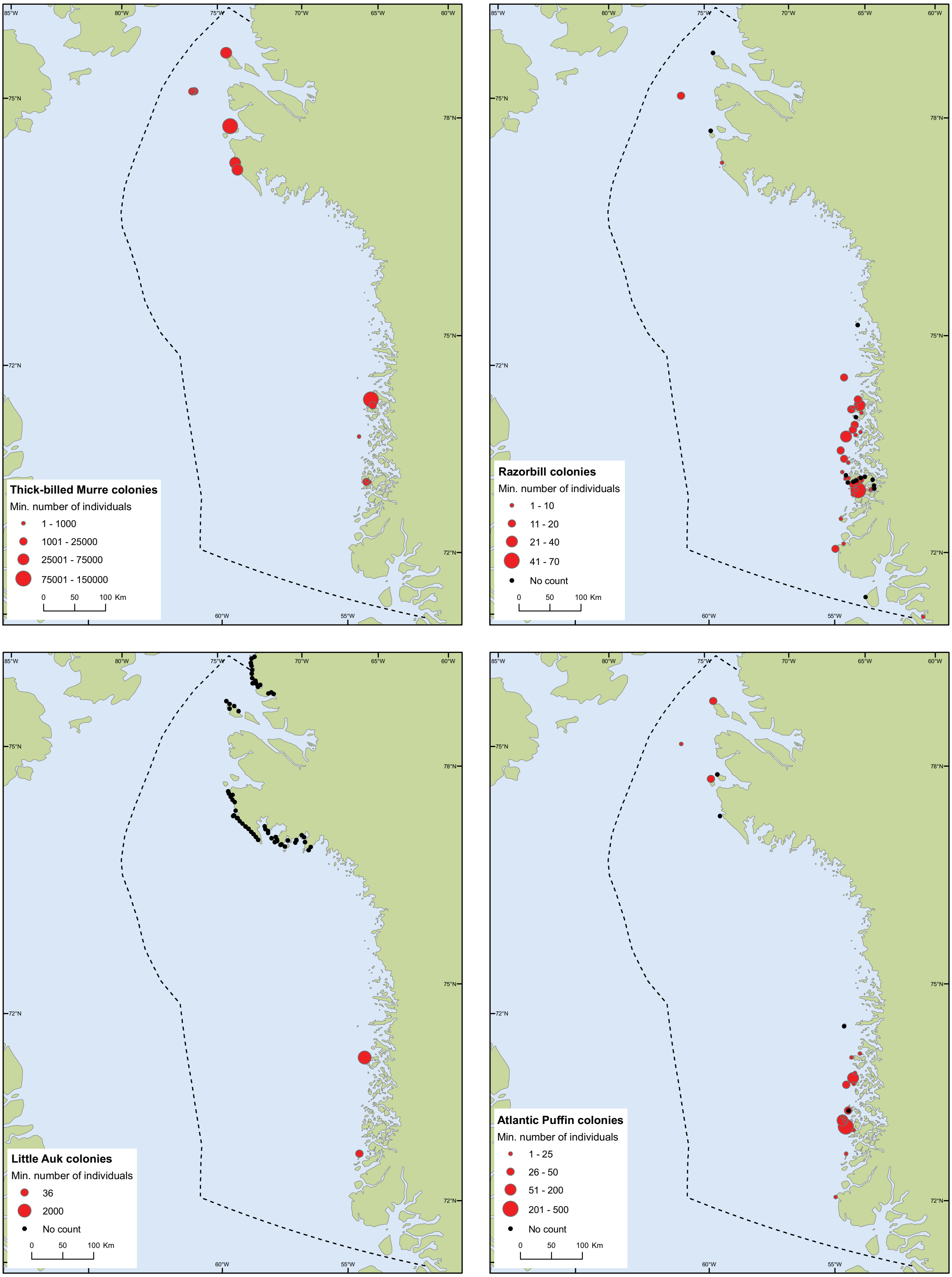
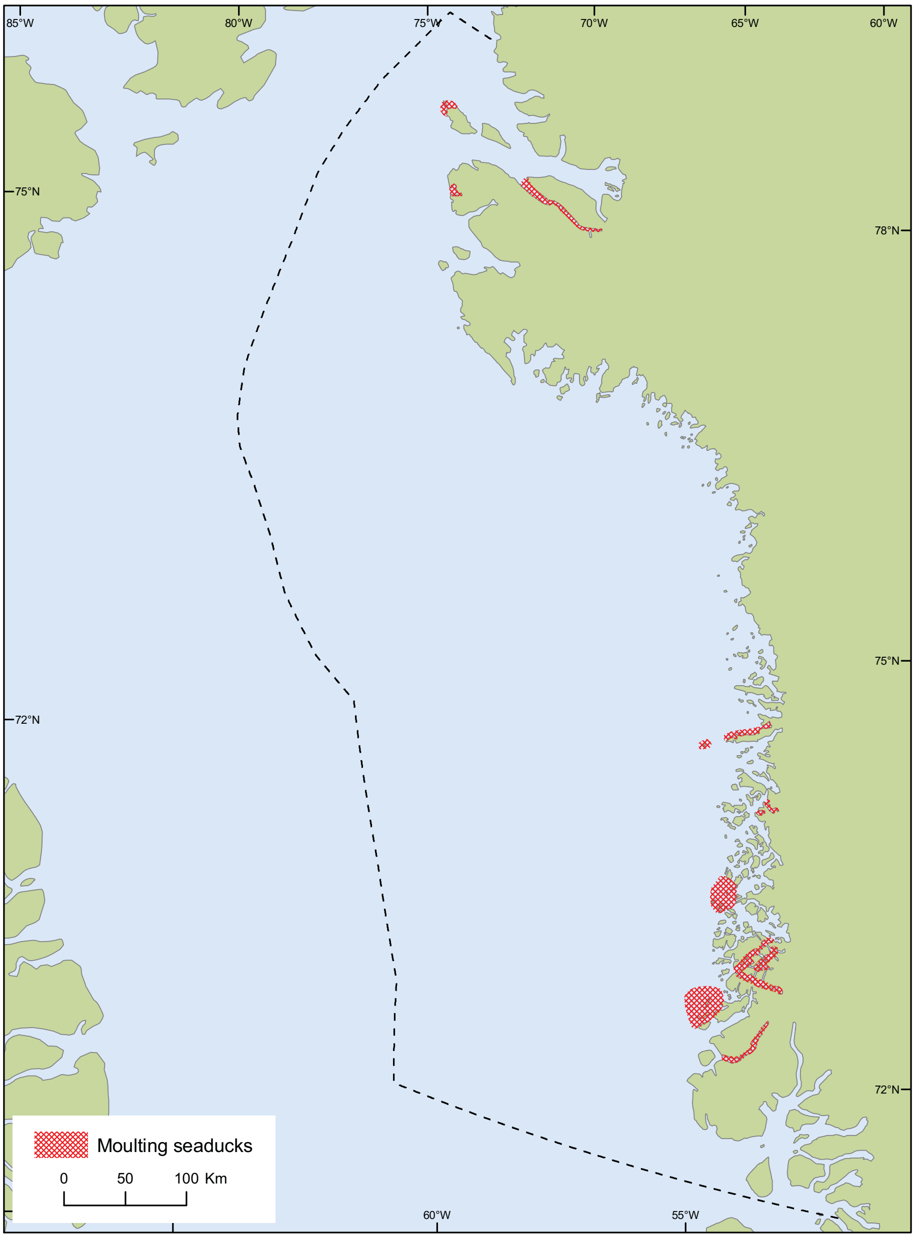


Figure 15C. Distribution and size of seabird breeding colonies in the assessment area. Note that the size of the huge colonies of little auk in Qaanaaq municipality is unknown. However, the total numbers breeding here has been estimated to more than 30 million pairs.

Figure 16. Important areas for moulting seaducks (mainly king eiders) in the assessment area. Moulting takes place in July, August and early September.



ice coverage. Concentrations here are linked to foraging areas, and may occur at ice edges, upwelling areas and areas with commercial fisheries.

Biology: Fulmars feed usually at the surface, but can also perform shallow dives. They spend much time flying.

Catch: Fulmars are not very attractive as hunting quarry and relatively few are taken by the hunters of the assessment area.

Conservation status: The fulmar population of the assessment area has a favourable conservation status, and it is not included on the Greenland Red List (listed as of 'Least Concern' (LC)).

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.

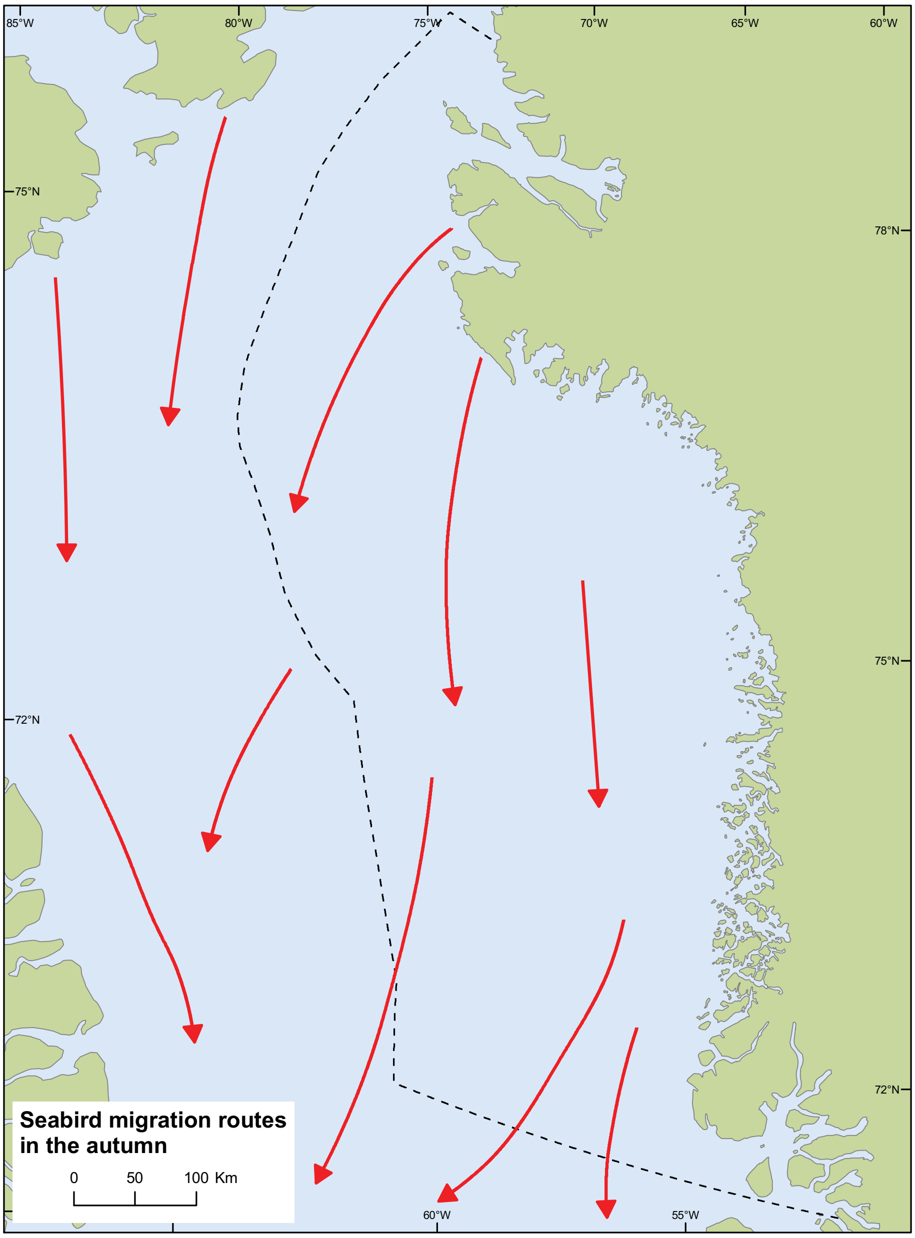


Figure 17. The supposed autumn migration flyways in the Bafffin Bay area. The majority of the birds are little auks and thick-billed murres, in total estimated at more than 100 million birds.

Great cormorant *Phalacrocorax carbo*
Distribution and population size: Cormorants breeds in several colonies on the coasts of the southern part of the assessment area (north to about 74° N) (Figure 15). In 1997 the population was estimated at about 150 pairs. It has increased considerably since then and may number more than 500 pairs today (Boertmann & Mosbech 1997), representing perhaps 10 % of the total Greenland breeding population. Moreover, the population may have extended the breeding range further north. Colonies are generally small with fewer than 20 pairs.

Cormorants are always closely associated to coastal waters where they feed in rather shallow water and they are also dependent on terrestrial resting places.

Biology: The breeding birds arrive as soon as open water is present, and they leave again in late autumn for wintering grounds to the south of the assessment area.

Cormorants are diving birds that feed on fish. They are always found in coastal areas because they depend on terrestrial roosts to rest and dry their feathers.

Catch: Cormorants are a hunted but not preferred quarry.

Conservation status: The cormorant population of the assessment area has a favourable conservation status, and it is listed as 'Least Concern' (LC) on the Greenland Red List.

Sensitivity and critical areas: The breeding colonies are sensitive because many cormorants often rest on the water surface below the breeding cliffs. Spring migration concentrations may occur, but have not been reported.

Common eider *Somateria mollissima*

Breeding distribution: This duck is closely associated with the marine environment. It breeds both dispersed and in colonies on low islands and feeds in shallow coastal waters throughout the assessment area (Figure 15).

Non-breeding concentrations: Males assemble in moulting concentration in remote fjords and archipelagos when the females have brooded for some time. Females (failed breeders) follow the males somewhat later and most birds moult within 100 km from the breeding site (Mosbech *et al.* 2006). Here they moult flight feathers simultaneously and become flightless for about three weeks. They subsequently migrate to wintering areas in the coastal waters of West Greenland to the south of Disko Bay (Lyngs 2003, Mosbech *et al.* 2007c).

Population size: The breeding number in the assessment area is unknown, but numbers probably amount to some thousands. The population declined considerably during the 1900s due to non-sustainable harvest. But recently, a population recovery has been demonstrated in Ilulissat and Upernavik, where active management and monitoring using local stakeholders has been carried out (Merkel 2008).

Catch: The common eider is an important quarry for the hunters of the region. Approx. 5,000 were reported to the hunting bag register as caught in the assessment area in 1995 (Piniarneq 1996).

Conservation status: The common eider population of the assessment area has an unfavourable conservation status due the decline in breeding numbers. It is listed as 'Vulnerable' (VU) on the Greenland Red List.

Sensitivity and critical areas: Breeding colonies, moulting areas and staging areas during migration are sensitive, as birds may stay on the water. Particularly some of the archipelagos in Upernavik seem to be important moulting and staging area during migration. Large flocks have been recorded for example at the 'Fladøerne'.

Glaucous gull *Larus hyperboreus*

Breeding distribution: This is the most common and widespread gull in the assessment area. It breeds along the coasts, both dispersed and in small colonies rarely with more than 100 pairs (Figure 15).

Non-breeding distribution: Glaucous gulls are present in the region as long as open water occurs. Glaucous gulls are usually found in coastal areas, but some also venture far offshore. Concentrations occur at breeding sites and at good foraging areas, which may be more or less unpredictable in their occurrence.

Population size: The total breeding population in the assessment area numbers probably more than 2,000 pairs.

Conservation status: The glaucous gull population of the assessment area has a favourable conservation status, and it is listed as of 'Least Concern' (LC) on the Greenland Red List.

Sensitivity and critical areas: Glaucous gulls are most sensitive at the breeding colonies. These colonies however are generally small and the population is spread widely along the coasts, and therefore population sensitivity is relatively low compared with other much more concentrated seabirds.

A similar species in most respects – Iceland gull, *Larus glaucoides* – occurs in the southern part of the assessment area (Figure 15).

Black-legged kittiwake *Rissa tridactyla*

Breeding distribution and population size: Kittiwakes are strictly colonial breeders placing their nests on vertical cliffs at the sea. There are at least 36 breeding colonies in the assessment area, with a total of about 40,000 breeding pairs (Labansen *et al.* in prep.) (Figure 15)

Non-breeding distribution: Kittiwakes are migratory, leaving the breeding areas in September / October and returning again when open waters appear in April / May. Many non-breeders occur in offshore areas in summer.

Biology: Kittiwakes feed usually on the surface when swimming; they can also perform shallow dives.

Conservation status: The population in West Greenland has an unfavourable conservation status, as it has declined much since mid-1900s, probably due to excessive hunt. However, the large colonies in the former Qaanaaq Municipality that make up more than 80 % of the population within the assessment area seem not to have declined (Merkel *et al.* 2007).

Catch: Kittiwakes are a preferred quarry for hunters of the assessment area. In 1993 approx. 3,000 were reported shot to the hunt record for the region to the north of Disko Bay (Piniarnneq 1996).

Sensitivity and critical areas: Kittiwakes will be most vulnerable at breeding colonies where large numbers of birds assemble on the sea surface. There may also be concentrations at feeding areas, e.g. in the marginal ice in spring and early summer.

Arctic tern *Sterna paradisaea*

Breeding distribution and population size: Arctic terns are mainly colonial breeders, placing their nests on small and low islands. Colony size ranges from a few pairs to about 20,000 pairs. At least 40 colonies are known from

Box 1

Fieldwork results seabird studies in 2007 and 2008 in the KANUMAS West assessment area

The results illustrate the different condition there are within this large area (Hakluyt Ø and Saunders Ø are in the former Qaanaaq Municipality and Kippako is approx 500 km to the south in Upernavik.

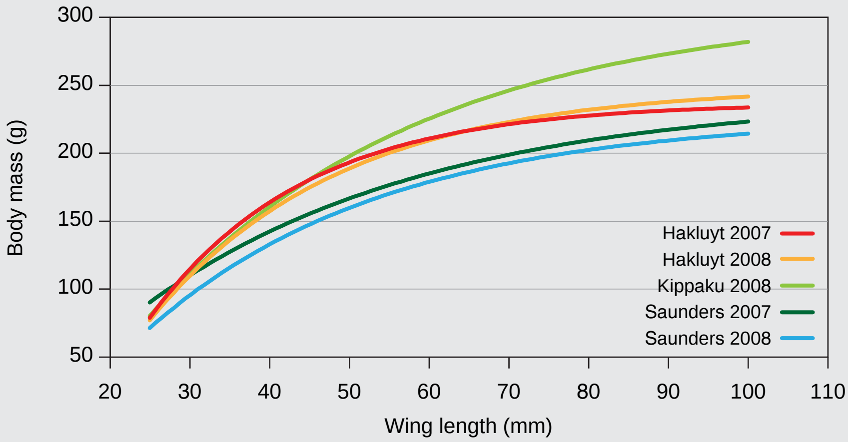


Figure 1. Body condition of thick-billed murre chicks. In order to assess feeding conditions, wing length and body mass were measured for samples (n = 65–152) of murre chicks at all study colonies. Asymptotic growth curves were then fitted to the data, see figure above. Results show that chicks at the southern study colony (Kippaku) attained a higher body mass before fledging than in the other colonies. Chicks at Hakluyt Ø initially grew faster than those at Saunders Ø, but fledging masses were similar. Interestingly, at both northern colonies growth patterns were very similar between years.

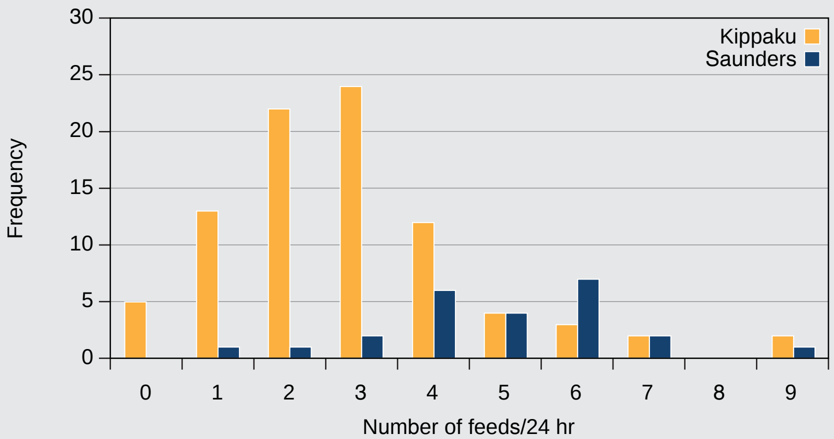


Figure 2. Feeding rates of thick-billed murre chicks. Twenty-four hour feeding watches were performed at Kippaku (2) and Saunders Ø (1) in 2008, with sample sizes of respectively 44 and 24 chicks. Mean feeding rate was substantially higher at Saunders Ø (mean 4.92 feeds/chick/24 hr) than at Kippaku (mean 2.87 feeds/chick/24 hr), see also figure above. It is striking that despite the higher feeding rate at Saunders Ø, chicks here were in poorer body condition than at Kippaku (see Box Figure 1). This may reflect smaller and/or less nutritious food units being prevalent at the northern colony.

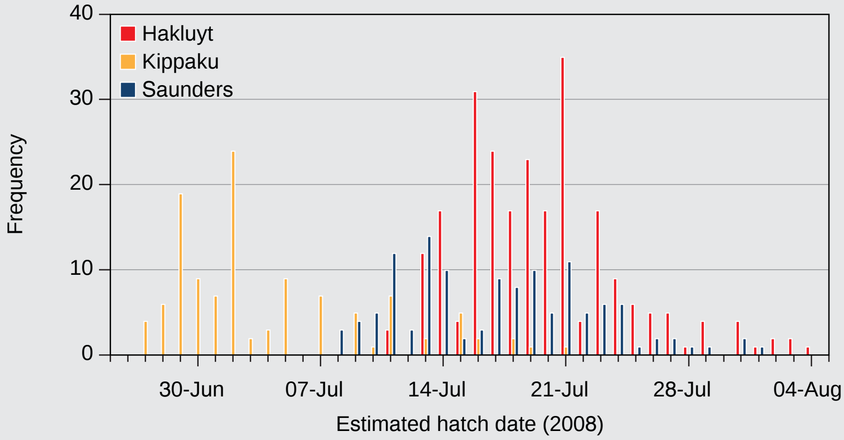


Figure 3. Breeding phenology of black-legged kittiwakes in 2008. Samples of black-legged kittiwake chicks were aged at all study colonies, and hatch dates back-calculated. In 2008, mean hatching was about two weeks earlier at Kippaku (mean = 4 July, n = 120) than at Saunders Ø (mean = 17 July, n = 138) and Hakluyt Ø (mean = 19 July, n = 251), see also figure above. Hatch dates were also very similar at the two northern colonies in 2007 (mean = 20 and 21 July, n = 54 and 86).

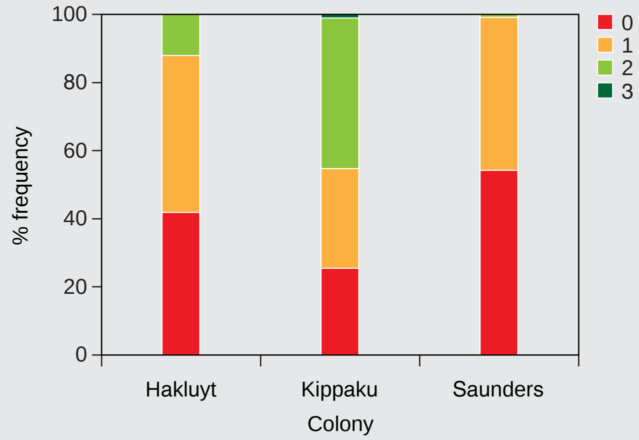


Figure 4. Breeding success of black-legged kittiwakes.Breeding success was estimated by counting chicks in active nests and attempting to identify failed nests. Most chicks were large, and mortality between survey and fledging is likely to have been low. In 2008, mean breeding success was much higher at Kippaku (mean = 1.21 chick/nest, n = 161) than at Saunders Ø (mean = 0.47 chick/nest, n = 301) or Hakluyt Ø (mean = 0.67 chick/nest, n = 432), see figure above. Breeding success was lower at the two northern colonies in 2008 than in 2007 (mean = 1.24 and 1.11 chick/nest, n = 58 and 112), although it is uncertain whether data from Saunders Ø in 2007 are strictly comparable.

the assessment area, and many in the southern part of the area hold more than 1,000 pairs (Egevang & Boertmann 2003) (Figure 15).

Biology: Arctic terns are highly migratory, wintering in the southern hemisphere. They arrive to the breeding colonies during May / early-June and leave again during August / September. The spend most of the time in coastal waters close to breeding colonies. Terns feed on fish and crustaceans by plunge diving, and they usually do not rest on the water surface, making them less exposed than other seabirds to marine oil spills.

Conservation status: The West Greenland Arctic tern population has an unfavourable conservation status as it has been decreasing, perhaps due to excessive egg-collecting (which was banned in 2001).

Sensitivity and critical areas: Breeding colonies are the most sensitive areas for Arctic terns. Offshore concentrations are not known, and are probably also infrequent as the migration both spring and autumn takes place over a very short time, without staging in assembling areas.

Thick-billed murre *Uria lomvia*

Breeding distribution and population size: This is one of the most numerous seabirds in the assessment area. By far the major part of the Greenland breeding population is found in colonies on the coasts of the assessment area. In the former Qaanaaq municipality there are five large colonies numbering in total 225,000 pairs and in Upernavik there are today three occupied colonies and a number of colonies either extinct or on the verge of extinction (Figure 15). There are approx. 100,000 pairs breeding in Upernavik.

Biology: Thick-billed murres of the assessment area are migratory, wintering in southwest Greenland and Newfoundland waters (Lyngs 2003, Boertmann *et al.* 2004).

Murres are pursuit divers, chasing fish and large zooplankton down to more than a 100 m depth. They spend very long time on the sea surface, and only come on land in the breeding season. When the chicks are approx. three weeks old and far from fully grown or able to fly, they leave the colony in company with the male bird and swim / drift to offshore waters. The male then sheds all flight feathers and becomes flightless for some weeks. Murres are particularly sensitive to oil spills, and during this period of flightlessness their vulnerability increases.

The migration pathways are still poorly known, but recent research by NERI, by means of satellite telemetry has given some preliminary results (Box 2). Further studies will carried out in 2009.

Catch: Murres are the most popular seabirds hunted in the assessment area. Approx. 13,000 were reported to the hunting bag register as shot in the assessment area in 2005 (Piniarneq 2006).

Conservation status: The West Greenland population has an unfavourable conservation status because it is decreasing, except for the colonies in the former Qaanaaq municipality. The decrease has been particularly strong in Uummannaq and the southern part of Upernavik, where several colonies are extinct today, some of which held up to 100,000 pairs before 1950. This decline is mainly ascribed to non-sustainable harvest, and more re-

Box 2

Identification of migration routes and foraging areas of thick-billed murres using satellite telemetry

Migration routes

When the young thick-billed murres leap from the ledges at an age of about 16 days they are not able to fly and glide through the air to the water, usually closely followed by one or two adults. Once in the water, the chick starts a swimming migration accompanied by the male adult, which during the first weeks of the swimming migration moults its flying feathers and is unable to fly. The female will typically continue to attend the ledge for about two weeks before starting the migration and the moult. During the swimming migration, murres are very vulnerable to oil slicks on the sea surface. To identify the migration routes of thick-billed murres from the colonies at Saunders Island, Kippaku and Inaq/Ritenbenk we equipped murres with satellite transmitters and data loggers.

To track the autumn migration of the murres we used implanted satellite transmitters with an external antenna (26 g pressure proof implantable Microwave PTT). Murres with chicks were selected. The advantage of the implanted PTT is that it is not shed with the feathers and potentially it can give information on the movements of a full year. The disadvantage is that the surgery typically will cause the murre to give up breeding that year.

Murres with internal satellite transmitters from Saunders Island were tracked for up to 166 days (median 46 days). Of the ten murres tracked, eight were tracked for some or all of their autumn migration. (Box Figure 5). The routes through northern Baffin Bay varied: four of the eight murres first headed towards Lancaster Sound and staged near the mouth, two staged in the local foraging area (approximately 60 km W-SW of Saunders Island), one staged in Melville Bay and one did not stage en route but flew directly south to western Davis Strait. However, regardless of staging area in northern Baffin Bay, all four murres which were tracked all the way through Baffin Bay followed an offshore route through central Baffin Bay. Four murres were tracked beyond Baffin Bay, and they all went to the western side of the Davis Strait towards the Labrador-Newfoundland wintering area. One murre tracked from Kippaku in northern Upernavik also went west to central Baffin Bay before heading south.

We have analysed the rate of movement of the eight murres tracked from Saunders Island for more than 33 days to see if the murres move with a speed where they most likely were performing a swimming migration. Based on analysis of frequency distributions of rate of movement between locations, it appears that swimming migration is characterised by a maximum speed between locations of 3 km/h. Six of eight murres did not have rates of movements exceeding 3 km/h for the first 25 days or more, and potentially could have moulted the flying feathers during this period. Two of the eight birds moved with rates exceeding 3 km/h after one and two weeks respectively, and thus probably flew some of the way to the moulting area.

In conclusion, our results show that the murres on autumn migration from Saunders Island tended to stage in northern Baffin Bay before heading south through the central part of Baffin Bay and into the Labrador Current in the western part of the Davis Strait and the Labrador Sea. The thick-billed murres from Ritenbenk tended to stage and moult in southeastern Baffin Bay, mainly to the south of the assessment area.

Foraging areas

While the locations of the large, seabird breeding colonies in West Greenland are well known, little is known about the actual foraging areas during breeding in the colonies. This is very important information in relation to identification of critical habitats which can be affected by potential oil spills. We have combined the use of telemetry with ship-based surveys to identify foraging range and areas around two important colonies of thick-billed murre in the KANUMAS West area: Saunders Island and Kippaku.

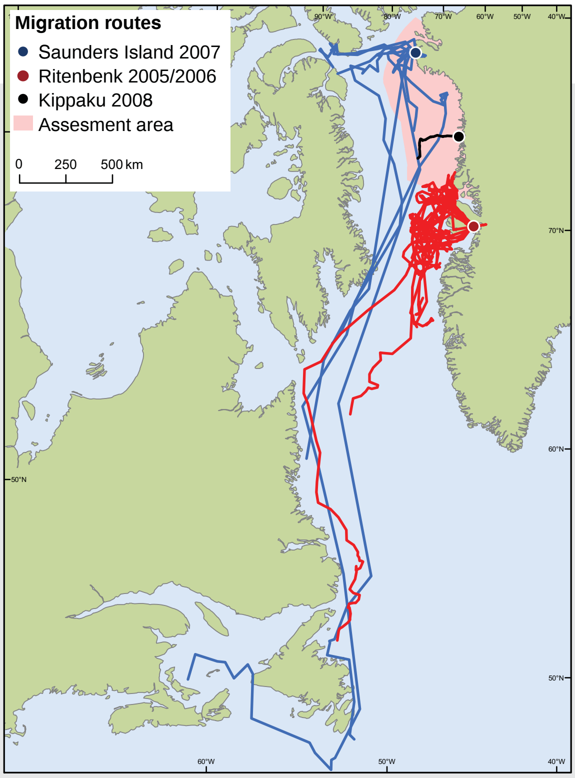


Figure 1. Track lines for the thick-billed murres autumn migration tracked with satellite transmitters from three breeding colonies in West Greenland. The figure shows tracks for eight thick-billed murres tracked with internal satellite transmitters from Saunders Island, one tracked with external satellite transmitter from Kippaku and 26 tracked with internal satellite transmitters from Ritenbenk.

Geolocation data loggers

To track the birds' migration we have also used geolocation data loggers, which are small archival tags recording time and light intensity. Some can also record additional information like temperature and pressure. The data loggers only store the information, and we therefore need to re-capture the birds in the following field season to get the information. Based on the data retrieved from the logger on day-length and time of local noon, the latitude and longitude respectively can be calculated. The accuracy of the geolocators is quite coarse, typically within approximately ± 150 km. However, even with this accuracy we can get very important information on the migration routes and wintering areas of the birds breeding in the colonies at Saunders Island and Kippaku.

In 2007 we deployed geolocating data loggers on 21 thick-billed murres at Saunders Island (5.5 g Lotek LTD2400). Murres with chicks were caught with a noose pole and had the tag attached to the tarsus with a metal ring. After attachment, the birds returned to their chicks within few minutes. In 2008, we retrieved 15 of the 21 deployed geolocating tags at Saunders Island, and they are now undergoing data download and processing.

In 2008 we deployed geolocating archival tags on 34 thick-billed murres (3.6 g Lotek LAT2500 (n=14) and 1.8 g British Antarctic Survey (BAS) MK13 (n=20)) and on 20 kittiwakes (BAS MK13) at Kippaku.

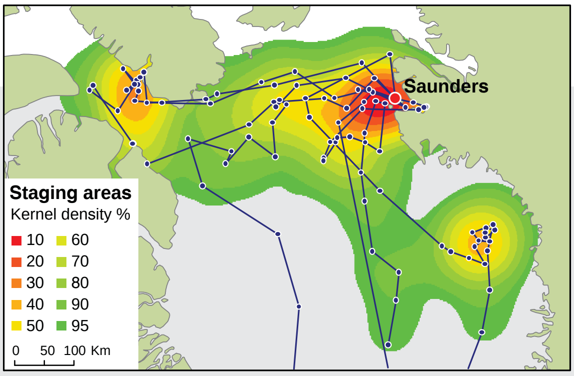


Figure 2. Post-breeding area usage for seven thick-billed murres tracked from the colony at Saunders Island. The figure shows track lines and Kernel home range contours for the period from when the birds left the colony (stopped commuting to the colony) to when they headed south. The Kernel home range 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.

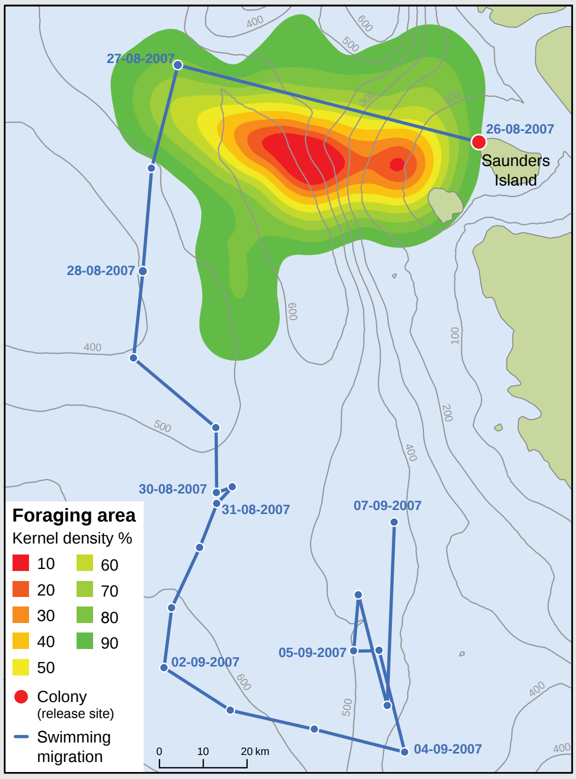


Figure 3. Foraging area for a thick-billed murre tracked with external satellite transmitter while commuting between the colony at Saunders Island and foraging areas. Foraging area is estimated as the Kernel home range contours, only including locations away from the colony. The murre were tracked for 33 days and undertook foraging trips for 21 days, and in that period it had a minimum of 14 foraging trips with a mean duration about 24 h each. The mean distance to the centre of the foraging area was about 60 km, and the foraging area was centred on the 500 m isobath SW of the colony The figure also shows the route for the apparent swimming migration after the commuting to the colony had stopped.

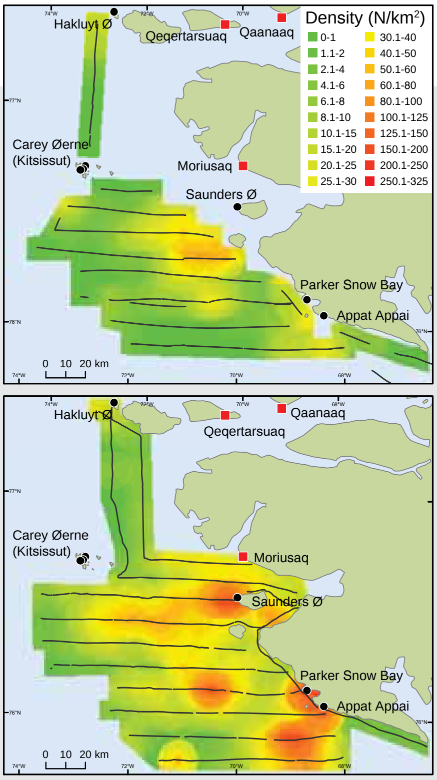


Figure 4. Densities of thick-billed murre recorded on ship-based line transect surveys in the breeding season in 2007 (upper) and 2008 (lower). The thick-billed murre colonies in the area are indicated with black dots. Significant concentrations are seen west and southwest of three southern colonies. Concentrations within few km of the colonies may not be foraging birds while it is most likely that concentrations further away represent foraging areas. It is seen that in both years there are foraging concentration areas out to about 40–60 km west and southwest of Saunders Island and the foraging area of the tracked bird in Figure 3 is within this area. In both years the murre concentrations were low south of the colony at Hakluyt Island in accordance with earlier observations that murre from this colony mainly forage to the north. (Colony sizes (pairs) Saunders Island 116,250, Parker snow Bay 42,000, Appat Appai 33,750, Hakluyt 31,500, Carey Øer 7,500 (Merkel *et al.* 2007).

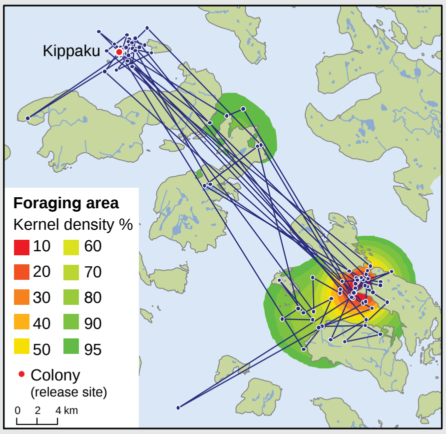


Figure 5. Foraging area for a thick-billed murre tracked with external satellite transmitter while commuting between the colony at Kippaku and foraging areas. The foraging area is estimated as the kernel home range contours only including locations more than four km away from the colony. The murre were tracked for 7 days and had at least 7 foraging trips with a mean duration of 6 hours and a mean distance to the foraging area of 31 km.

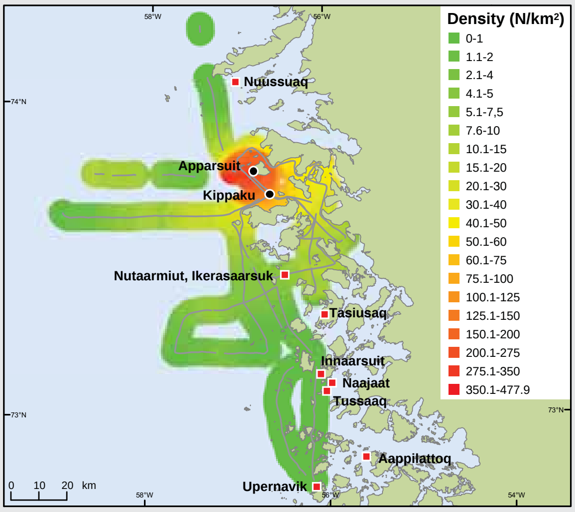


Figure 6. Densities of thick-billed murres recorded on ship-based line transect surveys in northern Upernavik in the breeding season 2008. The two thick-billed murre colonies in the area are indicated with black dots. It is seen that there are high densities in the archipelago east of the colonies and also west of the colonies but apparently not so far offshore. The density distribution mainly reflects the larger colony Apparsuit and the data indicate that the main foraging area is within 25 km of the colonies. The murres tracked form Kippaku also mainly foraged in the archipelago (Box Figure 9) (Colony sizes as total numbers of birds present in colonies: Apparsuit 113.000 and Kippaku 17.000 (Nyland 2004))

cently perhaps also chronic oil spills caused by trans-Atlantic shipping in the winter quarters in Newfoundland waters (Falk & Kampp 1997, Wiese *et al.* 2003).

Sensitivity and critical areas: Murres are very sensitive both to oil spills and disturbance at the breeding colonies, where large proportions of the total population can be impacted by a single incident. Vulnerable offshore concentrations occur at feeding grounds and probably also during the migration periods.

Black guillemot *Cepphus grylle*

Breeding distribution: This is probably the most widespread of the breeding colonial seabirds in the assessment area. There are colonies in most fjords, bays and coasts, and their numbers range from a few pairs to several hundreds (Figure 15). The total breeding population within the assessment area is unknown, but numbers at least 10,000 pairs. A few may stay throughout the winter in polynyas and leads (Reneaud & Bradstreet 1980).

Biology: The nests are placed in caves, cracks in the cliff or among stones. Black guillemots are more or less migratory, leaving the assessment area when the ice covers the shallow coastal foraging areas. They winter in the offshore drift ice and in the open-water area to the south of the assessment area.

Black guillemots feed on fish and large invertebrates by pursuit, diving from the surface and spend all of their time at sea except for the breeding season. In the breeding time they forage in the coastal environment, but during migration and winter they also occur far offshore and are often associated with ice.

Conservation status: The black guillemot population in the assessment area has a favourable conservation status and is listed as 'Least Concern' (LC) on the Greenland Red List. It is however a national responsibility species, because a very large fraction of the global population breed in Greenland and the majority of the Greenland population is found within the assessment area.

Sensitivity: Vulnerable concentrations occur mainly in the summer time at the breeding colonies, but also in the migrating period in spring when aggregations may occur in the marginal ice zone or at the edge of the fast ice of the coasts. However due to the wide dispersion of the colonies black guillemot sensitivity on a population level is low.

Little auk *Alle alle*

Breeding distribution and population size: This small alcid is the most numerous seabird in the North Atlantic. The most important breeding area for this species is in Qaanaaq, where more than 80 % of the global population is estimated to breed (Nettleship & Evans 1985). This population is estimated at aprox. 33 million pairs, distributed along the shores between northern Melville Bay and Etah in Inglefield Land (Boertmann & Mosbech 1998, Kampp *et al.* 2000, Egevang *et al.* 2003). There are smaller colonies in Upernavik with max. 5,000 pairs (Boertmann *et al.* 1996) (Figure 15). Little auks occur in huge flocks on the water below the colonies.

Offshore distribution: Very large spring concentrations have been described from the Canadian side of Baffin Bay (Renaud *et al.* 1982), but it is not known whether similar concentrations occur in autumn.

Biology: Little auks are planktivorous, feeding mainly on *Calanus* species and *Parathemisto* which they catch during pursuit diving. Breeding little auks in Qaanaaq were measured to dive to 35 m depths in Qaanaaq (Falk *et al.* 2000, Pedersen & Falk 2001). During the International North Water Polynya Study it estimated that the little auks were responsible for 92–96 % of the energy demand of the seabirds in the polynya, underlining their importance in the food web. As they forage close to the Greenland coast it also suggests the importance of production in this part of the polynya (Karnovsky & Hunt 2002).

Like other alcids little auks spend all of their time at sea except when breeding.

The breeding colonies are placed in screes, where the birds place the nests under stones and boulders.

Little auks are migratory wintering in the waters off Newfoundland and Labrador (Lyngs 2003). They arrive at the breeding colonies in May and leave again late August and Baffin Bay probably in September. After departure from the breeding sites the adult birds perform a simultaneous moult of the flight feathers and become flightless for some weeks.

Conservation status: The little auk population in the assessment area has a favourable conservation status and the species is listed as of 'Least Concern' (LC) on the Greenland Red List. It is however a national responsibility species (Table 4), because of the very large fraction of the global population which breed within the assessment area.

Sensitivity: The large concentrations of little auks on the water will be very sensitive to oil spills and the high concentrations of flightless birds in September would be particularly vulnerable, but there is no knowledge available to elucidate this important issue.

Atlantic Puffin *Fratercula arctica* and Razorbill *Alca torda*

These two alcid species occur in the assessment area in much lower numbers than the other species of the alcid family. There are probably less than a 1,000 pairs of each species within the area. Their breeding colonies are usually small with less than 50 pairs and they are usually found on small islands; in the case of the puffin almost always bordering the open ocean. The colonies are mainly found in the archipelago of Upernavik supplemented by a few in Qaanaaq (Figure 15).

Both species place their nests concealed in cracks and caves or below boulders, and both feed on fish and large zooplankton. As the other alcids they spend all of their time at sea except when breeding.

Besides the breeding concentrations there is no knowledge on concentrations of these two species during their spring and autumn migration.

Their behaviour and sensitivity towards oil spills are almost similar to murres and guillemots, although puffins moult their flight feathers much later in the year (winter and even spring) than murres.

Other significant bird species more or less associated to the marine environment

Sabines gull (*Larus sabini*) is a small gull with a limited breeding distribution within Greenland. Within the assessment area there are two breeding colonies on small islands in Melville Bay (Figure 15). Sabines gulls are migratory, wintering in the southern hemisphere and occurring in the assessment area from late May to August / September.

Ivory gull (*Pagophila eburnea*) does not breed within the assessment area, but close by at Ellesmere Island in Canada. It is a common visitor, mainly at the ice edge in the northern part of the assessment area.

Both are red-listed in Greenland and ivory gull is also red-listed globally, due to an expected population reduction due to climate change.

Geese use salt marshes and other nearshore habitats for feeding. These salt marshes are very low and often become inundated at high water levels. Geese occur in the assessment area when breeding, moulting and staging on migration. Significant concentrations of moulting snow geese (*Anser caerulescens*) occur at the coasts of the former Qaanaaq municipality; and internationally important concentrations of brent geese (*Branta bernicla*) may occur throughout the assessment areas during migration periods in May / June and again in August September as the entire flyway population moves through the assessment area both seasons. It is therefore a national responsibility species (Table 4). The endemic and red-listed Greenland white-fronted goose (*Anser albifrons flavirostris*) breeds in low numbers in inland areas of the southern part of the assessment area and Canada geese (*Branta canadensis*) occur probably rather commonly throughout the assessment area (Boertmann & Glahder 1999).

The brent geese belongs to a small discrete population breeding in high Arctic Canada (and occasionally in the former Qaanaaq municipality), and wintering in northwest Europe. The snow geese belongs to a very large population which has its main population breeding in Arctic Canada and winter quarters in northeast USA. The white-fronted geese belongs to a small decreasing population which breeds exclusively in West Greenland and winters in the British Isles. Canada geese on the other hand are increasing and belong to a population which has its main distribution in eastern Canada, with winter quarters in northeastern USA.

King eiders (*Somateria spectabilis*) do not breed in the assessment area. However, large numbers, primarily males, assemble from July in fjords, bays and straits to perform moult, and they become flightless for a period of three weeks (Salomonsen 1968, Mosbech & Boertmann 1999). Within the assessment area particularly the fjords in southern Upernavikare are important for moulting king eiders (Figure 16).

Phalaropes (*Phalaropus* spp.) are small shorebirds (waders) associated with the marine environment during the non-breeding period. The grey phalarope (*Phalaropus fulicarius*) breeds on small islands together with Arctic terns, e.g. those in the Melville Bay (Egevang *et al.* 2004), while the red-necked phalarope (*Phalaropus lobatus*) breeds at ponds and small lakes on the tundra.

4.6.2 Seabird migration pathways in the Baffin Bay area

Besides the large breeding populations of alcids (thick-billed murres and little auks) on the Greenland side of the Baffin Bay at least 650,000 pairs of hick-billed murre breed on the Canadian side (Nettleship & Birkhead 1985). All these breeding birds from Canada and Greenland, their off-spring, and populations of other species move southwards through Baffin Bay towards winter quarters off southwest Greenland and Newfound-land / Labrador (documented from recoveries of birds banded in breeding colonies, Lyngs 2003). The other species include for example black-legged kittiwake, ivory gull and black guillemot. Among these, the ivory gull is very important in a conservation context.

In total, it is estimated that at least one hundred million seabirds (adults and juveniles combined) move through Baffin Bay during September and October. Migration routes, critical areas (e.g. staging areas or important feeding areas) for these migrating seabirds are largely unknown. NERI has since 2007 focused on the migration of the thick-billed murres, by tracking birds by means of satellite telemetry. The first results are presented in Box 2. The study will be continued in 2008 and perhaps 2009.

4.6.3 Important seabird habitats

Besides the breeding colonies where large concentrations of seabirds can oc-cur on the water, significant concentrations of seabirds may occur elsewhere in the assessment area. Polynyas (see section 3.4.3) act as very important staging and feeding areas when the birds arrive from the south and other areas of the Baffin Bay are still ice-covered. There is a strong link between the polynyas and where the major seabird breeding colonies are situated, *viz.* the North Water and the little auk colonies on the Qaanaaq shores.

Other areas with early ice break-up, such as the coastal shear zone, may also create open waters to the benefit of breeding seabirds. This seems to be the case in Upernavik, where the concentration of seabird breeding colonies is much higher than in other parts of West Greenland, despite the extensive ice cover until late-May.

No information is available on specific, important offshore feeding areas, but these may occur where upwelling events are recurrent.

The coastal habitats utilised by geese (not seabirds in a strict sense) should also be mentioned in this context (see above).

4.7 Marine mammals

The marine mammals constitute another important element of the eco-system in the KANUMAS West area. Four species of seals, at least eleven species of whales, walrus and polar bear occur (Table 2). Polar bear and walrus are the best studied species within the assessment area. Accounts of these are therefore more detailed and comprehensive than those for the other species.

Table 2. Overview of marine mammals occurring in the assessment area. 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 abundance in assessment area	Protection/ exploitation	Greenland Red List status	Importance of assessment area to population	VEC
Polar bear	Whole year	Drift ice and ice edges	Relatively common and mainly when ice is present	Hunting regulated	Vulnerable (VU)	High	+
Walrus	Whole year	Polynyas, MIZ, shallow water	Mainly migrants in southern part, In NOW whole year	Hunting regulated	Endangered (EN)/Critical Endangered (CR)	High	+
Hooded seal	June–October	Mainly deep waters	Numerous	Hunting unregulated	Least Concern (LC)	Medium	
Bearded seal	Whole year	Waters with ice	Widespread in low numbers	Hunting unregulated	Data Deficient (DD)	Medium	+
Harp seal	June–October	Whole area	Numerous	Hunting unregulated	Least Concern (LC)	Medium	
Ringed seal	Whole year	Waters with ice	Common and wide-spread	Hunting unregulated	Least Concern (LC)	High	+
Bowhead whale	Winter (February–June)	Pack ice/ marginal ice zone	Locally abundant migrant and winter visitor	Protected (since 1932)	Near Threatened (NT)	Medium	+
Minke whale	Summer (April–November)	Coastal waters and banks	Rather common mainly in southern part	Hunting regulated	Least Concern (LC)	Low	
Sei whale	Summer (June–October)	Off shore	Occasional in southern part	Protected	Data Deficient (DD)	Low	
Blue whale	July–October	Edge of banks	Few, and in southern part	Protected (1966)	Data Deficient (DD)	Low	
Fin whale	Summer (June–October)	Edge of banks, coastal waters	Abundant mainly in southern part	Hunting regulated	Least Concern (LC)	Low	
Humpback whale	Summer (June–November)	Edge of banks, coastal waters	Rather abundant mainly in southern part	Protected (1986)	Least Concern (LC)	Low	
Pilot whale	Summer (June–October)	Deep waters	Occasional in southern part	Hunting unregulated	Least Concern (LC)	Low	
White-beaked dolphin	Summer	Shelf waters	Occasional in southern part	Hunting unregulated	Not Applicable (NA)	Low	
Killer whale	June–August	Ubiquitous	Rare but regular	Hunting unregulated	Not Applicable (NA)	Low	
White whale	Winter (November–May)	Banks	Abundant migrant and winter visitor in NOW	Hunting regulated	Critical Endangered (CR)	High	+
Narwhal	Whole year	Winter: edge of banks, deep waters. Summer: Fjords coastal waters	Abundant summer, winter and migrant visitor	Hunting regulated	Critical Endangered (CR)	High	+
Sperm whale	May–November	Deep waters	Unknown	Protected (1985)	Not Applicable (NA)	Low	
Bottlenose whale	Summer	Deep waters	Unknown	Protected (1985)	Not Applicable (NA)	Low	
Harbour porpoise	Summer (April–November)	Coastal waters	Only in southern part	Hunting unregulated	Data Deficient (DD)	Low	

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*

The KANUMAS WEST Assessment Area is an important polar bear habitat during autumn, winter and spring, and the bears that occur in belong to the Baffin Bay subpopulation (Taylor *et al.* 2001).

The overall distribution of polar bears in Baffin Bay is governed by the presence of mountainous coasts on each side of the ‘bay’, seasonal changes in ice conditions and current ice patterns in the region (Born 1995, Taylor *et al.* 2001). The annual land-fast ice along the coast and fjords of Baffin Island and northwestern Greenland is usually formed during October and remains until July (Teilmann 1999, Born *et al.* 2002, 2004). This ice is used extensively by polar bears (Taylor *et al.* 2001). The offshore pack ice in Baffin Bay consists mainly of annual ice that dissolves and disappears in July (Ferguson *et al.* 1999, 2000, Stirling & Parkinson 2006, Amstrup *et al.* 2007).

When the central Baffin Bay field of consolidated pack ice disappears during spring and summer the polar bears are faced with the choice of either using eastern Baffin Island or the Melville Bay area as a summer retreat. Satellite telemetry during 1991–1997 indicated that the majority of polar bears follow the spring retreat of the pack ice towards the west and spend the open-water season on Bylot and Baffin Islands (Taylor *et al.* 2001; Figure 18, 19). However, in some years the ice remains during summer in the Melville Bay area and polar bears can be encountered on this ice (Figure 19). Own observations and interviews with subsistence hunters living in Northwest Greenland indicated that polar bears can be m*et al*ong the coasts of Northwest Greenland during summer, when some bears choose to spend the open-water season on or by the glaciers in Melville Bay (Born *et al.* 2008).

During winter, spring and summer Baffin Bay polar bears select areas with more than 95 % ice cover of thick first-year ice found in large floes. During autumn, they select 95 % ice cover of multi-year ice, as this was the predominant ice type (Ferguson *et al.* 2000). This habitat preference was also seen during aerial surveys of the western and northwestern parts of Baffin Bay (Koski 1980). The bears have a preference for ice edges (Ferguson *et al.* 2000).

In the shear zone between the land-fast ice in the Melville Bay and the Baffin Bay pack ice there is a lead running between Holm Ø to Kap York. This lead which has a more or less fixed position each winter attracts polar bears because it is used by ringed seals (Rosing-Asvid & Born 1990, Born *et al.* 2008) and is also a migration route for other marine mammals during spring. During winter and spring some polar bears occur at the shear zone in this area as indicated by satellite telemetry (Taylor *et al.* 2001; Figure 19) and information from the subsistence hunters living in Northwest Greenland (Born *et al.* 2008). The polar bear hunters often move along the edge of the land-fast ice at this lead during their sled hunting trips in spring (Born *et al.* 2008).

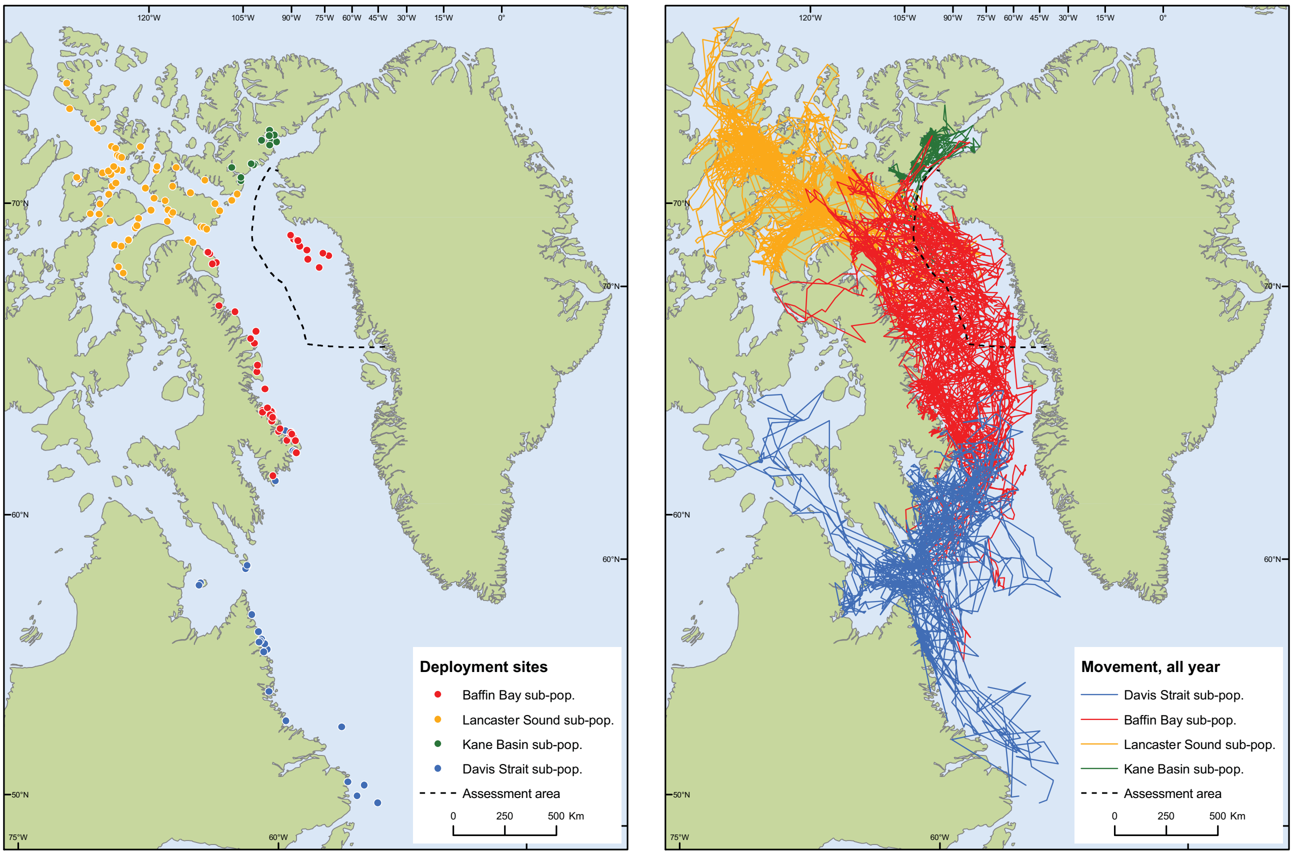


Figure 18. Left map: Locations where adult female polar bears were instrumented with satellite transmitters (1991-1995) given by sub-population. A total of 41 bears were instrumented in the Baffin Bay sub-population (9 in NW Greenland and 32 along eastern Baffin Island) and their movements were tracked during 1991-1997. The identification and delineation of the various sub-populations based on hierarchal cluster analyses is described in Taylor *et al.* (2001). Unpublished data: Greenland Institute of Natural Resources, Nunavut Wildlife Management Division, University of Saskatchewan.

Right map: Track lines showing the overall movement during 1991-1997 of 41 polar bears instrumented with satellite transmitters. A certain degree of overlap between the different sub-populations is apparent. The instrumented polar bears made little use of the fast ice and North Water Polynya area in the KANUMAS area in NW Greenland (i.e. the Melville Bay area). This was thought to be an avoidance response due to a relatively high hunting pressure in the area (Taylor *et al.* 2001). Unpublished data: Greenland Institute of Natural Resources, Nunavut Wildlife Management Division, University of Saskatchewan.

Fourty-one adult female polar bears that were tracked by use of satellite telemetry in Baffin Bay during 1991–1997 only entered maternity dens in the Baffin Island-Bylot Island areas (M.K. Taylor & E.W. Born unpublished data). The central parts of the Melville Bay were established as a nature reserve in June 1980 (Aonymous 1980), allegedly because female polar bears have maternity dens in this area (Vibe 1971). However, interviews with experienced polar bears hunters living in the former municipalities of Upernavik and Qaanaaq in 1989–1990 (Rosing-Asvid & Born 1990) and 2006 (Born *et al.* 2008) confirmed that maternity dens are only rarely found in Northwest Greenland.

Since the beginning of the 1990s the polar bear hunters living in Northwest Greenland have observed an increased occurrence of polar bears in their regularly used hunting areas between approx. 72° N and approx. 80° N – i.e. the Assessment Area (Born *et al.* 2008). During an interview survey in 2005, a similar increase 'coastal' occurrence of bears was reported by Inuit living on the eastern coast of Baffin Island (Dowsley & Taylor 2006). In Northwest Greenland this increased occurrence was reflected in a significant increase in the catch of polar bears in the former Upernavik municipality during 1993–2005 (Born & Sonne 2006). The majority of the inter-

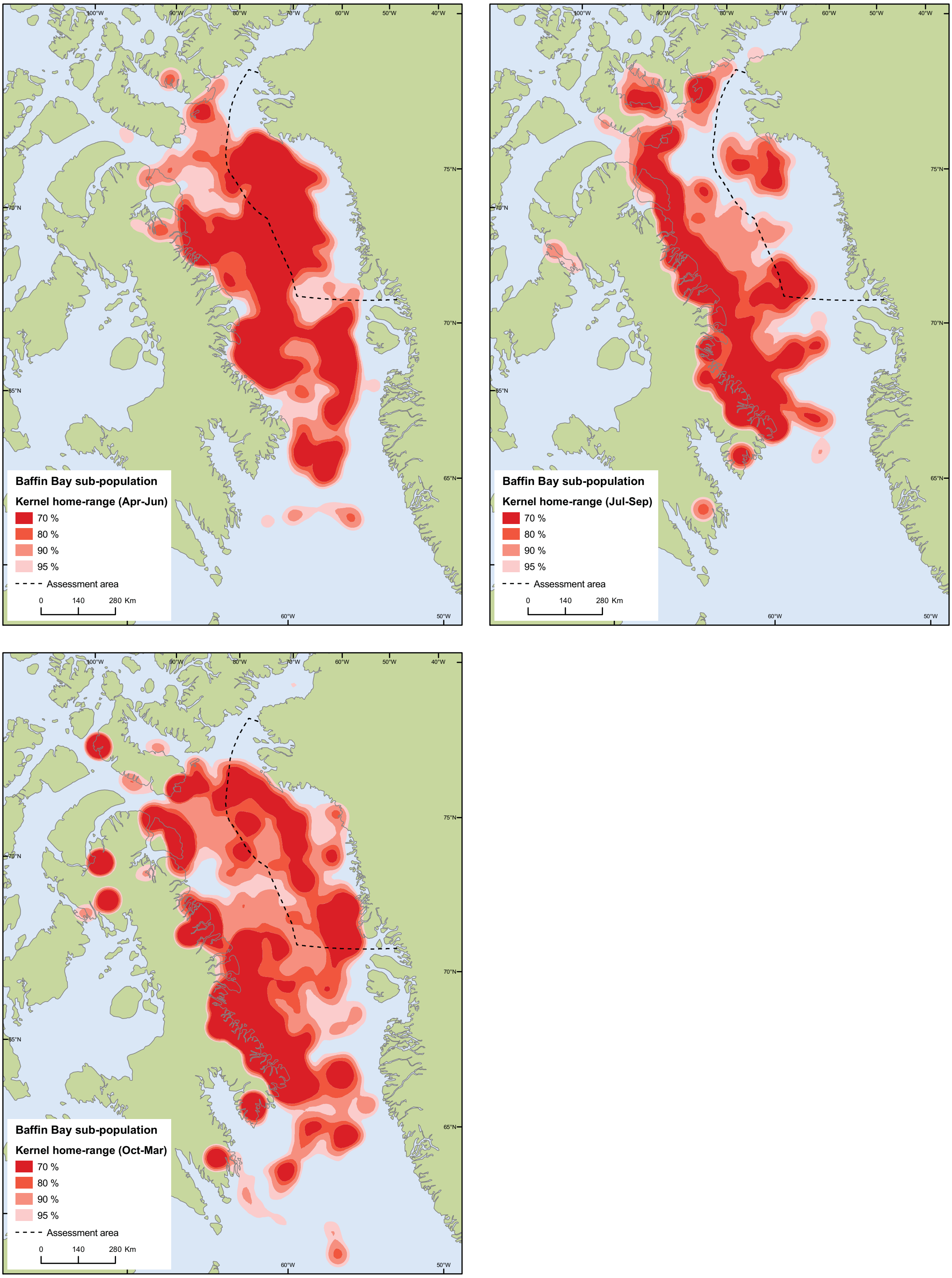


Figure 19. Home ranges (calculated as Kernel home range contours) of the Baffin Bay sub-population of polar bears based on satellite-telemetry tracking of 41 female polar bears 1991-1997. October-March (winter). April-June (spring). July-September (summer, or open water season). The definition of seasons relevant to polar bear ecology follows Born *et al.* (1997) and Wiig *et al.* (2003). Sources: Taylor *et al.* (2001), unpublished data from GINR, Nunavut Wildlife Management Division, University of Saskatchewan. This information on polar bear area use obtained from satellite-telemetry may not longer be representative, given the fact that sea ice conditions and polar bear occurrence have changed in Northwest Greenland.

viewees in Northwest Greenland and on Baffin Island were of the opinion that the increase reflected a real increase in the Baffin Bay subpopulation. However, in both areas the informants reported marked changes in the sea ice and several suggested that the apparent increase in bears within the hunting areas could rather reflect a change in distribution due to the reduction in sea ice (Dowsley & Taylor 2006, Born *et al.* 2008). Since 1979 the spring break-up of the sea ice in Baffin Bay has occurred significantly earlier in the season and the total amount of sea has decreased since c. 2000 (Stirling & Parkinson 2006). This decrease has been most pronounced in northeastern Baffin Bay (Born 2005) which is used intensively for polar bear hunting (Born *et al.* 2008).

With analogy to the situation in southwestern Hudson Bay, Stirling & Parkinson (2006) and Born *et al.* (2008) suggested that the apparent increase in nearshore observations of polar bears reflects a change in distribution due to reduced sea ice. Based on a population estimate of approx. 2,100 bears for the Baffin Bay subpopulation (Taylor *et al.* 2005) and the reported combined Canadian and Greenlandic catches it was concluded that the population was subject to over-exploitation and had declined rather than increased (Aars *et al.* 2006, Aonymous 2007).

Conservation status: The population occurring in the assessment area has an unfavourable conservation status, mainly due to the expected reduction in the habitat. Amstrup *et al.* (2007) incorporated projections of future sea ice in four different 'ecoregions', based on 10 general circulation models by the International Climate Change Panel (ICCP), into two models of polar bear habitat and potential population response. One ecoregion comprises the polar bear habitat with seasonal ice ('the seasonal ice region') – including the Baffin Bay – where sea ice is usually absent during the open-water period. One of the models (a deterministic 'carrying capacity model') predicted a 7–10 % decrease in the polar bear population in the seasonal ice region approx. 45 years from now (22–32 % decline approx. 100 years from now), whereas the other model (quasi-quantitative 'Bayesian network population stressor model') predicted extinction of bears in these areas – including Baffin Bay and Davis Strait – by the mid-21th century.

The polar bear is listed as 'Vulnerable'(VU on both the global Red List (IUCN 2008) and on the Greenland Red List.

Delineation of populations: The Baffin Bay subpopulation is essentially closed to the east and west because of Greenland and Baffin Island, although movements across Baffin Island and into neighbouring subpopulations have been recorded (Taylor *et al.* 2001; Figure 18).

Recoveries from the subsistence hunt in Northwest Greenland of polar bears that have been tagged in Canada indicate that occasionally polar bears from other subpopulations enter the KANUMAS West assessment area (Born 1995, Born unpublished data; Figure 18). Between 1977 and 2004, a total of 55 tags (family groups counted as 1 recovery) have been delivered in Greenland from the Baffin Bay subpopulation. Of these 9 (approx. 16 %) were from bears that had been tagged in other management zones than Baffin Bay (i.e. Davis Strait 1; Lancaster Sound 5; Viscount Melville Sound 1, and Kane Basin 2; Greenland Institute of Natural Resources unpublished data). Information obtained during the interview survey in 2006 indicates that only about half of the recovered tags are being delivered to the authorities (Born unpublished data).

The northern boundary of the Baffin Bay subpopulation is the North Water Polynya that extends south past Jones and Lancaster Sounds in most years. This boundary is relatively weak because pack ice continually drifts in and out, providing polar bears from Lancaster Sound with access to Baffin Bay and *vice versa* (Taylor *et al.* 2001).

The southern boundary runs from Cape Dyer, Baffin Island to Qeqertarsuaq / Disko Island, Greenland (Figure 18), where there is a submarine ridge influencing on ice and current conditions in Baffin Bay and Davis Strait (Taylor *et al.* 2001). Satellite telemetry during 1991–1997 indicated that this boundary was surprisingly strong given that Baffin Bay and Davis Strait are covered with pack ice from December until July. The ice platform presents no difficulties for polar bears that are capable of making unidirectional long-distance movements in active pack ice against both wind and current drift (e.g. Wiig *et al.* 2003).

Genetic analyses showed that polar bears in Baffin Bay differ significantly from those in Davis Strait and Lancaster Sound, whereas no difference was found between the Baffin Bay and Kane Basin subpopulations. It was suggested that this lack of difference was caused by a 'source-sink' relationship, meaning that the larger Baffin Bay subpopulation has supplied Kane Basin with polar bears as a result of long-term over-exploitation of the Kane Basin subpopulation (Paetkau *et al.* 1999, Taylor *et al.* 2008).

Movements: Female polar bears instrumented with satellite radios made remarkably few excursions onto the fast ice of Melville Bay (Taylor *et al.* 2001; Figure 18) despite the fact that the land-fast ice in the Melville Bay is good ringed seal habitat (Born *et al.* 1999). It was suggested that this space-use pattern is an avoidance response (Taylor *et al.* 2001). The fast ice and the adjacent offshore pack ice are used intensively by the Greenlanders for hunting of polar bears during late winter and spring (Rosing-Asvid & Born 1990, Born *et al.* 2008).

Non-denning bears return to the sea ice at Baffin and Bylot Islands in November (Ferguson *et al.* 1997), and many proceed across Baffin Bay to Greenland waters (Taylor *et al.* 2001). Of a total of 32 polar bears fitted with satellite transmitter on eastern Baffin Island during autumn, 17 (approx. 53 %) occurred inside the KANUMAS WEST Assessment Area for periods of variable duration. Fifteen (approx. 47 %) entered the assessment area during winter, 12 (approx. 38 %) during spring and six (approx. 19 %) occurred there during summer (for periods see Figs. 1–3). By comparison, of nine polar bears instrumented in the Melville Bay during spring, all used the assessment area at some point in the year. Six (approx. 66 %) occurred there during winter, five (approx. 56 %) in summer, and all during spring (Born unpublished data). This indicates the importance of these parts of the Baffin Bay to polar bears.

Most Baffin Bay individuals do not move south except along the Baffin Island coast because of the open-water barrier caused by the West Greenland Current. However, when the sea ice conditions permit, some Baffin Bay individuals may move as far south as the offshore hooded seal (*Cystophora cristata*) whelping areas that vary between years from Southeast Baffin Island to Nuuk, Greenland (Bowen *et al.* 1987, Stirling and Parkinson 2006).

The polar bears in Baffin Bay move considerable distances during the year. The home range size of polar bears exploiting Baffin Bay averaged 192,000 km^2, considerably larger than the home ranges of bears inhabiting areas with more consolidated ice (Ferguson *et al.* 1999). It was suggested that the explanation for the large home ranges of bears in Baffin Bay was that these bears explore a habitat with large seasonal flux of annual ice in which the distribution of various prey, in particular ringed seals, is variable and patchy. In addition 'offshore' polar bears have access to other food sources (narwhals, beluga whales, bearded seals, hooded seals and harp seals), the distribution of which changes seasonally and between years. Furthermore, the overall movement rates of polar bears exploiting the Baffin Bay pack ice are higher than those of polar bears inhabiting the land-fast ice (Ferguson *et al.* 2001).

Polar bears typically show fidelity to den and spring feeding areas (Ramsay & Stirling 1990, Wiig 1995). This was also the case for the majority of polar bears tracked in Baffin Bay during 1991–1997. Five of the polar bears that were instrumented in the Melville Bay area during spring 1992 and 1993 transmitted for more than a year. They all returned in consecutive years to the same general spring feeding area in Northwest Greenland – in one case up to four consecutive years (Born unpublished data).

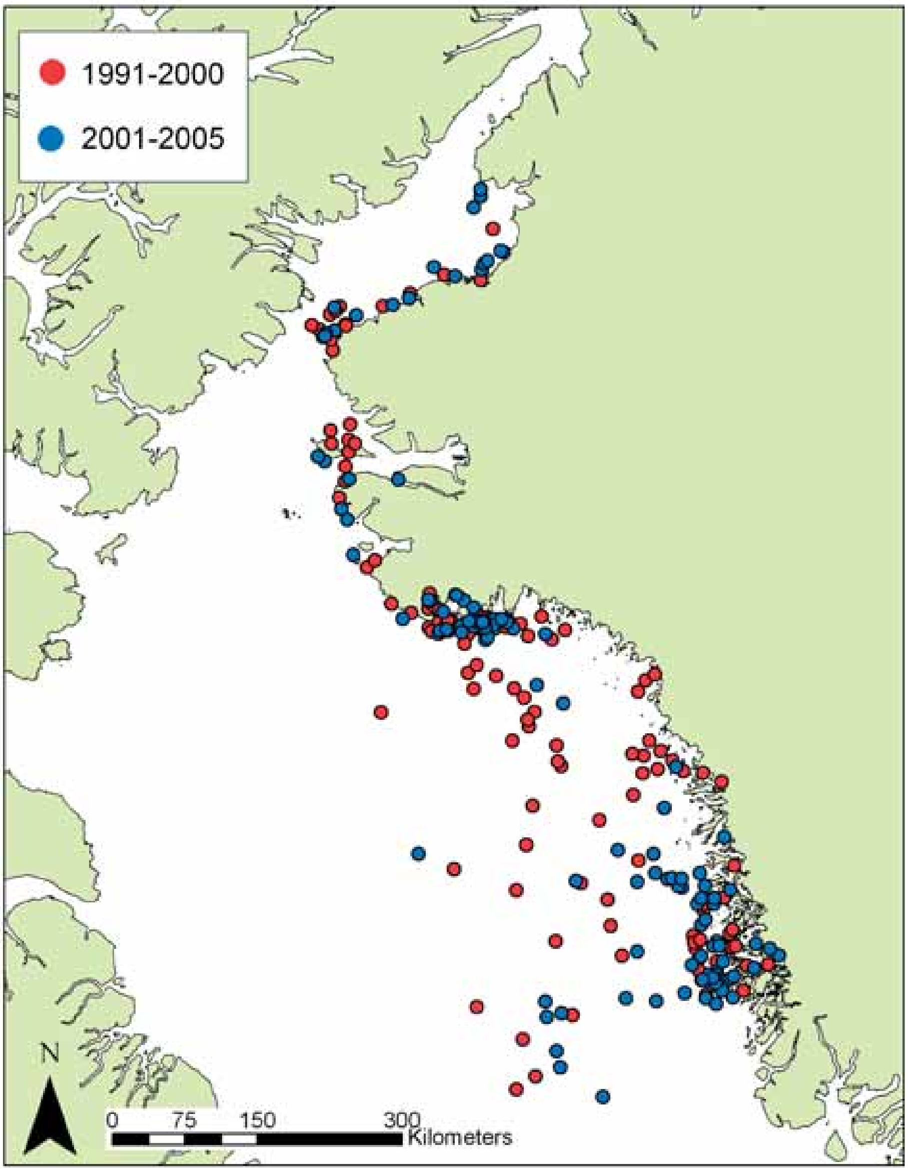
The majority of satellite transmitters in the study by Taylor *et al.* (2001) were deployed during autumn along the western shores of Baffin Bay (Taylor *et al.* 2001; Figure 18). Due to logistical constraints satellite radios were not deployed offshore (i.e. in the western parts of the assessment area). This geographical bias in deployment sites and the fact that the sea ice conditions in the polar bear habitat inside the assessment area have changed markedly since the mid-1990s calls for caution when interpreting previously collected satellite data in relation to current and future polar bear habitat choice and oil activities.

Size of the subpopulations: On the basis of a large-scale mark-recapture population study, 1994 to 1997, Taylor *et al.* (2005) estimated the Baffin Bay subpopulation to number 2,074 bears (95 % CI 1,544–2,604 bears) in 1997. Given the recorded catch from this population by Canadian and Greenlandic subsistence hunters (150–200+ / year, Stirling & Parkinson 2006), the subpopulation was thought to be over-exploited and consequently decimated to approx. 1,600 in 2004 (Aonymous 2007).

The estimates of the size of the neighbouring subpopulations based on mark-recapture are: Kane Basin approx. 164 (95 % CI 94–234 bears, Taylor *et al.* 2008) and Lancaster Sound approx. 2,541 polar bears (95 % CI 1,759–3,323, Aars *et al.* 2006). Davis Strait numbers approx. 2,200 polar bears (Peacock 2008).

The catch: Traditionally the hunt of polar bears is of great cultural and economical importance to the subsistence hunting communities in Northwest Greenland (Born & Rosing-Asvid 1989, Rosing-Asvid & Born 1990, Rosing-Asvid 2002, Born *et al.* 2008). The Melville Bay area and adjacent pack ice in northeastern Baffin Bay (i.e. within the assessment area) are important areas for the hunting of polar bears from the Baffin Bay subpopulation, whereas polar bears from the Kane Basin subpopulation are taken in the former Qaanaaq municipality north of Savisivik (Rosing-Asvid & Born 1990, Rosing-Asvid 2002, Born *et al.* 2008; Figure 20). Typically, the catches during spring when dog sleds are used were concentrated at a shallow water bank about 100 km from the coast in Melville Bay ('Qoorfiit') and at offshore shallow water banks in the former Upernavik municipality. Polar

Figure 20. The distribution of 293 polar bear catches in the Qaanaaq and Upernavik municipalities shown for two periods (1991-2000: n=145; 2001–2005: n=148). Source: Born *et al.* (2008).



bears are still taken offshore during spring but due to the reduced extend of sea ice these catches have mainly been taken during boat trips in recent years (Born *et al.* 2008). During 1993–2005 (i.e. since the introduction of a new catch reporting system until introduction of quotas in 2006), the catch of polar bears in Greenland from the Baffin Bay population averaged 101 / year (range: 60 (1994) – 206 (2003) bears / year). Of these an average of 84 polar bears / year (range: 60 (1994) – 188 (2003) were taken inside the assessment area (i.e. reported for the former municipalities of Uummannaq, Upernavik and Qaanaaq (only north to Savissivik)). On average 69 % of this catch was reported from the former Upernavik municipality (Born 2007). The quotas for the Greenland take from the Baffin Bay population for the years 2007, 2008 and 2009 are 73, 71 and 68 per year, respectively. Nunavut raised its quota for its take from the same population for the 2005 / 2006 hunting season from 64 to 105 polar bears.

Critical and important areas: Polar bears may occur almost everywhere in the assessment area when ice is present. Some areas seem to be more important than others, e.g. the recurrent ice edge system south of Kap York and probably also the edges of the North Water Polynya.

Sensitivity: Furthermore, if the fractions of the population occurring in the assessment area described above are representative of the overall subpopulation, a considerable proportion of the Baffin Bay subpopulation may be detrimentally affected by oil activities, in particular during winter and spring. Polar bears are very sensitive to oiling as they depend on the isolative properties of their fur and because they will ingest the toxic oil as part of their grooming behaviour (Øritsland *et al.* 1981, Geraci & St Aubin 1990). Therefore polar bears coming into contact with oil are likely to succumb. It is however, currently not possible to determine the fraction of the total number of polar bears in the Baffin Bay subpopulation that may become affected by oil exploration and potential exploitation because of lack of updated information on area use by these activities.

While moving on pack ice the polar bears enter the water to swim when moving from one ice floe to another (Aars *et al.* 2007), thereby increasing their risk of becoming fouled in the case of an oil spill. Also the fact that polar bears show a preference for the ice edge where a potential oil spill would accumulate increases the chances of encountering oil. At Svalbard, three polar bears that were monitored for between 12 and 24 months with satellite-linked dive recorders had an average monthly percentage time in water ranging between 0.9 and 13.2 %. 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).

Oil exploration and exploitation activities and an oil spill in the KANUMAS West area may also affect polar bears belonging to the Kane Basin and Lancaster Sound subpopulations and to a lesser extent the Davis Strait and Viscount Melville Sound subpopulations.

Walrus *Odobenus rosmarus*

A limited number of walruses winter in leads and cracks between the land-fast ice and the moving pack ice in the assessment area and, moreover, an unknown number of walruses apparently use the assessment area as a migration corridor during spring and perhaps also autumn.

Walruses have not been studied specifically within the assessment area; however extensive studies have been carried out both to the south and to the north of the assessment area.

Data sources: Information on the occurrence of Atlantic walruses in West and Northwest Greenland was summarised by Born (1990) and Born *et al.* (1994, 1995). The following review of distribution and abundance in the assessment area between Illorsuit/Ubekendt Ejland (approx. 71° 10’ N) in the Uummannaq area and Iterlassuaq/Granville Fjord (approx. 76° 47’ N) in the Wolstenholme Fjord is based mainly on these sources. The movements of walruses in central western Greenland were studied during spring 2005, 2006, 2007 and 2008 (Mosbech *et al.* 2007a, Dietz & Born unpublished data). Furthermore, the distribution and abundance of walruses between approx. 65° 30’ N and approx. 74° N were determined during aerial surveys conducted in the spring of 2006 (Heide-Jørgensen *et al.* 2006, Mosbech *et al.* 2007a). The status of the walrus subpopulation in West and Northwest Greenland (i.e. to the south and north of the Assessment Area) was evaluated by the North Atlantic Marine Mammal Commission in 1995 and 2005 (NAMMCO 1995, 2005).

Biology: The following life history traits are relevant to the evaluation of the potential effects on walruses from oil-related activities. One important characteristic of walruses is that they are gregarious year round (Fay 1982, 1985), which means that impacts will concern groups rather than single individuals (Wiig *et al.* 1996). Walruses 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 generally have an affinity for shallow water areas with suitable benthic food, traditionally used terrestrial haul-outs ('*uglit*', singular '*ugli*') in the vicinity of these banks, and wintering areas with not too dense ice and access to food (Born *et al.* 1995 and references therein). In western and northwestern Greenland such habitat is mainly found between approx. 66° 30' N and approx. 70° 30' N and between approx. 76° N and approx. 78° 30' N (Born *et al.* 1994, 1995, Born 2005a), which means that they are mainly outside the KANUMAS West area.

During the mating season (January–April; Born 2001, 2003 and references therein) male walruses engage in ritualised visual and acoustical display in the water (Fay *et al.* 1984, Sjare & Stirling 1996, Sjare *et al.* 2003).

Distribution: It has not been determined whether walruses occurring in the southern and central part of the assessment area belong to the West Greenland wintering stock or to the North Water stock or whether they represent a mixture from both of these putative subpopulations (Born 2005a). Walruses in the assessment area are basically transient (Born *et al.* 1994, 1995); therefore, the situation north and south of the assessment area where the transient animals derive from, is described.

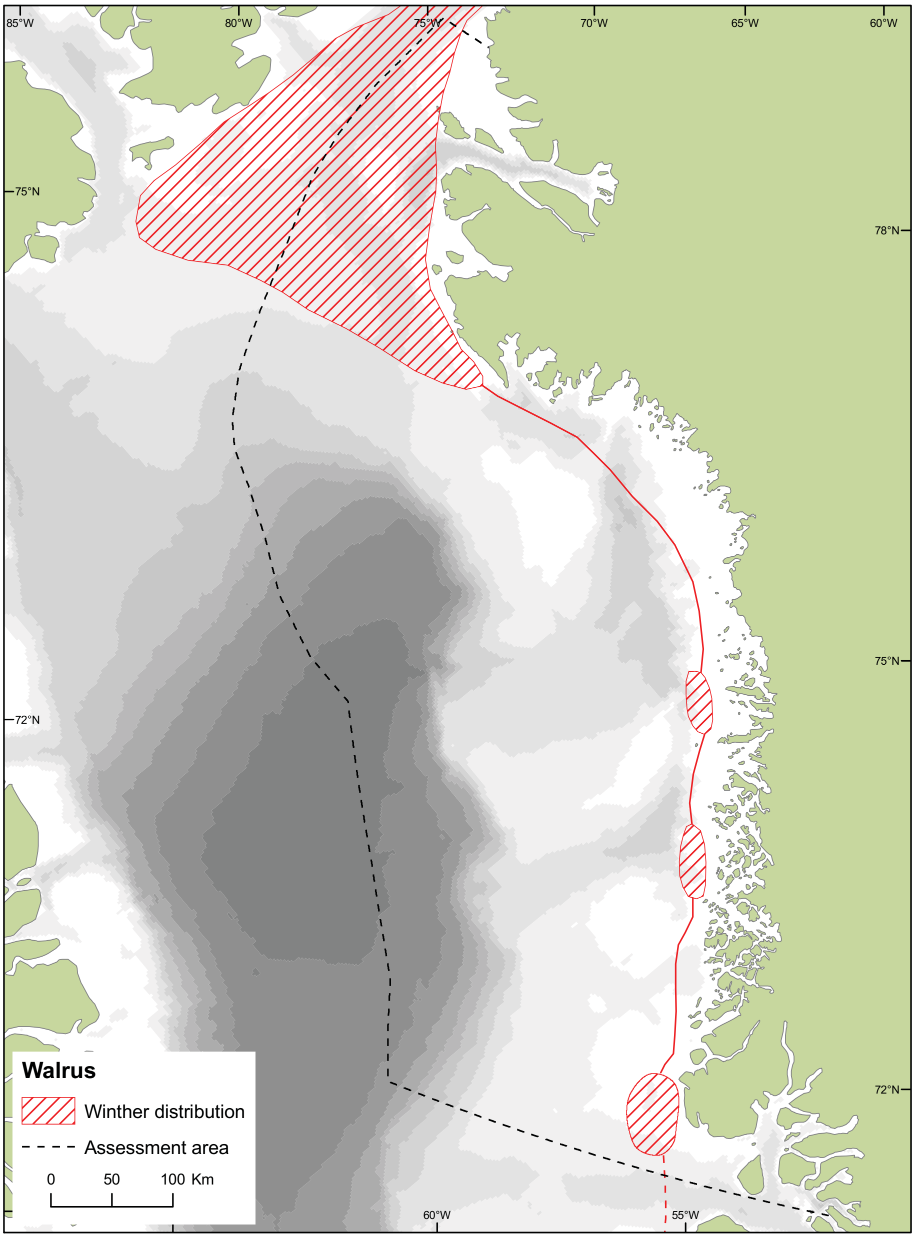
Generally, the historical and present distribution of walruses in the Uummannaq and Upernavik areas appear to be similar (Born *et al.* 1994). Walruses are not numerous in these areas and they appear to be mainly transient (Figure 21). A limited number can occur during winter in cracks and leads in the shear zone between the fast ice and the Baffin Bay pack ice. Northward migrating walruses are observed along the edge of the fast ice in the Uummannaq area during spring, but they rarely enter Uummannaq Fjord, where the water is deep.

Farther north, migrants occur along the ice edge at the outer archipelago of the Upernavik area during spring. Occasionally, walruses are also observed closer to the mainland coast. Walruses are most likely to be encountered in certain areas: Kiatassuup qeqertarsui (Ryders Islands, approx. 74°45' N), and between Kiatassuaq / Holms Island and Nuussuaq / Kraulshavn, and at Kitsissorsuit / Ederfugle Islands (Born *et al.* 1994, 1995).

Walruses were once reported to have hauled out occasionally near Eqqorleq and Tussaaq in the southern part of the Upernavik area. However, to our knowledge walruses no longer regularly haul out on land in the assessment area.

Little is known about the shallow water benthic community and foraging conditions for walruses in the assessment area. In the Upernavik area benthic communities were studied at a few locations in 1936. At approx. 72º N, the total average wet weight of the *Macoma* community, which mainly constituted walrus food components such as the bivalves *Macoma*, *Mya* and *Hiatella*, was 160–388 gww / m^2 (Vibe 1939). In this area, average ben-

Figure 21. The general distribution of walrus in the assessment area.



thic biomasses as high as 1,482 gww / m^2 were found locally (Vibe 1939), although such levels were considered exceptionally high (Vibe 1950). Hence, there is suitable walrus foraging habitat, at least locally. However, given the fact that the relatively narrow strip of shallow water areas along the coast is generally covered with fast ice during winter, wintering conditions for walruses would appear not to be ideal in these areas.

To the south of the assessment area walruses from the West Greenland wintering stock occur (e.g. NAMMCO 2005). From October–November until late-May the walruses are found on the pack ice, approx. 30 to 100 km off the coast between Sisimiut and Qeqertarssuatsiaq (Hareø). Subadults and females with young are generally reported to occur closer to the coast than males. These walruses prefer areas with dense pack ice (usually more than 60 % ice cover) in water that is less than 100 m deep. Although larger congregations numbering one to two hundred have occasionally been reported from this area, most walruses observed during aerial surveys were either single or in pairs. Observations of newborn calves in this area are extremely rare (Born *et al.* 1994, 1995, Born 2005a). Although the walrus whelping season is protacted (Born 2001) walruses observed apparently left the Sisimiut-Qeqertarssuatsiaq wintering grounds (Born *et al.* 1994) prior to the peak of calving season in late-June (Born 2001). Recordings of underwater sounds indicate that walruses mate in Central West Greenland (Born *et al.* 1994).

Several systematic aerial surveys conducted during 1981–2006 (Born *et al.* 1994 and references therein, Heide-Jørgensen *et al.* 2006, Mosbech *et al.* 2007a) showed that winter distribution of walruses off Central West Greenland is similar to that indicated by historical information with two main concentrations; the shallow water banks between approx. 66° 30’ N and approx. 68° 15’ N, and the banks along the western coast of Disko Island (Born *et al.* 1994, Heide-Jørgensen *et al.* 2006, Mosbech *et al.* 2007a). However, during the aerial surveys in late March and April–May 2006 two small groups of walruses were observed further north within in the assessment area at approx. 71° 10’ N (Mosbech *et al.* 2007a) and approx. 73° N (Heide-Jørgensen *et al.* 2006).

Walruses winter in the eastern parts of the North Water polynya between Qeqertarsuaq / Wolstenholme Island and Ullersuaq / Cape Inglefield (Freuchen 1921, Vibe 1950, Born *et al.* 1995 and references therein), which is partly inside the northernmost part of the assessment area. The thin ice there is frequently broken up by storms, giving the walruses access to shallow feeding banks (Vibe 1950). During winter walruses are hunted on the thin ice or from the edge of the fast ice, including the Savissivik and Wolstenholme Island areas (Born *et al.* 1995) which are situated inside the assessment area. Walruses in the eastern parts of the North Water polynya area are segregated on the basis of sex and age class, with females and subadults generally occurring farther north than adult males (Born *et al.* 1995).

In the past, walruses arrived in the eastern parts of the North Water area from the south during spring (Freuchen 1921, Vibe 1950). These migrants joined the animals that had overwintered there. Although information from local people indicates that some walruses still do come from the south during spring (Born *et al.* 2008, Born unpublished data), it appears that the pronounced influx during June and July described by Freuchen (1921) and Vibe (1950) no longer takes place.

Today only occasional stragglers occur in the eastern parts of the North Water polynya during summer (May–June until October–November), which contrasts to the situation earlier when walruses were apparently abundant in, for example, Murchison Sound during the open-water season (Born *et al.* 1995 and references therein).

They previously also occurred farther east in Wolstenholme Sound and also penetrated McCormick Fjord (Vibe 1950). Most likely, these changes have been caused by an increase in hunting pressure (Born *et al.* 1995).

Delineation of population: Genetic analyses (Cronin *et al.* 1994, Andersen *et al.* 1998, Andersen & Born 2000, Born *et al.* 2001, Andersen *et al.* submitted) indicate that three subpopulations exist in the Baffin Bay-Davis Strait region: Eastern Hudson Bay-Hudson Strait, West Greenland and the North Water. The analysis also indicated that (1) walruses in those parts of Canada and in West and Northwest Greenland probably once belonged to a single ancestral population, and (2) walruses from the Hudson Strait area contribute to the spring hunt off West Greenland. Such genetic evidence implies a direction of migration consistent with the suggestion by Freuchen (1921) and Vibe (1950, 1956a) of a large-scale counter-clockwise migration of walruses in the Baffin Bay region. Preliminary genetic analyses indicate that there is no genetic difference between walruses from West Greenland south of Disko Island and walruses from Southeast Baffin Island (L.W. Andersen *et al.* unpublished data).

Born *et al.* (1995) suggested that walruses wintering along the western coast of Disko Island and farther north may represent the southern extreme of the North Water subpopulation, whereas those occurring farther south belong to the West Greenland subpopulation (Born *et al.* 1995). However, two walruses equipped with satellite transmitters at Store Hellefiskebanke in spring 2007 moved north to the banks along the western side of Disko Island before transmission stopped (Dietz & Born unpublished data). During spring 2008 two walruses among ten equipped with satellite tags moved north along the coast of West Greenland as far as approx. 74º N before returning south. One subsequently moved to Southeast Baffin Island, whereas contact with the other was lost on its way south again along the coast of West Greenland (Dietz & Born unpublished data). This indicates that at least some walruses that winter at Store Hellefiskebanke migrate north in spring and might hence be subject to hunting in the assessment area.

Samples of walrus tissues for genetic analysis are not available from the assessment area and therefore the genetic affinity of walruses occurring in this area has not been determined. Overall, the scarcity of information prevents a firm conclusion concerning the demographic affinities of the likely relatively few walruses occurring in the southern and central assessment area. Those occurring in the northern part undoubtely belong to the NOW population.

Movements: According to contacts in the town of Qeqertarsuaq / Godhavn walruses are never observed moving southward south of the town of Qeqertarsuaq during fall, whereas those wintering near the northwest coast of Disko Island are believed to move north in May. Observations made during aerial surveys along the coast between southwestern Disko Island and Svartenhuk during spring 1982 indicated that the walruses wintering along the west coast of Disko Island progressively moved north in the shear zone between the fast ice and the pack ice (Born *et al.* 1982).

Scattered observations offshore in Davis Strait in March–July suggest that walruses migrate across Davis Strait from western Greenland to eastern Baffin Island during spring (Born *et al.* 1982, Born *et al.* 1994). Satellite telemetry during spring of 2005–2008 supports the notion that the majority of walruses that winter in Central West Greenland move west to summer at southeastern Baffin Island (Dietz & Born unpublished data in Mosbech *et al.* 2007a, Dietz & Born unpublished data).

According to Freuchen (1921) and Vibe (1950) the walruses crossed Melville Bay far offshore during their spring migration north into the Smith Sound region. Although there are indications that some walruses move north in the shear zone between the land-fast ice and the Baffin Bay pack ice during spring, a ‘large-scale’ spring migration north along the western coast of Greenland as indicated in Freuchen (1921) is not witnessed today.

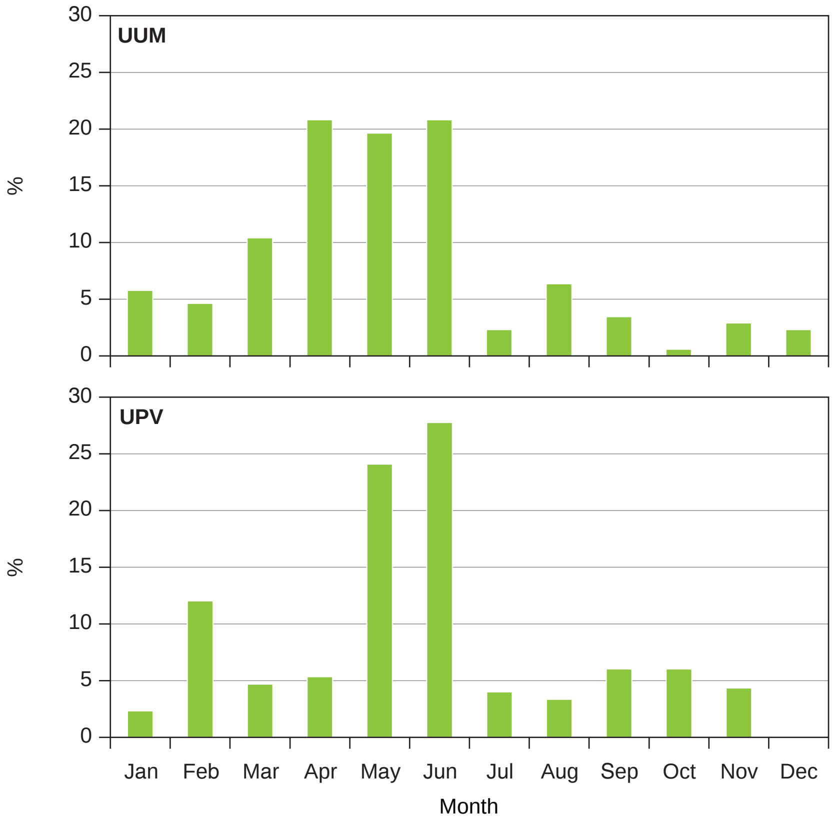


Figure 22. Seasonal distribution of the catch of walruses in the Uummannaq area (UUM, N=177) and the Upernavik area (UPV, N=300) during 1993-2006 (Source: Department of Fishery, Hunting and Agriculture, Nuuk).

The catch of walruses in the Uummannaq area peaks in March–June and in Upernavik in May–June (Figure 22). This seasonality may reflect the timing of a northward migration of walruses along the coast during spring. But it can also to some extent be explained by different hunting patterns as well as favourable weather and light conditions, and thereby favourable travelling and hunting conditions, arriving a little later in the spring in Upernavik compared to Uummannaq.

Population size: There are no historical estimates of abundance of walruses in western Greenland. Catches over several decades of many hundreds of animals indicate, however, that perhaps several thousand walruses wintered in Central West Greenland at the beginning of the 20th century (Born *et al.* 1994, 1995, Witting & Born 2005a).

Estimates of abundance based on aerial surveys between 66° N and 70°30' N from 1981–1982 and 1990–1991 revealed no trend since 1981 (Born *et al.*1994). Line transect estimates in 1990 and 1991 produced a point estimate of the visible population wintering in Central West Greenland, between approximately 66°15' N and 70° 30' N of about 500 animals (95 % CI: 204–1512) (Born at al. 1994). This estimate was not corrected for animals which might have been submerged and hence not detected during the surveys.

An aerial survey conducted during late March–mid-April 2006 by the Greenland Institute of Natural Resources resulted in an estimate corrected for animals submerged and therefore out of sight of the west Greenland wintering stock of 3,085 animals (90 % confidence interval 1,239–7,681 animals) for the areas between 65° 30' N and 70° 30' N (Heide-Jørgensen *et al.* 2006). Data from the spring 2008 aerial surveys are currently being analysed.

The 2006 survey resulted in an estimate corrected for animals out of sight of 69 walruses (90 % confidence interval 14–334 animals) in the southern parts of the assessment area between 71° 30’ N and 73° N (Heide-Jørgensen *et al.* 2006).

Another aerial survey that focused on marine birds in April–May 2006 resulted in an uncorrected estimate of 46 walruses between 70° N and 71° 10’ N (i.e. at the southern margin of the assessment area) (Mosbech *et al.* 2007a).

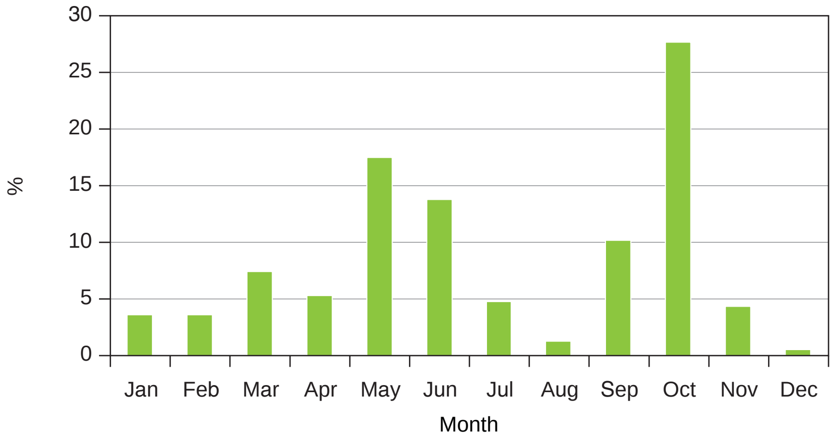
There is no estimate of abundance of walruses in the North Water proper (i.e. northern Baffin Bay-Smith Sound) (NAMMCO 2005). However, annual catches (not including losses) during 1993–2006 of 67–265 walruses per year in the former Qaanaaq municipality (Born 2005b) indicate that the exploited population must be large to sustain this catch.

The catch: In the Uummannaq and Upernavik areas walruses are either caught when they winter in the shear zone between the fast ice and the Baffin Bay pack ice, or when they move along the ice edge in spring.

According to former, official game records the annual catch of walruses in the Uummannaq and Upernavik areas decreased between 1940 and 1987. The average annual catch in the period 1940–1959 in the former municipalities of Upernavik and Uummannaq combined was around 22 walruses; between 1960 and 1987 the catch averaged 11 walruses per year. Over the entire period, the catch in the Uummannaq area comprised about 20 % of the total catch of walruses in these two regions (Born *et al.* 1995). It must however be noted that for many years the catch records during the periods mentioned were insufficient. A new system of reporting catches (the ‘*Piniarneq*’, i.e. ‘*The catch*’) was introduced in 1993. During 1993–2006 (last year with an entire year of reporting), the reported catch of walruses in the Uummannaq area averaged 12.6 per year (SD = 12.5, range: 0–38 animals; Department of Fishery, Hunting and Agriculture, DFFL, Nuuk). The corresponding figures for the Upernavik area are 21.4 walrus per year (SD = 15.5, range: 7–58 walruses, DFFL). The annual catch of walrus has not shown any trend in either of the two areas from 1993 to 2006 (data not shown). The seasonal distribution of the hunt reported in *Piniarneq* in the two municipalites is shown in Figure 22.

Due to the more predictable and abundant occurrence in the eastern parts of the North Water area for the major part of the year, the catch of walruses has always been of great importance in the former Qaanaaq municipality. The catch of walrus provides the local people with food for themselves and their sled dogs and the trade of walrus ivory is also a source of cash income (Vibe 1950, Born 1987, Born *et al.* 1995). Basically the walruses are caught during three types of hunt (Born 1987, Born *et al.* 1995): (1) Ice edge and thin ice hunt during winter and particularly spring. This hunting activity is mainly conducted from February to April at western Wolstenholme Island and off Neqe at the northern entrance to Iluulerloq / Murchison Sound; (2) ‘Summer’ boat hunting (May–August) using skiffs. After an intense hunting activity from mid-May through June the walruses leave the area and go to eastern Ellesmere Island; (3) Boat hunt (September–November) when the walruses reappear in the Qaanaaq area in the fall they are hunted by boat until formation of fast ice. These hunting patterns are reflected in the seasonal distribution of catches in the former Qaanaaq municipality (Figure 23).

Figure 23. Seasonal distribution of the catch of walruses in the former Qaanaaq municipality (QAA, N=1,753) 1993–-2006 (Source: Department of Fishery, Hunting and Agriculture, Nuuk).



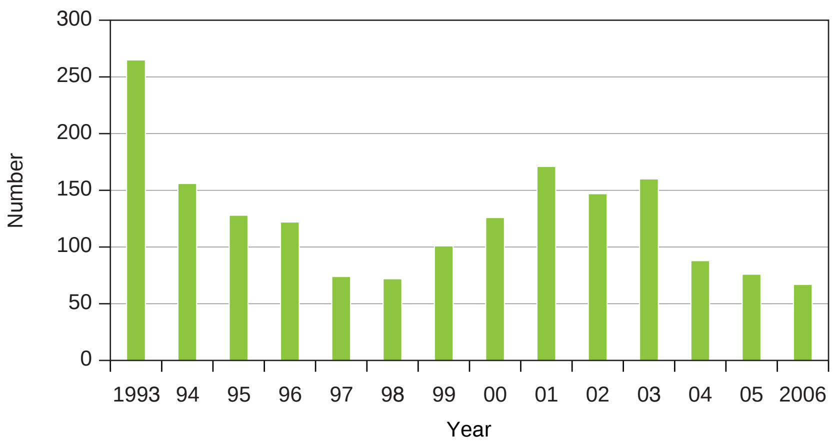
Historically, the catch reports from Qaanaaq were inadequate. However, an estimated 100–300 walruses were landed annually between the 1940s and the late 1980s (Witting and Born 2005 and references therein). During 1993–2006 the reported catch of walruses in the entire Qaanaaq area has averaged 125.2 per year (SD = 53.7, range: 67–265 walruses, source: DFFL). In the southern part of the area, the catch reported from the two settlements Savissivik and Moriussaq has averaged 15.8 walruses per year (SD=14.3, range: 4–43 walruses) during the same period. However, since 1993 the reported catch in the former Qaanaaq municipality has decreased markedly - a decrease which has been nearly statistically significant (r^2= –0.240, F=3.783, P=0.073; df: 12 / 1), (Figure 24).

The reason for the decrease in the catch of walruses is unclear. It may represent a general decrease in the number of hunters that are interested in hunting walruses and / or reflect that ice conditions have become more unsafe and unpredictable during the last decades due to global warming.

During the last approx. 15 years the sea ice has decreased and become more unstable in the Qaanaaq area. This development has in particular impeded or prevented the thin ice hunt of walruses during late winter and early spring, and has also made the summer walrus hunting season using skiffs shorter (Born *et al.* 2008). Hence, it cannot be excluded that the apparent decrease in the walrus catch reflects a decrease in hunting effort caused by environmental changes.

Important and critical areas: The preferred habitat for walrus is shallow waters with high densities of bivalves. The generally sedentary nature of walruses during winter and the inherent gregariousness of females ap-

Figure 24. Number of walruses caught in the former Qaanaaq municipality during 1993–2006 (Source: Department of Fishery, Hunting and Agriculture, Nuuk).



pear 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.

As the major part of the walruses in the assessment area are probably migrants or wintering at a number of places in the dynamic shear zone, it is not possible to designate important or critical areas. An exception is the mollusc banks at Qeqertarsuaq / Wolstenholme Ø and Appat / Saunders Ø in the former Qaanaaq municipality, where walruses are known to occur during autumn, winter and spring. Other critical habitats are the shallow waters at Kiataq / Northumberland Ø and the shallow water areas at the entrance to Iluleerloq / Murchison Sound.

Conservation status: The walrus populations occurring in the assessment area have an unfavourable conservation status, probably due to excessive hunt. The West Greenland population is red-listed as 'Endangered' (EN) and the North Water population as 'Critically Endangered' (CR).

Sensitivity: An environmental impact assessment of shipping along the Northern Sea Route (the Northeast Passage) found the walrus populations could be negatively impacted by disturbance from traffic and by oil spills (Wiig *et al.* 1996). This will also apply to our assessment area.

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 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.

Furthermore, the currents that are flowing north along the coast in the assessment area may bring oil slicks northwards into the important walrus wintering grounds in the Qeqertarsuaq / Wolstenholme Island-Appat / Saunders Island area and affect the North Water population.

However, walruses do only occur in high concentrations in the northernmost part of the assessment area, and the most likely impact of disturbing activities outside these areas will therefore be displacement of a relatively few individuals.

4.7.2 Seals

Four species of seals occur in the assessment area; two are migrants occurring only when open water is present, and two are residents and more or less dependent on the sea ice.

The effects of oil on seals were thoroughly 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 large migratory seal does not breed within the assessment area. It occurs late in the open-water season (July to October) and usually in offshore waters. It is a deep diver, feeding regularly below 500 m, where it mainly takes large fish and squid.

The West Atlantic population whelp in March–early-April off Newfoundland and in Davis Strait (Stenson *et al.* 1996). Some seals arrive in the assessment area when sea ice starts to break up in May, and a few will stay there throughout the open-water period May–November. Most hooded seals will, however, migrate toward Southeast Greenland during spring and almost the entire population moults on the drift ice there during late June–July. Most juveniles stay off the east coast until they mature. The adult seals migrate to Davis Strait and Baffin Bay during the end of July. Unpublished data from an ongoing telemetry study show that only a small fraction (approx. 5 %) of the adult seals (< 20,000 seals) occur in assessment area, mostly offshore.

Conservation status: The population occurring in the assessment area has a favourable conservation status. The seals are part of a very large population in the Davis Strait / Baffin bay region. The hooded seal population is managed internationally through a working group under ICES and NAFO and catches are sustainable (ICES 2005).

The catch: The Greenland catch is believed to be sustainable and there is no limitation on the hunt. The annual catch in the assessment area is about 500 / yr. The hooded seal is listed as of 'Least Concern' (LC) on the Greenland Red List.

Sensitivity: Non-whelping hooded seals are not particularly sensitive to oil spills and disturbance.

Hooded seals can be affected by oil spills in the same way as all other seals (i.e. tissue damage and poisoning).

Important and critical areas: No particularly important areas are known for hooded seals within the assessment area.

Bearded seal *Erignathus barbatus*

This is a large seal, usually associated with the sea ice and is considered as resident in the assessment area. They feed on fish and benthic invertebrates found in waters down to 100 m depth (Burns 1981, Gjertz *et al.* 2000). Bearded seals make breathing holes where the ice stays relatively thin and they either winter in reoccurring leads and polynyas or they follow the pulse of the expanding and shrinking sea ice. 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).

Distribution: Bearded seals are widespread in the Arctic and occur usually in low densities. They are present throughout the assessment area where suitable habitats are available, and no particular important areas for the species are known.

The catch: Catch statistics show that bearded seals stay in the assessment area throughout the year. The annual catch in the assessment area is about 400 indiv. / year, but only 20–30 bearded seals are normally caught during winter (December–March). In some of the very mild winters, however, the ice edge is within reach of the hunters living in the assessment area and catch number increases during such winters.

Conservation status: The population occurring in the assessment area has a favourable conservation status. The uniform and widespread distribution of this species is believed to be a good protection against over-exploitation (Aonymous 1998). The bearded seal is listed as ‘Data Deficient’ on the Greenland Red List due to lack of knowledge.

Sensitivity: Bearded seals vocalise very often, especially during the breeding season in spring (Burns 1981); they therefore may be vulnerable to acoustic disturbances (noise). They could also be sensitive to destruction of breeding habitat (on stable ice) by ship traffic. The benthic feeding habits of bearded seals make them vulnerable to oil-polluted benthos. Hooded seals can be affected by oil spills in the same way as all other seals (i.e. tissue damage and poisoning).

Critical and important habitat: The bearded seal is the least known seal in Greenland, and there is very little information about the location of critical habitats. Critical habitats are likely to include areas with suitable feeding grounds in the NOW polynya, in the dynamic shear zone and along the ice edge.

Harp seal *Phoca groenlandica*

This seal is a migrant visitor to the assessment area occurring in the open-water season from late-June to November. They breed and whelp on sea ice outside the assessment area – the nearest in Newfoundland waters and recently also off South Greenland. Harp seals are gregarious often travelling in flocks typically consisting of 5–20 individuals. Capelin (*Mallotus villosus*) and polar cod are their main prey in the coastal parts of assessment area (Kapel 1995). Their offshore prey is unknown, but amphipods *(Parathemisto* spp.*)* are likely to be important.

The West Atlantic population that whelp on the ice off Newfoundland in early March is estimated at about 6 million individuals (Hammill and Stenson 2005). A high fraction of these seals spend the summer and autumn foraging in Davis Strait and Baffin Bay. The proportion of seals that enter the assessment area is unknown and probably also variable, but might be in the region of 10 % of the population.

Conservation status: The population occurring in the assessment area has a favourable conservation status, and harp seals are very numerous and the population is increasing (ICES 2005). It is listed as of 'Least Concern' on the Greenland Red List.

The catch: The catch in the assessment area has been steadily increasing from around 2,000 / yr in the early 1970s to around 8,000–9,000 / yr in recent years. The catch starts in June as sea ice disappears and peaks in October prior to the start of ice formation.

Critical and important habitats: None is known from the assessment area. Non-breeding harp seals are highly mobile and not associated to specific sites; it is therefore likely that there are no specifically important sites for this species in the assessment area.

Sensitivity: Non-breeding harp seals are not considered as particularly sensitive to oil spills or to disturbance. Harp seals can be affected by oil spills in the same way as all other seals (i.e. tissue damage and poisoning).

Ringed seal *Phoca hispida*
This small seal is resident in the assessment area. It is a small seal adapted to ice-covered waters, where it maintains breathing holes in thick winter ice and gives birth in lairs made in a snowdrift covering a breathing hole. The main breeding habitats are considered to be coastal fast ice and consolidated pack ice. The pups are born in late-March and April and lactation lasts about 7 weeks (Hammill *et al.* 1991). Polar cod (*Boreogadus saida*) and Arctic cod (*Arctogadus glacialis*) are the main prey of ringed seals in nearshore waters in the assessment area (Siegstad *et al.* 1998). Prey selection is unknown for offshore areas, but amphipods (*Parathemisto* ssp.) are likely to be important there. Polar bear is an important natural predator.

A tracking study carried out in the North Water (NOW) in 1996 showed that two out of eight tracked seals (deployed in August) moved out of the NOW area, while the remaining six stayed near the edge of the polynya (Teilmann *et al.* 1999) until contact was lost during autumn and mid-winter.

Ringed seals are abundant in the entire assessment area, but an estimate of abundance is difficult to obtain, because the seals are in the water and under the ice most of the time. Surveys in the 1980s revealed large concentrations of ringed seal in the Baffin Bay pack ice (Finley *et al.* 1983). Average densities of ringed seals on fast ice as well as on consolidated pack ice in the Baffin Bay area vary between 1.3–2 seals / km^2 in June (Kingsley 1998 and references therein). This density range can probably be applied to a large part of the assessment area.

Catch: Ringed seals are caught in high numbers in the assessment area north of 75°N. Further south catches decrease when the sea ice disappears from the area around June, but increase again when ringed seals return with the expanding sea ice around December. Less than 10 % of the seals caught are adults (Christiansen 1983). The sale of ringed seal skins is very important for local hunters and the meat is of high importance in the household economy. The annual catch of ringed seals in the assessment area has increased significantly in recent years, probably as a result of very mild winters with reduced sea ice. The long-term annual average (over 50 years) is around 25–30,000 seals, but the catch number started to increase in 1998, and in 2005 the catch peaked at around 50,000 ringed seals. Most of this increase was, however, compensated for with a similar drop in catches further south. The skin trade statistics during an earlier warming period in the 1920s and 1930s reveal a similar pattern with many skins purchased in the northern part of the Baffin Bay as the trade decreased in the southern part.

A likely explanation for this pattern is that the loose sea ice, which is preferred by the juvenile seals, only constitutes a significant part of the assessment area in the first winter months during cold winters. As the sea ice consolidates the young seals move further south, but in mild winters the sea ice stays open and loose throughout the year and fewer of the young seals move south. The number of juvenile seals caught in the assessment area and further south along the Greenland west coast is higher than what can be produced locally, reflecting an influx from extra-limital populations in Canada (Christiansen 1983). The overall catch along the west coast has been relatively stable for many years and is therefore considered to be sustainable.

Conservation status: The ringed seal population of the assessment area has a favourable conservation status. Moreover, there are no especially critically areas for the population. It is listed as of 'Least Concern' (LC) on the Greenland Red List.

However, a significant reduction in the sea ice as predicted by various climate change scenarios has the potential to impact the population negatively (Laidre *et al.* 2008).

Sensitivity: Breeding ringed seals depend on stable sea ice during the two months when they establish breeding territories. This stationary behaviour makes them vulnerable to disturbance and particularly to activities which disrupt the stable ice. However ringed seals were not particularly shy towards seismic operation in Arctic Canada, where they showed only little avoidance to the ships (Lee *et al.* 2005). Ringed seals can be affected by oil spills in the same way as all other seals (i.e. tissue damage and poisoning).

Critical and important habitats: Ringed seals do not form whelping congregation as harp and hooded seals, and no other particular concentrations areas are known.

4.7.3 Baleen whales

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

All the rorquals 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. The rorquals undertake these long migrations to take advantage of the summer peak 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 spring months, as most models predict. This may result in an increased importance of the KANUMAS West assessment area to these large whales.

Baleen whale sensitivity to oil activities: Oil activities that potentially can impact whales include seismic exploration, exploratory drilling, ship, helicopter and aircraft noise, discharges to water, dredging, and marine constructions.

Baleen 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, Figure 25). Due to their potential ability to communicate acoustically over very long distances, the baleen whales may be sensitive to acoustic pollution from sources such as seismic airgun, drilling, offshore construction, aircraft and vessel supply activities.

The low frequency of airgun arrays used for geophysical exploration (<300 Hz) overlaps with the vocalisations and estimated hearing range of baleen whales, including bowhead whales and rorquals (Figure 25), and consequently these animals may be affected by this type of disturbance. Research on the Alaskan Beaufort Sea has shown that bowhead whales do indeed change behaviour when exposed to low frequency sound from airgun arrays (e.g. bowhead whales: Reeves *et al.* 1984, Richardson, Wursig & Greene 1986, Ljungblad *et al.* 1988).

Seismic exploration can produce short duration broadband impulse sounds with high peak source levels (220–255 dB re 1 mPa peak at 1 m). Humpback whales have been observed to consistently change course and speed in order to avoid close encounters with operating seismic arrays (McCauley *et al.* 2000).

Drilling and offshore construction activities, such as blasting, have potential to produce behavioural disturbance and physical damage (Ketten 1995, Nowacek *et al.* 2007). Off Newfoundland, Ketten *et al.* (1993, in Gordon 2003) 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 shortly before by scientists in an area where blasting was occurring (Lien *et al.* 1993). In this case, the blasting did not provoke obvious changes of behaviour among the whales, even though it may have caused serious injury, suggesting that whales may not be aware of the danger posed by loud sound.

Nowacek *et al.* (2007) report that only one study (Patenaud *et al.* 2002) has documented responses of whales to aircraft. They measured behavioural reactions of bowhead whales to a Bell 212 helicopter at altitudes lower than 150 m and lateral distances of less than 250 m.

Responses to noise fall into three main categories: behavioural, acoustic and physiological (Nowacek *et al.* 2007). Behavioural responses include

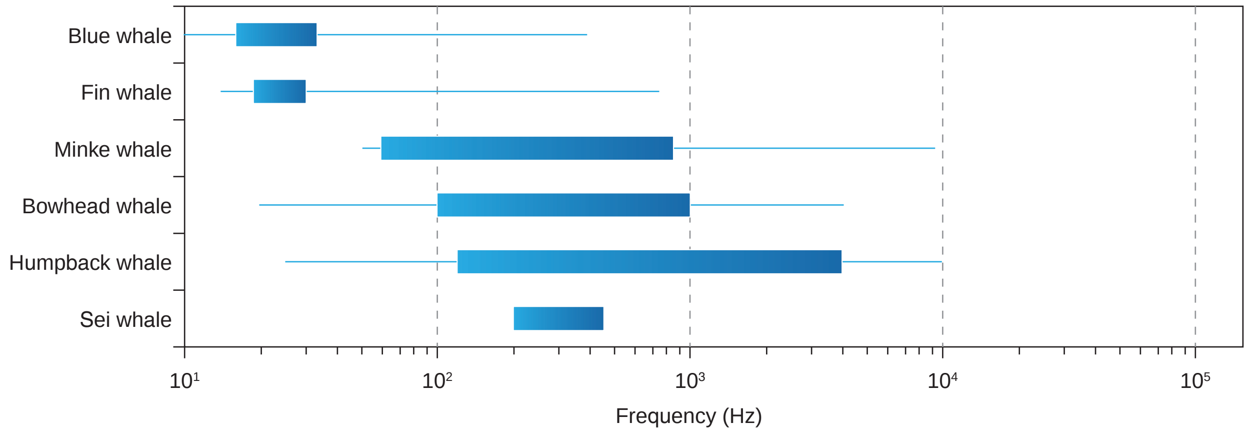


Figure 25. Known frequency ranges used by the baleen whales present in the KANUMAS area. The thick bar shows the range of the most common types of vocalisations, while the thinner line shows recorded extremes of frequency. Adapted from Mellinger *et al.* (2007).

changes in surfacing, diving and heading patterns, and may result in avoidance of the area or reduced feeding success. Low frequency sounds may effectively mask the calls of baleen whales, thus interfering with their social activities and / or navigation and feeding activities. Acoustic responses to masking by anthropogenic noise include changes in type or timing of vocalisations. Physiological responses include hearing threshold shifts and auditory damage. In addition, there may be indirect effects associated with altered prey availability (Gordon *et al.* 2004).

Oil spills pose a severe potential threat to whales. This threat is enhanced by the fact that an oil spill cannot be effectively cleaned up on ice. The whales do not avoid oil-contaminated waters as they seem not able detect oil. If whales have direct contact with oil slicks, immediate contact with the oil will be through the skin and perhaps the eyes. If oil is swallowed, the baleens and the gastrointestinal tract are likely to be injured. Not much is known about the toxic effects of oil on whale skin, but the oil is likely to adhere and possibly stay for a long time on the skin, hence causing a toxic effect. Ingestion of oil can also be toxic. Baleen whales feed by filtration through the baleen plates. Spilled oil fouling the baleen plates can seriously affect filtration and is unlikely to be able to be removed effectively by any means (Werth 2001).

The potential impacts of oil exploration or spills are relevant where spatial and temporal overlap between the whales and the activities occur. Seismic exploration is mainly conducted in the ice-free summer and autumn months, at times when rorquals are present in the KANUMAS area. The southern part of the assessment area could be a critical habitat for rorquals during summer.

Bowhead whale *Balaena mysticetus*

The bowhead whale is the only baleen whale that spends its entire life in Artic waters. Bowhead whale is a specialised filter feeder with very long baleen used to filter large volumes of water containing small zooplankton prey, such as euphausiids and copepods, about 1 cm long. The whale is attracted by substantial concentrations of zooplankton that are often found at the ice edge or in dense pack ice. They also feed on benthic invertebrates in coastal areas throughout the Arctic.

Bowhead whales usually travel alone or in small groups of up to six individuals and when feeding they are slow swimmers. Calving is assumed to take place in spring after a gestation period of just over one year. Reproduction is slow so females calve at about three- to four-year intervals from the age of at least 15–20 years (Burns *et al.* 1993). Life span may exceed 200 years (Carroll 2007).

Traditionally, five bowhead whale stocks are recognized, occurring in Okhotsk Sea, Bering-Chukchi-Beaufort Sea, Foxe Basin-Hudson Bay, Baffin Bay-Davis Strait and Spitsbergen. New information indicates that the Foxe Basin-Hudson Bay and the Baffin Bay-Davis Strait stocks are actually a single stock (Heide-Jørgensen *et al.* 2006, Heide-Jørgensen *et al.* 2008, Postma *et al.* 2006, IWC 2008). All the bowhead whale stocks were subject to commercial whaling and severe over-exploitation for centuries, leading to a global ban on commercial harvest in 1932. This ban is still valid. Aboriginal subsistence whaling is currently allowed in Russia, Alaska and Canada (Carroll 2007). In Greenland, bowhead whales have been protected during most of the 20th century. The International Whaling Commission (IWC 2008) has approved a quota of 2 bowhead whales a year for West Greenland for the period 2008–2012. It is expected that the first whales might be taken in 2009. The bowhead whale falls into the category 'Near Threatened' (NT) on the Greenland Red List and 'Endangered' (EN) on the global Red List (IUCN 2008).

Distribution: Bowhead whales utilise the eastern parts of Baffin Bay seasonally for feeding and undertake migrations through areas proposed for oil exploration in the KANUMAS West area (Heide-Jørgensen & Laidre 2008). Recent satellite tracking studies (Figure 27) in Canada and Greenland show that bowhead whales occurring in West Greenland are part of a population that extends from Foxe Basin through the Canadian high Arctic archipelago, Hudson Bay and Hudson Strait, and along the east coast of Baffin Island (Heide-Jørgensen *et al.* 2006).

The current distribution of bowhead whale in West Greenland is reduced compared to its historical distribution (Figure 26). The most sightings from the west coast are from south of the assessment area in Disko Bay north to Uummannaq, and the core area for bowhead whales along the West Greenland coast is just south of the assessment area in the western part of Disko Bay and offshore waters in Baffin Bay north of Disko Island ((Heide-Jørgensen *et al.* 2007a). The core area at Disko Bay reflects the specially favourable conditions for the spring bloom of primary production in this area (Laidre *et al.* 2007). It is not known whether similar primary production conditions occur in the assessment area (Rysgaard pers. comm.), and satellite imagery does not indicate significant concentrations of primary production that could be utilised by bowhead whales (Heide-Jørgensen & Laidre 2008). Therefore bowhead whales apparently use the southern and south-western part of the assessment area only as a spring migration corridor (Figure 27).

However, a few bowheads also winter in the North Water Polynya (Figure 26) and, depending of the ice conditions, occur within the northern part of the assessment area until at least June when they probably move westwards.

Abundance: In March and April 2006 the numbers of bowhead whales in an area in West Greenland were assessed, resulting in an estimated abundance of 1,230 (95 % confidence limits 490–2,940), with the highest concen-

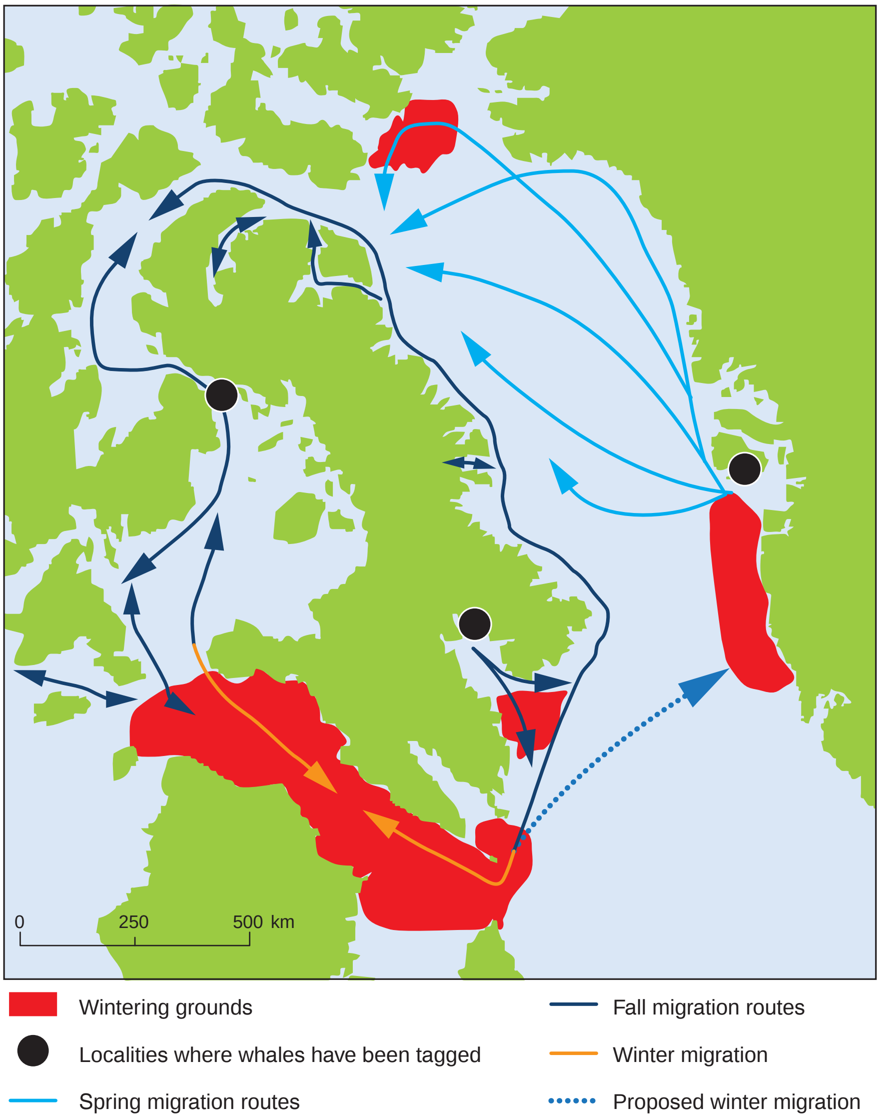


Figure 26. Wintering grounds, spring and autumn movements of bowhead whales in Baffin Bay. The assessment area is indicated with a black line. (Heide-Jørgensen unpubl.).

tration through March and April occurring south of Disko Island (Heide-Jørgensen *et al.* 2007a, 2008a). These whales constitute a fraction of the total population moving through the Baffin Bay to the Canadian summer grounds, where the population in 2001–02 was estimated at 6,344 (95 % confidence limits 3,119–12,906) (IWC 2008).

Critical and important areas: Due to the transient nature of the bowheads in the southern part of the assessment area, there seem to be no areas there which are particularly critical or important to the population. In the northern part the North Water Polynya is a winter habitat, but it is not known how many whales occur there.

Despite recent signs of recovery (Heide-Jørgensen 2005), numbers of bowhead whales in Baffin Bay are probably still much lower than the original population size (Allen & Keay 2006).

Conservation status: The population occurring in the assessment area has a favourable conservation status as it seems to be increasing and be more numerous than previously believed. It is listed as 'Near Threatened' (NT) on the Greenland Red List. The Baffin Bay stock has been protected since 1910, but in recent years a few have been taken in the Canadian site and Greenland was permitted by the IWC to take two per year in 2008–2012.

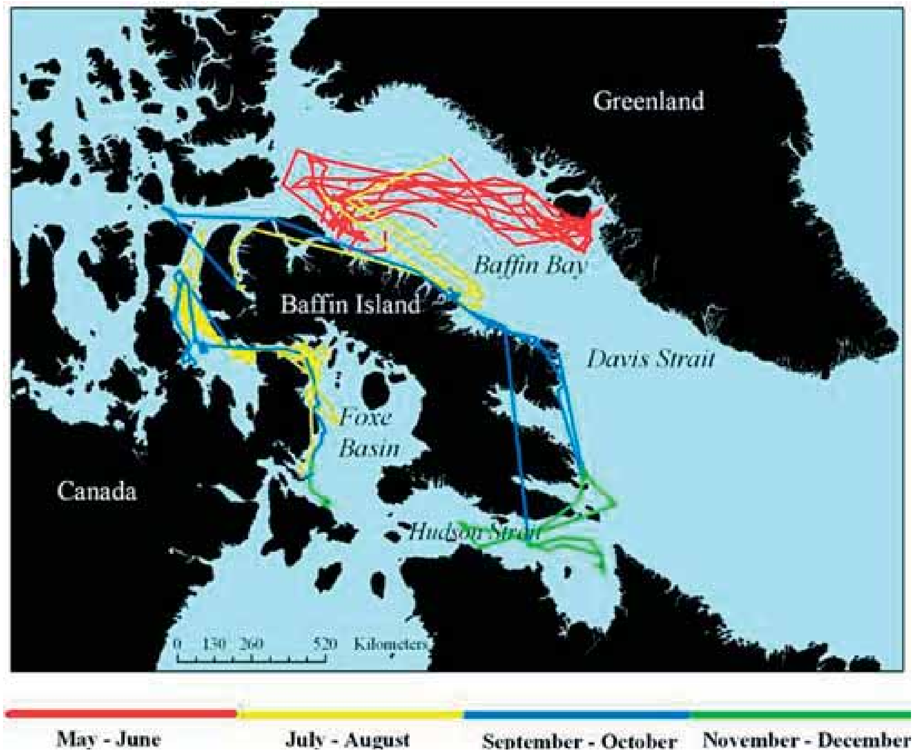


Figure 27. Map showing satellite tracks of bowhead whales from Disko Bay in 2001–2003. Bowhead whales leave Disko Bay during May and June and spend the summer in coastal areas near Baffin Island. In autumn they move south to Hudson Strait, where they mix with bowheads from Foxe Basin. In January and February they return to the West Greenland Assessment area indicated with a black line. Source: Heide-Jørgensen (2005).

However, bowhead whales are still protected by Greenland legislation and the quota for 2008 was not used.

Sensitivity: Bowhead whales are sensitive to disturbance and can be displaced to suboptimal habitats by seismic exploration and exploration drilling (National Research Council 2003).

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).

See also the introduction to baleen whales.

Minke whale *Balaenoptera acutorostrata*

Minke whales are the smallest baleen whale 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 schooling 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, to 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 winters.

Distribution: Minke whales occur as summer visitors mainly in the southern part of the assessment area (Figure 28). In recent years minke whales have been reported as far north as Siorapaluk in the former Qaanaaq Mu-

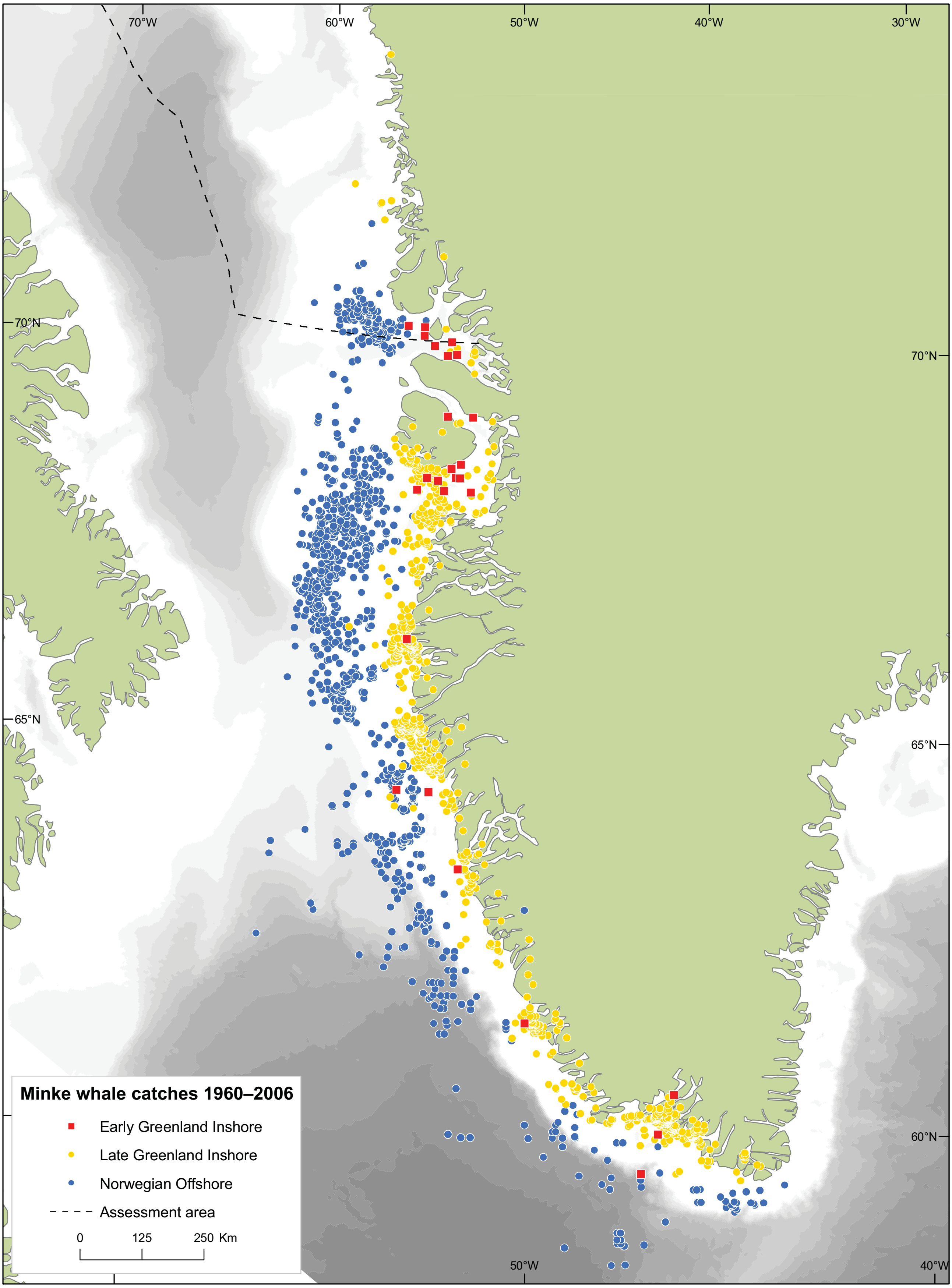


Figure 28. The distribution of minke whales in the assessment area (and West Greenland) shown by the reported catches in the period 1960 to 2006, distributed on three different hunting regimes. Only about 18 % of the minke whales taken by the collective hunt (from small boats) have been reported with accurate positions (Ugarte 2007). Therefore are catches from the assessment area under-represented in this figure.

nicipality, which most likely is an effect of climate change. There is no knowledge on specific, important areas for minke whales within the assessment area.

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 29). 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 catch: Minke whales have been hunted in West Greenland since the middle of the 20th century. Quotas for West Greenland are set by the IWC. The Greenland government divides the quota among the different municipalities. The annual quota for West Greenland in the period 2008–2012 is 200 minke whales. Most whales are taken south of Disko Island, where there are boats equipped with harpoon cannons. Further north in the assessment area, minke whales are taken from dinghies with outboard engines that work as a unit, using hand harpoons and high-powered rifles. This type of hunt is called the 'collective hunt'. In 2008, the quota for the collective hunt in the assessment area was seven minke whales for the former municipality of Upernavik and six for Uummannaq. There is no quota set for the area north of Upernavik, but in 2008 hunters have reported sightings of minke whales as far north as Qaanaaq.

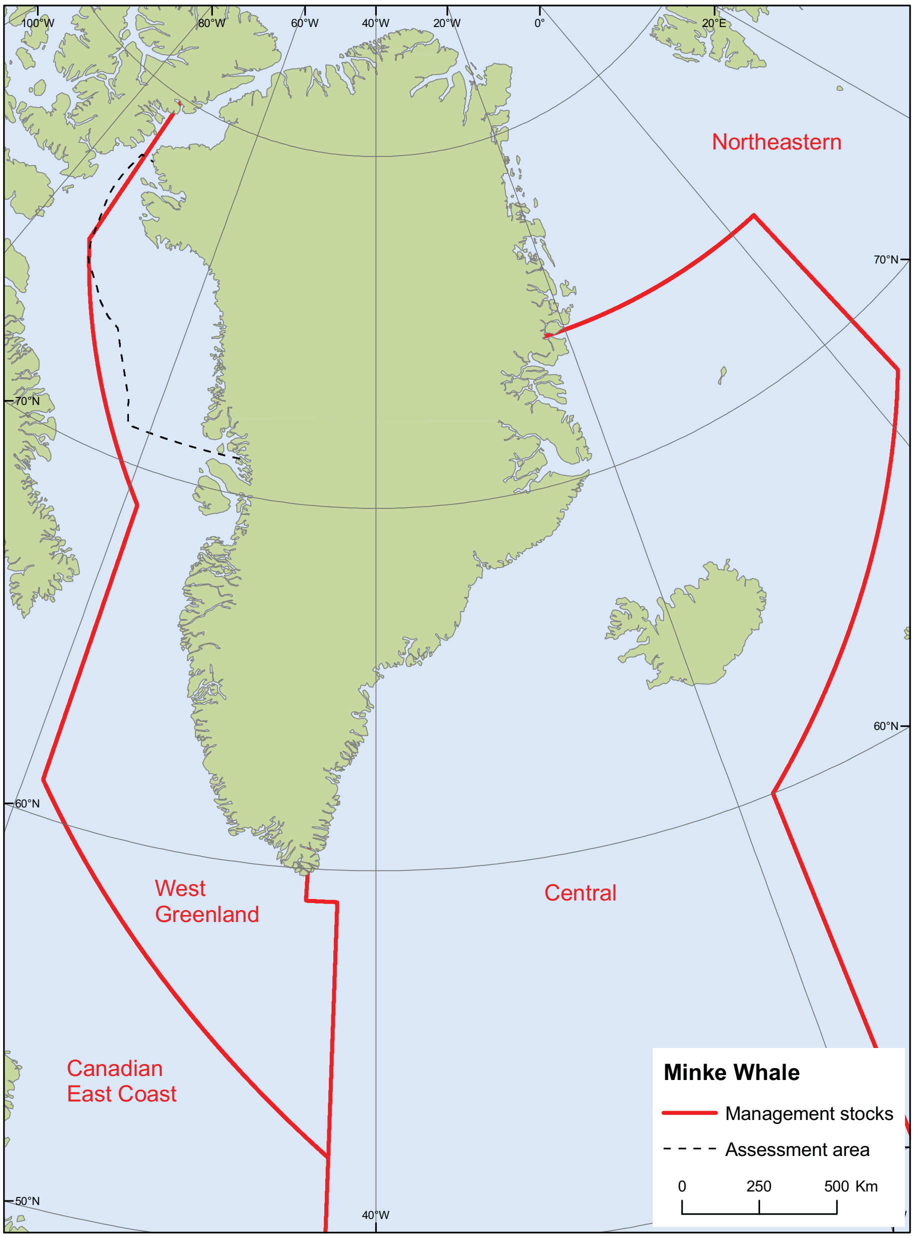
From 1968 to 1986, small-type whaling boats from Norway caught minke whales in the waters off West Greenland. During the early and mid-1970s, Norwegian catches off West Greenland averaged 175 minke whales annually. After 1977, following recommendations by the IWC, the Norwegian catches were reduced to 75 minke whales annually (Kapel & Petersen 1982). The Norwegian boats stopped catching minke whales in Greenland in 1986.

The Norwegians recorded data on each whale caught, including size, sex, reproductive status and location where the whale was caught. From this dataset, we can see that several minke whales were caught within the southern part of the assessment area (Figure 28).

Whaling data indicates that there are an excess of female minke whales in West Greenland, even though similar numbers of female and male offspring are born (Simon *et al.* 2007). This indicates that only a portion of the population, with a majority of females, migrates to the summer feeding grounds off West Greenland. Females seem to prefer colder waters and move further north than males in warm years (Laidre *et al.* 2008).

Several surveys of large whales in West Greenland, south of the KANUMAS area have been carried our since 1984, the last one in 2007. Based on the fluctuation of abundance estimates from eight different years, Heide-Jørgensen & Laidre (2008) concluded that a varying proportion of North Atlantic minke whales use the West Greenland banks as summer feeding grounds.

Figure 29. The management stocks of minke whale in the North Atlantic. Only one stock occurs within the assessment area.



From a survey in 2005, the minke whale abundance for West Greenland was estimated to be 10,792 whales (95 % CI 3,594–32,407; Heide-Jørgensen *et al.* 2007b). The actual number of minke whales in West Greenland is assumed to be higher because this survey did not cover the northernmost part of West Greenland (i.e. the assessment area), where minke whales also occur.

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 (review in Rankin and Barlow 2005). They may be affected by anthropogenic noise in these frequencies.

See also the introduction to baleen whales.

Sei whale *Balaenoptera borealis*

Sei whales are on average 14 m long and weigh 20–25 tonnes. They 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 2008)

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).

Distribution: Sei whales are probably rare within the assessment area, and have only been recorded in the southern part. According to local hunters, the occurrence of sei whales in Uummannaq Fjord, partly within the assessment area, has increased substantially during recent years.

As in other high latitude areas, the presence of sei whales in West Greenland fluctuates widely, and their occurrence has been linked to influx of relatively warm waters from the Atlantic (Kapel 1979). Sei whales in West Greenland are assumed to 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 actually make use of the assessment area.

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)' in the Greenland Red List.

Surveys of cetaceans in West Greenland have been carried out at regular intervals since 1984. Sei whales were rarely observed in the earlier surveys, but appear relatively abundant in the most recent surveys of 2005 and 2007. Numbers of sei whales off West Greenland, calculated from a ship survey in 2005, were 1,529 (95 % CI 660–3,540) (Heide-Jørgensen *et al.* 2007b). This is an underestimation of the actual numbers because the survey did not cover all the potential habitat of sei whales off West Greenland and because animals underwater at the time of the survey, and animals missed by observers were not accounted for.

Sensitivity: See also the introduction to baleen whales.

Blue whale *Balaenoptera musculus*

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.

Blue whales 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: Due to lack of survey effort, their presence in the assessment area is almost unknown, but they have at least been reported form the southern part. However, as in the Eastern Atlantic and Antarctica, they may be present in offshore waters up to the ice edge.

Winter calving grounds for the blue whales occurring in West Greenland are unknown. There are important known feeding grounds in eastern North America (St. Lawrence Bay, Newfoundland, Labrador) and the Greenland Sea / Denmark Strait, including waters from northern and western Iceland, as well as East Greenland. Blue whales are also present west of Svalbard and in the Norwegian Sea / Barents Sea. Direct observations of blue whales in West Greenland are rare, but unpublished data indicates that blue whales use the Davis Strait area, including the area immediately south of the assessment area.

Conservation status: 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 the North Atlantic waters. Blue whales are categorised as 'Data deficient' in the Greenland Red List. In the IUCN Red List, blue whales are classified as globally 'Endangered' and 'Vulnerable' 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 (Širovi *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.

See also the introduction to baleen whales.

Fin whale *Balaenoptera physalus*

Fin whales are the second longest animal on the planet next to blue whales, with average lengths in the northern hemisphere of 19–20 m and average weights of 45–75 tonnes. Fin whales are found worldwide from temperate to polar waters but are less common in the tropics.

Fin whales favour prey items such as krill (*Euphausia* spp.) and small schooling fish, such as herring (*Clupea harengus*) and capelin (*Mallotus viscosus*). 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 catch statistics (Simon *et al.* 2007) indicate that at least some individuals remain at high latitudes year round.

Distribution: Fin whales occur regularly during summer in fjords of the southern part of the assessment area, and may occur further north in offshore areas. However, the offshore waters in Baffin Bay have never been systematically surveyed for cetaceans, and there are no data on the distribution or numbers of fin whales in the assessment area. Local knowledge indicates that fin whale abundance has increased in recent years.

Conservation: Fin whales have an unfavourable conservation status on a global scale, and are categorised as 'Endangered' in the global IUCN / Red List (IUCN 2008). The reason for the global IUCN / Red List category was an estimated worldwide reduction 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, and are listed as of 'Least Concern' (LC) on the Greenland Red List.

Fin whales are genetically similar in widely spread areas in the North Atlantic. Current genetic research (Pampoulie *et al.* 2008) is dealing with two likely scenarios. Fin whales are assumed either to be separated populations that split from a common ancestry in a not too distant past, by expanding through the North Atlantic shortly after the last glaciation, or to form a single population comprised of individuals that move over very large areas.

Satellite tagging data show that fin whales make extensive movements in West Greenland, suggesting that fin whales off West Greenland should be treated as one large management unit, rather than small separate populations or stocks (Heide-Jørgensen *et al.* 2003).

The catch: In West Greenland pelagic whalers from Norway and Denmark hunted fin whales from 1922 to 1958 (Kapel & Petersen 1982). The annual average catch was 109 whales, except during the Second World War (1940-45) when no European whalers operated in Greenland (Simon *et al.* 2007).

Greenlanders started catching fin whales from fishing boats equipped with harpoon cannons in 1948. Until the 1970s, this catch took 0–13 fin whales per year. The IWC aboriginal subsistence quotas have regulated fin whale takes in West Greenland since 1977. The quotas have ranged from 6 to 23 whales annually and have remained stable at 19 whales since 1995. The total quota is seldom used and the average catch is 10 fin whales per year (Kapel & Petersen 1982, Caulfield 1997, Witting 2008). This provides however, 100 tonnes of meat, or approximately 30 % of the total amount of meat from large whales consumed in Greenland.

Due to the lack of boats equipped with harpoon cannons in the northernmost parts of West Greenland, most fin whales are taken south of the assessment area. However, a few have been caught off Uummannaq, in the southernmost part of the region, by boats travelling from the towns of the Disko Bay area (Simon *et al.* 2007).

Due to their economic importance, there have been considerable efforts to estimate the numbers and the abundance trends of large whales, including fin whales in West Greenland, south of Disko Island. The estimate from an aerial survey in September 2007 is 4,656 (cv 46 %) fin whales, and the population may be increasing (Heide-Jørgensen *et al.* 2008a, Witting 2008). The actual number of fin whales in West Greenland must be larger because the survey did not cover the northernmost parts of the fin whale's range, including the assessment area.

Sensitivity: Fin whales produce distinctive low frequency calls that can be detected over tens of kilometres (Širović *et al.* 2007), and they can be sensitive to anthropogenic noise.

See also the introduction to baleen whales.

Humpback whale *Megaptera novaeangliae*

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 Cape Verde islands.

Distribution: Due to lack of survey effort, the distribution patterns and numbers of humpback whales in the assessment area are unknown. For West Greenland south of the assessment area, a series of eight line-transect surveys carried out between 1984 and 2007 was used to estimate a rate of increase of 9.4 % per year (Heide-Jørgensen *et al.* 2008b). This high rate of increase is consistent with the observed rate of increase at other feeding grounds in the North Atlantic. The abundance estimate for 2007 was 3,299 humpback whales (CV = 0.57). The actual abundance of humpback whales in West Greenland may be larger, since the survey did not cover important humpback whale habitats in the far north (including the assessment area) or offshore areas with depths exceeding 200 m.

It is likely that the range of humpback whales in West Greenland will expand as the population continues to increase. In recent years humpback whales were found more widely distributed in West Greenland and records of observations further north, into the assessment area, are now frequent. Within the assessment area, local knowledge indicates that Uummannaq fjord may be an important feeding ground for humpback whales.

Conservation: The population occurring in the assessment area has a favourable conservation status as it is abundant and increasing. Whaling has seriously depleted all humpback whale stocks, and humpback whales received worldwide protection in the 1980s. Globally humpback whales are red-listed as 'Vulnerable' (VU) (IUCN 2008) and in Greenland as of 'Least Concern' (LC).

Humpback whales can be individually identified by the pattern on the fluke, which they often raise above the surface at the start of a deep dive. Movement patterns of thousands of humpbacks photographed across the North Atlantic show high levels of site fidelity with occasional long-distance movements between four main feeding aggregations (Figure 30): Gulf of Maine, eastern Canada, West Greenland and the eastern North Atlantic (Stevik *et al.* 2006).

Satellite telemetry suggests that humpback whales use much of the West Greenland waters by remaining relatively stationary at suitable feeding grounds for a period of days and then moving up to hundreds of kilometres to a different location, where they remain stationary again (Heide-Jørgensen & Laidre 2007). This pattern is consistent with an ongoing photo-identification study in a fjord of central West Greenland, where individual humpback whales seem to return year after year, remain in the fjord for several days, and then leave (unpublished data).

The main prey items of humpback whales in West Greenland are probably capelin (*Mallotus villosus*), which is abundant in coastal and fjord waters; sandeels (*Ammodytes* sp.), abundant in offshore banks; and krill (*Meganyctiphanes* sp.), which can be found both offshore and in the fjords. By mov-

Figure 30. Feeding aggregations of humpback whales in the North Atlantic: Gulf of Maine, Eastern Canada, West Greenland and Eastern North Atlantic.

ing between known feeding grounds, humpback whales target multiple sites for foraging and are able to exploit several species in a variety of environments during a single feeding season.

The catch: Until their protection in 1986, humpback whales were an important source of whale meat for the people in West Greenland, who caught on average 14 animals annually, yielding approximately 112 tonnes of whale meat (IWC 1991). In 2008, the Scientific Committee of the IWC advised that a catch of ten humpback whales per year would be sustainable (IWC 2008). On the basis of this advice, Greenland is currently negotiating a renewed quota for humpback whales. Currently, up to approximately five humpback whales are unintentionally caught in fishing gear every year.

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 cooperative 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 (Figure 21). Peak frequencies tend to be around 315 Hz and 630 Hz (Parsons *et al.* 2008).

See also the introduction to baleen whales.

4.7.4 Toothed whales

Two species of toothed whales, the narwhal and the white whale or beluga, are specialised inhabitants of the Arctic and can be found in the assessment area year round.

Five species of toothed whales that are common in the northern North Atlantic may be found in the assessment area. Only two of these are probably regular visitors to the assessment area: killer whale and sperm whale. Pilot whale (*Globicephala melas*), white-beaked dolphin (*Lagenorhynchus albirostris*) and bottlenose whale (*Hyperoodon ampullatus*) may also occur. All are found in boreal waters and sperm whale and killer whales occur in all oceans. They avoid densely ice-covered waters, so their use of the assessment area is restricted to the ice-free months. With the expected reduction of sea-ice cover due to climate change, their stay in the assesment area may be extended.

Toothed whale sensitivity to acoustic pollution: Sounds play an important role in the lives of all marine mammals. Toothed whales produce clicks for echolocation[1] and communication. In addition, killer whales produce pulsed calls made of clicks in very rapid succession. Narwhals, white whales, 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 contacts and may include information about the identity of the whistler. Figure 31 shows the frequency ranges of echolocation clicks, calls and whistles produced by toothed whales in the assessment area.

Masking by anthropogenic sounds, including noise from ships, oil exploration and development, 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).

Toothed whale sensitivity to oil spills: The effect of oil spills on killer whales has been well described by Matkin *et al.* (2008). They monitored the demographics and group composition of killer whales from Prince Williams Sound 5 years prior to and 16 years after the 1989 Exxon Valdez oil spill. Killer whale groups in the proximity of the spill did not avoid the oil; they suffered losses of up to 41 % in the year following the spill and 16 years later either had not recovered at all or had recovered at rates lower than those for groups not affected by the oil.

Smultea & Würsig (1995) tracked dolphins swimming toward oil slicks and concluded that the animals detected the oil but did not avoid travelling through it.

Long-finned pilot whale *Globicephala melas*

Distribution: The long-finned pilot whale occurs in temperate and sub-polar 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,

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

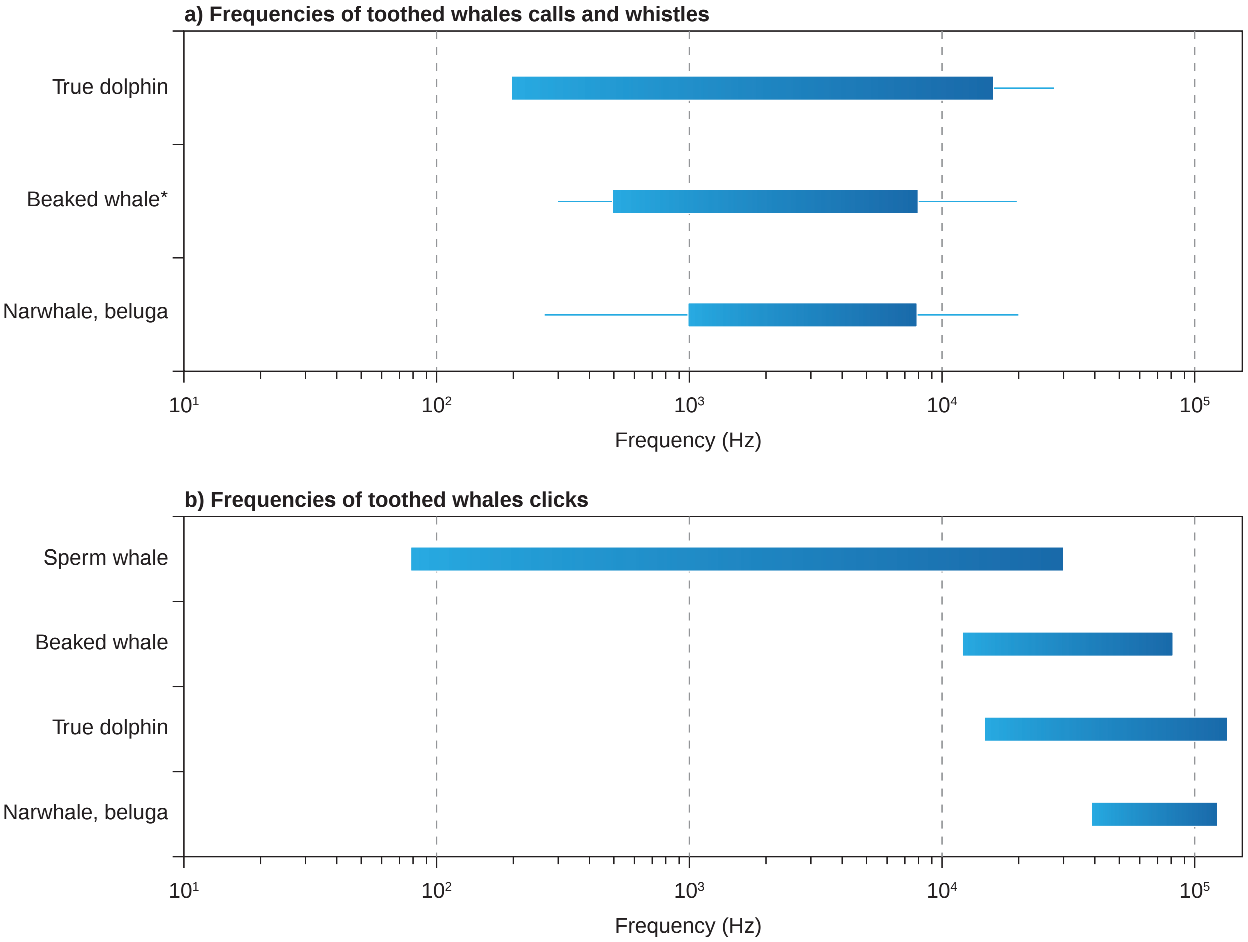


Figure 31. Known frequency ranges of pulsed calls and whistles (a) and echolocation clicks (b) made by toothed whales in the KANUMAS area. True dolphins (family Delphininae) include killer whale, pilot whale and white beaked dolphin. Beaked whales (family Ziiphidae) include bottlenose whale. Figure modified from Mellinger at al. (2007).

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 Homerule, unpublished data) show, however, that pilot whales occasionally occur as far north as Uummannaq and Upernavik in the southern part of the assessment area and in late summer or early autumn, from July to October. Their occurrence is probably correlated with the influx of relatively warm Atlantic water (Heide-Jørgensen & Bunch 1991).

Biology: Long-finned pilot whales are very social and generally found in groups of 20–100 individuals, where they frequently associate with other marine mammals. 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 caught opportunistically in West Greenland. Annual catches in West Greenland vary between 0 and 300, where most animals are caught south of Disko Bay. But irregular catches from Uummannaq and Upernavik on the west coast show that some years long-finned pilot whales are not uncommon north of Disko in late-summer or early-autumn, from July to October. Their occurrence is probably correlated with the influx of relatively warm Atlantic water (Heide-Jørgensen & Bunch 1991).

Population: Pilot whales occurring in the assessment area (and the rest of Greenland) probably represent vagrants from a single large North Atlantic population, of the which the size is unknown, exept that it is large.

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

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 the Arctic. According to several published sources, Disko Bay is the northern limit of their distribution in West Greenland (e.g. Reeves *et al.* 1999, Kinze *et al.* 1997). However, unpublished and unverified catch statistics may indicate that white-beaked dolphins occur as far north as Upernavik, well into the assessment area.

White beaked dolphins primary habitat is waters less than 200 m deep, especially along the edges of continental shelves.

The species has been very little studied and very little is known about its biology and ecology. Scientific studies of white-beaked dolphins in West Greenland are virtually not existent. The diet of white-beaked dolphins in West Greenland is unknown. In other areas, they feed mainly on a variety of small schooling fishes such as herring, capelin, sandeel and cod, but may also eat squid and crustaceans (Jefferson *et al.* 2008).

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 often associate with other species of whales.

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

In Greenland, white-beaked dolphins are caught for subsistence. There are no catch statistics for this species previous to October 2005. For the KANUMAS West area, catches of white-beaked dolphins were reported from September 2007 (six dolphins in two locations). Catch statistics after September 2007 are still not fully available.

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

Sensitivity: See the introduction to toothed whales.

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 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 specialisations, there are different ecotypes of killer whales. 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 northeastern Pacific where the ecotypes called 'residents', 'transients' and 'offshores' feed on salmon, marine mammals and sharks, respectively (Ford & Ellis 2006, Baird & Dill 1995, Hermann *et al.* 2005). Moreover, in Antarctica, where three ecotypes feed on tooth-fish, 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.

Killer whales produce calls and whistle-like sounds for communication and clicks for echolocation (Simon *et al.* 2007). Calls serve several purposes and group-specific call repertoires play a fundamental role in the social organisation and mating system of killer whales (Barret-Lennard 2000). Whistles are important during short-range social contact (Thomsen *et al.* 2002).

Conservation: Killer whales are listed as 'Data Deficient' (DD) on the global IUCN Red List (IUCN 2008) and as 'Data deficient' (DD) on the Greenland Red List (Boertmann 2007).

Distribution: Norwegian small-type whalers caught 13 killer whales at four locations in Southwest Greenland from 1968 to 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 (Jonsgård 1977 in Øien 1988).

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 all areas of West Greenland, with more sightings in Qaanaaq, Disko, Nuuk and Qaqortoq.

Killer whales are hunted in Greenland, partly for human subsistence and partly to feed dogs, but also because they are considered as a pest (i.e.

as competitors to seal and whale hunters). Since 1996, when the current reporting system was established, killer whales have been taken twice in the assessment area.

Sensitivity: A recent study indicates that killer whales are more sensitive to oil spills than hitherto believed for toothed whales (Matkin *et al.* 2008), see the introduction to toothed whales. If killer whales assemble within the assessment area, as they do in other parts of the world, a substantial part of a regional population could be affected. It is however not likely that such aggregations occur in the assessment area.

White whale (beluga) *Delphinapterus leucas*

The white whale is a medium-sized toothed whale up to 5 m long and up to 1,500 kg in weight. The closest relative is the narwhal. Nursing times of two years have been observed. White whales are slow-swimming mammals. Their main prey is polar cod and other fish but also squid and shrimps (Heide-Jørgensen & Teilmann 1994). White whales usually travel in groups of two to ten whales, although larger pods often occur.

Distribution: White whales migrate through the assessment area, where they occur in October–November and again in May–June. They may also occur in winter as one population spends the winter in the North Water and as the central West Greenland wintering grounds occasionally range as far north as the southern assessment area (Figure 32, 33).

The summer grounds of white whales are in the Canadian Arctic archipelago, where they often occur in extensive estuaries.

Movements: The migration has been documented by two white whales equipped with satellite transmitters in Canada and tracked to the winter quarters south of Disko Bay (Heide-Jørgensen *et al.* 2003b). Generally the knowledge on the migrations of white whales in West Greenland is limited compared to that on narwhal migrations.

White whales are expected to acquire the major part of their annual food intake in their winter quarters.

Catch and population trends: Commercial harvesting of white whale in West Greenland and Baffin Bay began in the late-1800s (NAMMCO 2008). Their occurrence in west Greenland has reduced over the past 90 years, largely due to excessive hunting. After a period with large catches in Nuuk (from 1906–22) and in Maniitsoq (1915–29), white whale disappeared from the area south of 66° N (Heide-Jørgensen & Acquarone 2002). Between 1927 and 1951, large catches were reported in the southern part of the former municipality of Upernavik, and since 1970 in the northern part. In the 1990s catches in this area were about 700 whales per year. Aerial surveys flown in West Greenland between 1981 and 1994 found that white whale numbers decreased by 62 % during that period, probably because of over-harvesting (Heide-Jørgensen & Reeves 1996).

Further surveys in 1998 and 1999 confirmed the decline and found 7,941 (95 % CI: 3650–17,278) white whales in West Greenland, including whales missed by the observers and whales that were submerged during the survey (Heide-Jørgensen & Acquarone 2002).

Figure 32. Positions of satellite-tracked white whales distributed according to month. Red areas indicate winter quarters (GINR unpublished).

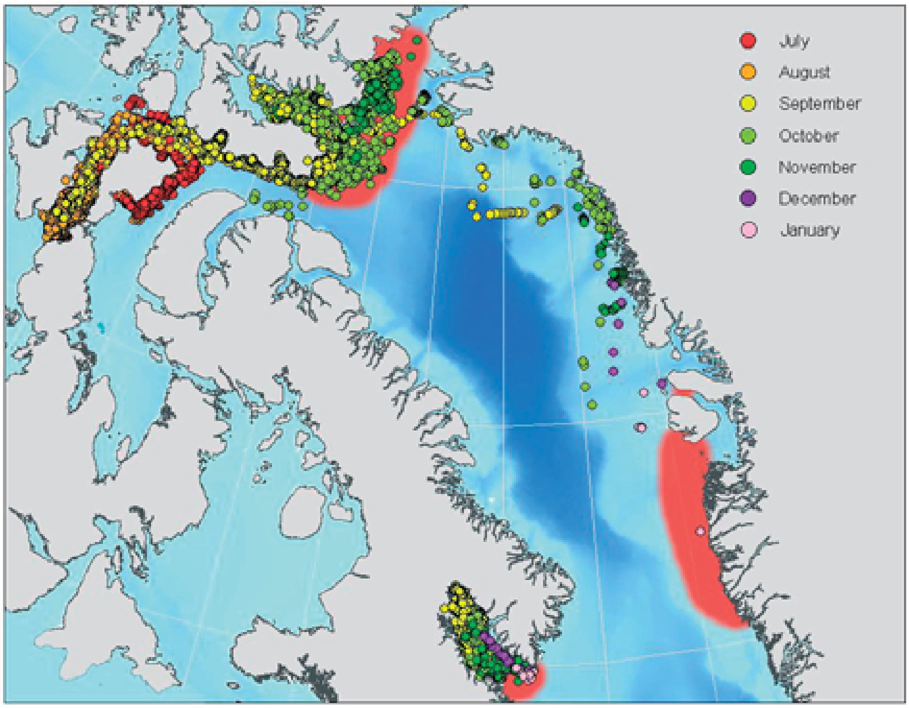
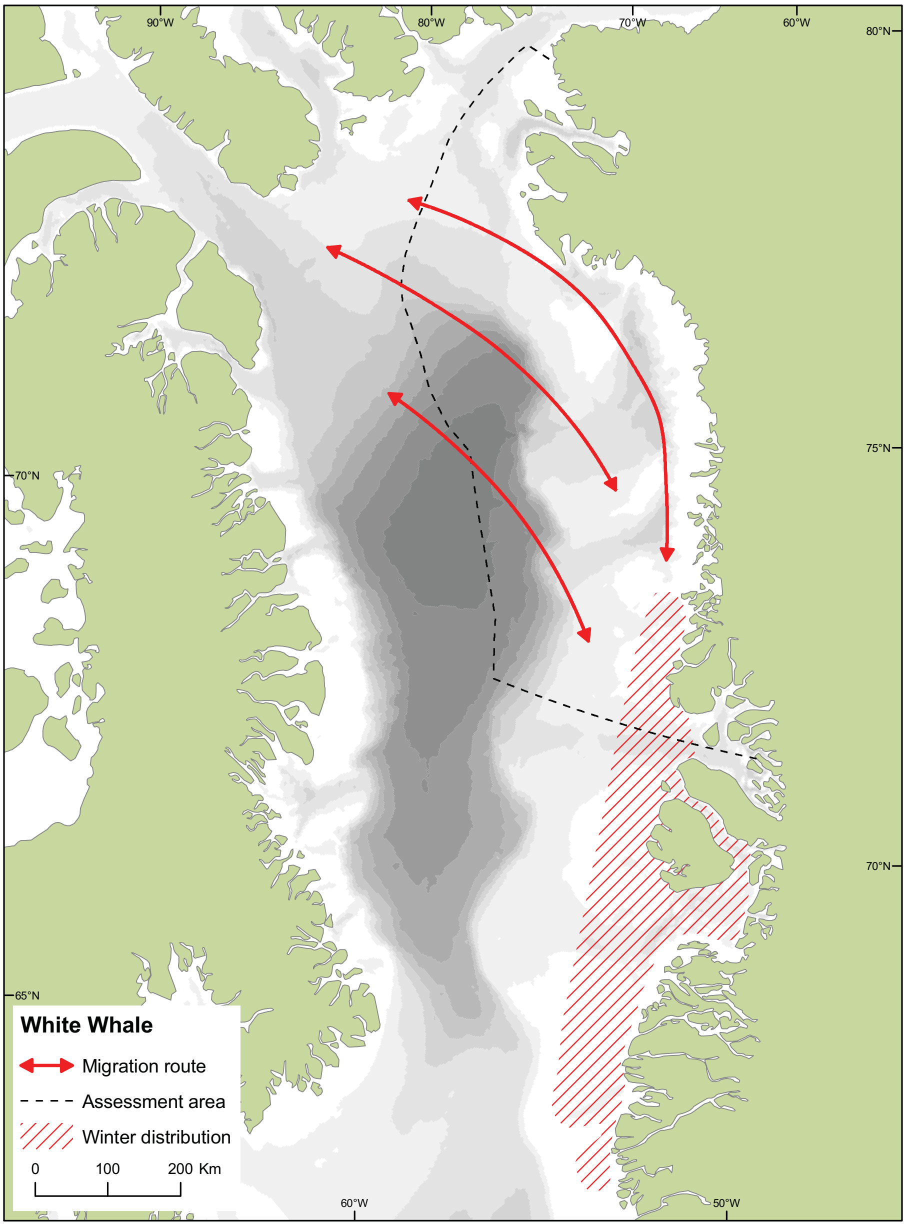


Figure 33. White whale winter grounds and migration routes.



Earlier commercial catches off west Greenland had greatly reduced the population. The total number of white whale caught by hunters in West Greenland, averaged 550 in the period 1993–2003. The recent annual catches of between 500 and 1,000 white whales often exceeded the catch of all other whale species combined (Heide-Jørgensen & Rosing-Asvid 2002).

As the the number of white whale wintering off West Greenland has declined since 1981, the Canada / Greenland Joint Commission for the Conservation of Narwhal and White Whale concluded that the West Greenland stock was substantially depleted and advised that delay in reducing the catch to approximately 100 animals per year would result in further population decline and further delay the recovery of this stock (NAMMCO 2001). In 2004, a quota of 320 white whales per year was established for West Greenland. This quota has been gradually reduced and in the 2007 / 2008 season it was 160.

In 2006, the total abundance of white whales in West Greenland was estimated to be 10,595 (95 % CI 4,904-24,650). The greatest abundance of white whales in 2006 was found in the areas south of Disko Bay at the northern portion of Store Hellefiskebanke, a pattern similar to that found in surveys of white whales conducted since 1981. The whales were mainly observed at the eastern edge of the pack ice that covers Baffin Bay and Davis Strait. The survey from 2006 suggested that the population might not be declining any more (Heide-Jørgensen *et al.* in prep.).

Conservation status: The population occurring in the assessment area has an unfavourable conservation status, because it has declined due to excessive catch. It is therefore listed as 'Critical Endangered' (CR) on the Greenland Red List. In Canada it is listed as 'Threatened / Special Concern' depending on the stocks.

Critical and important habitats: As white whales mainly are transient in the assessment area, no specific important or critical areas are known. The migration corridor is a critical habitat, but no particularly important staging areas are known en route. There are, however, traditional hunting grounds. The winter habitats in NOW are critical habitats.

Sensitivity: White whales are generally believed to be sensitive to noise from seismic surveys and drilling (Lawson 2005). In Arctic Canada white whales avoided seismic operations by 10–20 km (Lee *et al.* 2005).

See also the introduction to toothed whales.

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, where they do not obtain food, and wintering grounds in deep and densely ice-covered waters where they feed. Intense benthic feeding behaviour has been documented between November and March for narwhals from northern Canada and West Greenland (Laidre *et al.* 2003, Laidre) and, considering the low feeding activity during the summer period, a major portion of the annual energy intake is suggested to be obtained in Baffin Bay in winter (Laidre *et al.* 2008).

In winter narwhals stay in dense pack ice and breathe through leads and cracks in the ice. When these leads open up into large channels in spring the narwhals return to their summering grounds (Grønlands Naturinstitut 2006).

Distribution: Narwhals are one of the most abundant cetaceans in the Baffin Bay region, numbering at least 50,000 animals (Koski & Davis 1994, Innes *et al.* 2002) and they are abundant in most parts of the assessment area although during different seasons (Figure 34).

Narwhals are site faithful to summering and wintering grounds, although the stock movements in Baffin Bay are complex and still not fully understood.

In summer two stocks are found within the assessment area, one in Melville Bay and one in Inglefield Bredning. In spring and autumn, several stocks both from Greenland and the Canadian Arctic move through the assessment area, and at least one Canadian population winter in the southern assessment area in the central parts of Baffin Bay (Figure 35). Another winter aggregation occurs in Uummannaq Fjord (southern assessment area). The summer ranges of this aggregation are so far unknown.

Movements: Satellite tracking studies have shown that narwhals follow regular migratory schedules and narrow migratory routes between summer and winter grounds (Heide-Jørgensen *et al.* 2003). The population summering in Melville Bay migrate through a strip following the continental shelf towards wintering feeding grounds located in a restricted area in the deeper basins of Baffin Bay, where they remain from November to June (Figure 35) (Heide-Jørgensen *et al.* 2005).

The southern central part of Baffin Bay outside the assessment area, where narwhals from Melville Bay spend the winter, is also a wintering ground for larger numbers of narwhals summering in Canada in straits around Somerset Islands, and the Eclipse Sound population near northern Baffin Island (Dietz & Heide-Jørgensen 1995, Dietz *et al.* 2001, Heide-Jørgensen *et al.* 2002, 2003, Heide-Jørgensen 2004) (Figure 35).

Catch: Narwhals are important for the communities in the assessment area (Heide-Jørgensen 1994). From 1993–2003, annual catch averaged 519 narwhals for the whole of West Greenland. As a result of an apparent decline in the numbers of narwhals in surveyed areas, the Greenland Home Rule Government introduced hunting quotas in 2004. Advice for the management of narwhals in West Greenland is given by the Canada / Greenland Joint Commission for the Conservation of Narwhal and Beluga (JCNB 2006). The current advice is that, in order to ensure that the stocks will increase, catches for West Greenland, excluding Melville Bay, should not exceed 135 narwhals per year. Due to lack of population estimates, JCNB was unable to provide advice for the stock in Melville Bay. In recent years, catches in the Qaaduitsup municipality seem to include animals from the Smith Sound area, from which there is no assessment and no biological advice. The quota for narwhal for the 2007 / 2008 season is 93 for Melville Bay and 207 for the rest of West Greenland (Greenland Home Rule 2008). JCNB is seriously concerned that present takes of narwhals in West Greenland are not sustainable and will lead to further depletion of the stocks (JCNB 2006).

Figure 34. Overall distribution of narwhals, with indication of important summer grounds. The assessment area is indicated with hatched line.

Conservation status: The population occurring in the assessment area has an unfavourable conservation status, as it is decreasing due to excessive hunt. It is listed as 'Critical Endangered' (CR) in Greenland, and in Canada as being of 'Special Concern'.

Narwhals are protected in the inner part of the Melville Bay nature protection area.

Critical and important habitats: In summer the inner Melville Bay and Inglefield Bredning are habitats for separate populations. During autumn narrow migration pathways have been documented along the shelf break, and in winter a Canadian stock (from Somerset Island) has a well-defined wintering area in central Baffin Bay in the southern part of the assessment area (Figure 35).

Sensitivity: Narwhals are generally believed to be sensitive to noise from seismic surveys and drilling (Wiig *et al.* 1996), and in a preliminary impact assessment of seismic surveys in West Greenland waters, three important

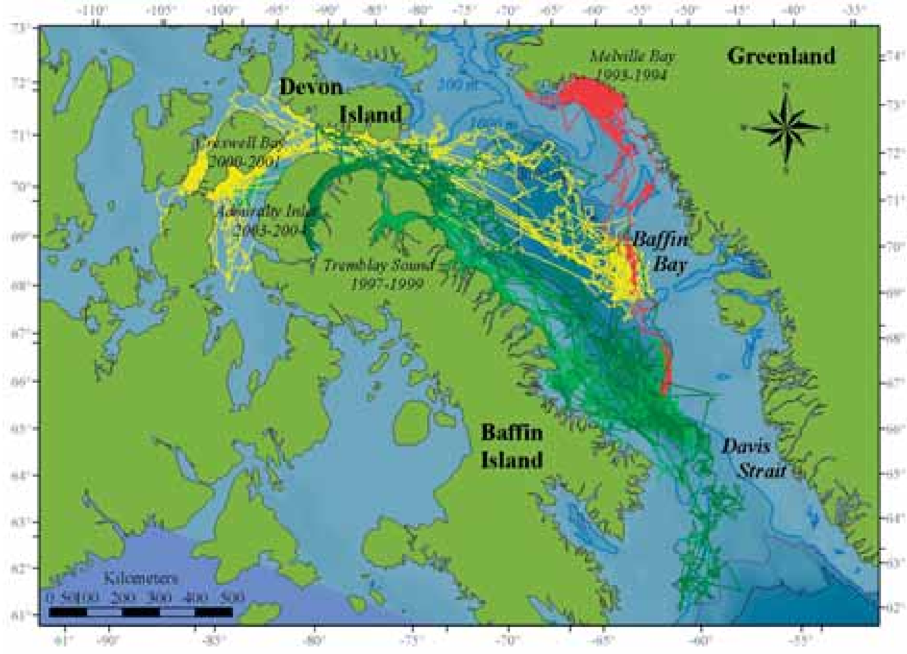


Figure 35. Track lines for narwhals tagged in different Canadian summer grounds and in Melville Bay. Dark green lines = tagged in Admiralty Inlet; yellow = at Somerset Island; pale green = Eclipse Sound; red = Melville Bay.

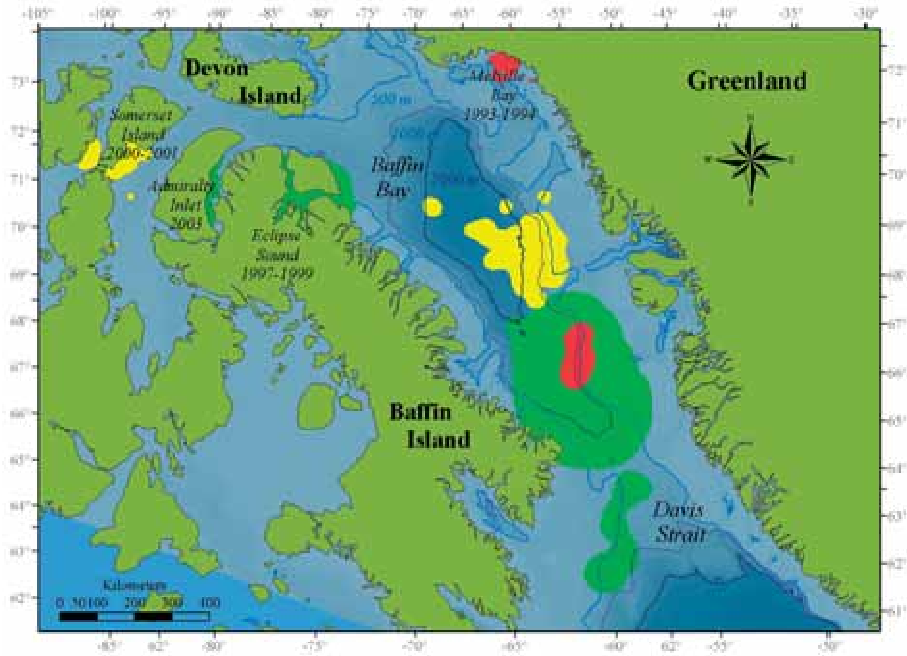


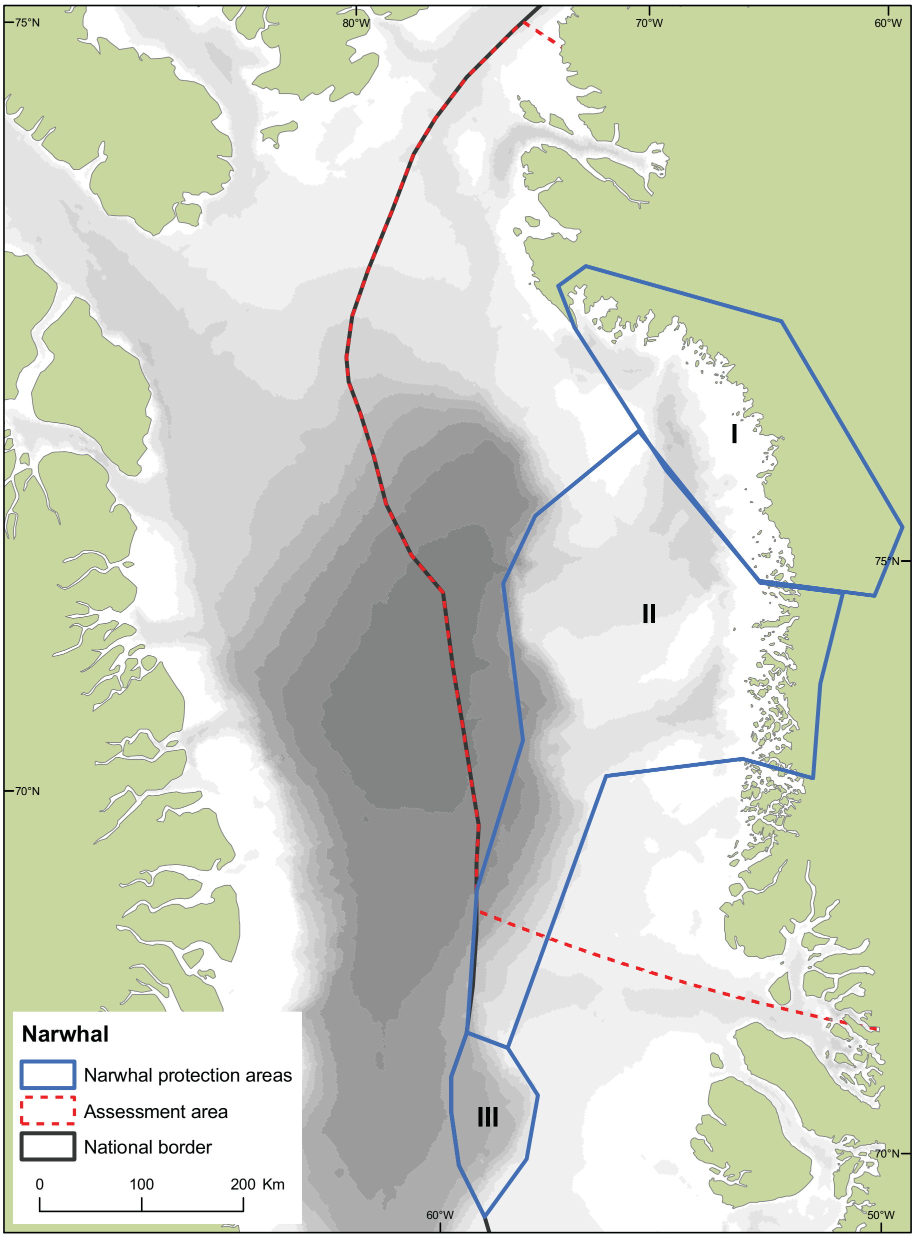
Figure 36. Summer grounds (in coastal areas) and winter grounds (in Baffin Bay) for narwhals of the summer populations from Figure 35. (95 % Kernel home range polygons). Note especially the small winter ground for the Melville Bay stock (red).

narwhal areas are designated (Figure 37). Here seismic operation should be avoided when narwhals are present (Mosbech *et al.* 2000a).

Sperm whale *Physeter macrocephalus*

With males reaching lengths of 18 m and weights of 50 tonnes, sperm whales are the largest toothed whale. On average, male sperm whales are 15 m long and weigh 45 tonne, 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 occasion-

Figure 37. The narwhal protection areas in relation to seismic operations in the assessment area. Area 1 is the summer habitat, where seismic operation should be avoided or limited 15 July to 25 October. Area 2 is the migration corridor, where seismic operations should be minimized 15 October to 1 December. Area 3 is the winter habitat where seismic operations are impossible to conduct.



ally 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 & 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 of the family Architeutidae that weigh up to 400 kg (reviews in Rice 1989 and Whitehead 2003). Sperm whales in the northeastern Atlantic feed heavily on the deep-water squid *Gonatus fabricii* (Santos *et al.* 1999), favouring mature squid with mantle length of approx. 19–26 cm (Simon *et al.* 2003). Male sperm whales off northern Norway tagged with multi-sensor instruments feed both at shallow depths of approx. 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 long-line 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 (*Cyclopterus lumpus*), but redfish (*Sebastes marinus*), anglerfish (*Lophius piscatorius*), cod (*Gadus morhua*) and blue whiting (*Micromesistius poutassou*) were also common.

Distribution: Berzin (1971) reviewed captures of sperm whales in the Davis Strait as far back as 1812, including a mention from 1870 about sperm whales being relatively scant in the region, and a report of 181 males caught by a fleet of seven boats in 1937. Sperm whales are still regularly reported in ice-free areas in the Davis Strait (unpublished data).

Offshore boat traffic further north in the KANUMAS area is rare, and there have been no dedicated surveys for cetaceans in this area. The presence of sperm whales could be expected during ice-free periods in suitable habitat, such as deep-sea waters close to continental slopes and underwater canyons with abundance of cephalopod or fish prey.

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 & Gyllensten 1998).

Conservation: Sperm whales were the target of commercial whaling during 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. At the present time, sperm whales are not caught anywhere in the North Atlantic. In the Greenland Red List, sperm whales are listed as 'Not Applicable' (NA) and globally as 'Vulnerable' (VU) (IUCN 2008).

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 whales in this region may have habituated to anthropogenic noise.

4.8 Summary of VECs from KANUMAS West assessment area

The VEC (Valued Ecosystem Conmponent) concept is explained in section 9.1.2. It must be underlined that the designation of VECs will always be constrained by the availability of 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 and large variability 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.

Benthos

There are many areas with high densities of benthos, and sites in shallow waters are often important feeding grounds for walrus, bearded seal and eiders. Such areas have been sampled in the summer of 2008, but data have not yet been analysed. To date, there is no data available to indicate important sites for benthos.

Northern shrimp is an important species as it forms the basis of the most important fishery in Greenland. However, only a small proportion (1 %) of the landings is taken within the assessment area. But the amount is expected to increase in the future if water temperatures increase.

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.

Fish

VECs among the fish include the Greenland halibut (the only species utilised on a commercial basis), polar cod (ecological key species), capelin (ecological key species) and Arctic char. 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

Great cormorant occur in the southern part of the assessment area. A significant part of the Greenland population is estimated to occur here, and cormorants are generally vulnerable to oil spills.

Common eider is an important species, breeding in colonies throughout the coastal parts of the assessment area. The population has been decreasing throughout the past century. But active management involving local stakeholders has shown that this trend can be reverted. Common eider is an important quarry species for the hunters of the assessment area. Concentrations, including the breeding colonies and moulting flocks, are vulnerable to oil spills and disturbance.

King eider occurs in late summer in large moulting concentrations along the coasts. These flocks are particularly vulnerable to oil spills and disturbance.

Kittiwake breeds in large and dense colonies, where high proportions of the population may be exposed to oil spills and disturbance. It is also an important quarry species for the hunters of the assessment area.

Arctic tern breeds in large and dense colonies along the coast, where they are vulnerable to oil spills and disturbance.

Thick-billed murre. The population breeding in the assessment area is of high international conservation value and of very high national conservation value as 15 % of the global population and >90 % of the Greenland population is found there in summer. The Greenland population is assessed as 'Vulnerable' (VU) on the national Red List. Murres are particularly vulnerable to oil spills (Wiese & Ryan 2003)

Atlantic puffin. The population breeding in the assessment area is of national conservation value as approx. 25 % is estimated to breed there (mainly in the former Upernavik municipality). It listed as 'Near Threatened' (NT) on the Greenland Red List, and it is vulnerable to oil spills.

Little auk. The population breeding within the assessment area is of extremely high international conservation value as well as of national conservation value as more than 50 % of the global population is found there in the summer. This species is vulnerable to oil spills and it is utilised by the inhabitants of the former Qaanaaq municipality.

Marine mammals

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

Walrus occur mainly as migrants in the assessment area. The numbers probably constitute a low proportion of the total population, but both are red-listed and both are hunted. The shear zone off the outer coast is their primary habitat.

Bowhead whale. This whale has a high international conservation value due to its rarity. An unknown proportion of the Baffin Bay population will move through the southern part of the assessment area, and some also winter in the northern part. Their primary habitat is the marginal ice zone.

Bearded seal. This species is probably abundant in the assessment area, where a significant part of the Greenland population may be found. Its biology in Greenland is poorly understood, but in other areas bearded seals are known to feed at or close to the bottom, with benthic organisms being an important part of their diet. As benthic feeders they may be ecologically affected by oil spills. They are very active acoustically and therefore may be affected by anthropogenic noise related to oil exploration and development.

Ringed seal is an ecological key species due to its abundance and its role as main prey for the polar bear (Figure 10). It is moreover the most important marine mammal to the hunters of the assessment area. No particularly important areas are known in the assessment area for the species.

Bowhead whale. This whale has a high international conservation value due to its rarity. An unknown proportion of the Baffin Bay population will move through the southern part of the assessment area, and some also winter in the northern part. Their primary habitat is the marginal ice zone.

Narwhal. A significant part of the global population occurs within the assessment area – summering, migrating or wintering – and its conservation value is therefore of international importance. There is also concern for the population as it is decreasing, and it is red-listed as 'Critically Endangered' (CR). In summer narwhals aggregate in Melville Bay, during migration often along well-defined routes, and in well-defined areas in winter also. Narwhals are important quarry for the hunters of the assessment area.

White whale. The population occurring in the assessment area has a high national conservation value as it makes up the entire West Greenland winter population. It is listed as 'Critically Endangered' (CR) on the Greenland Red List due to decreasing population (unsustainable harvest) and it is an important species for the subsistence hunters in the area. The primary habitats are the shelf waters – in winter and spring between land and the drift ice, often in the shear zone.

Other ecological features

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

5 Natural resource use

5.1 The commercial fisheries

Commercial fisheries represent the most important export industry in Greenland, underlined by the fact that fishery products accounted for 91 % of the total Greenlandic export revenue (2.3 billion DKK) in 2006 (Statistics of Greenland 2008). Very few species are exploited by the commercial fisheries in Greenland, and this is especially so in the assessment area. The three most important species on a national scale are deep-sea shrimp (export revenue in 2006: 1,200 million DKK), Greenland halibut (510 million DKK), Atlantic cod (128 million) and snow crab (53 million DKK) (Statistics of Greenland 2008).

Greenland halibut and shrimp are the main commercially exploited species within the KANUMAS West assessment area accounting for 15 % and 1 % of the total Greenland catch, respectively.

Greenland halibut fishery

In the assessment area the fishery for Greenland halibut (*Reinhardtius hippoglossoides*) has both inshore and offshore components. The inshore fishery is conducted in the former municipalities of Uummannaq and Upernavik where landings in 2006 amounted 5,500 tonnes taken within the assessment area (this is approx. 18 % of the total Greenland landings of Greenland halibut). The fishery takes place throughout the year in fjords with deep water and the fish are caught on long-lines either from small vessels or from the winter ice (Figure 38).

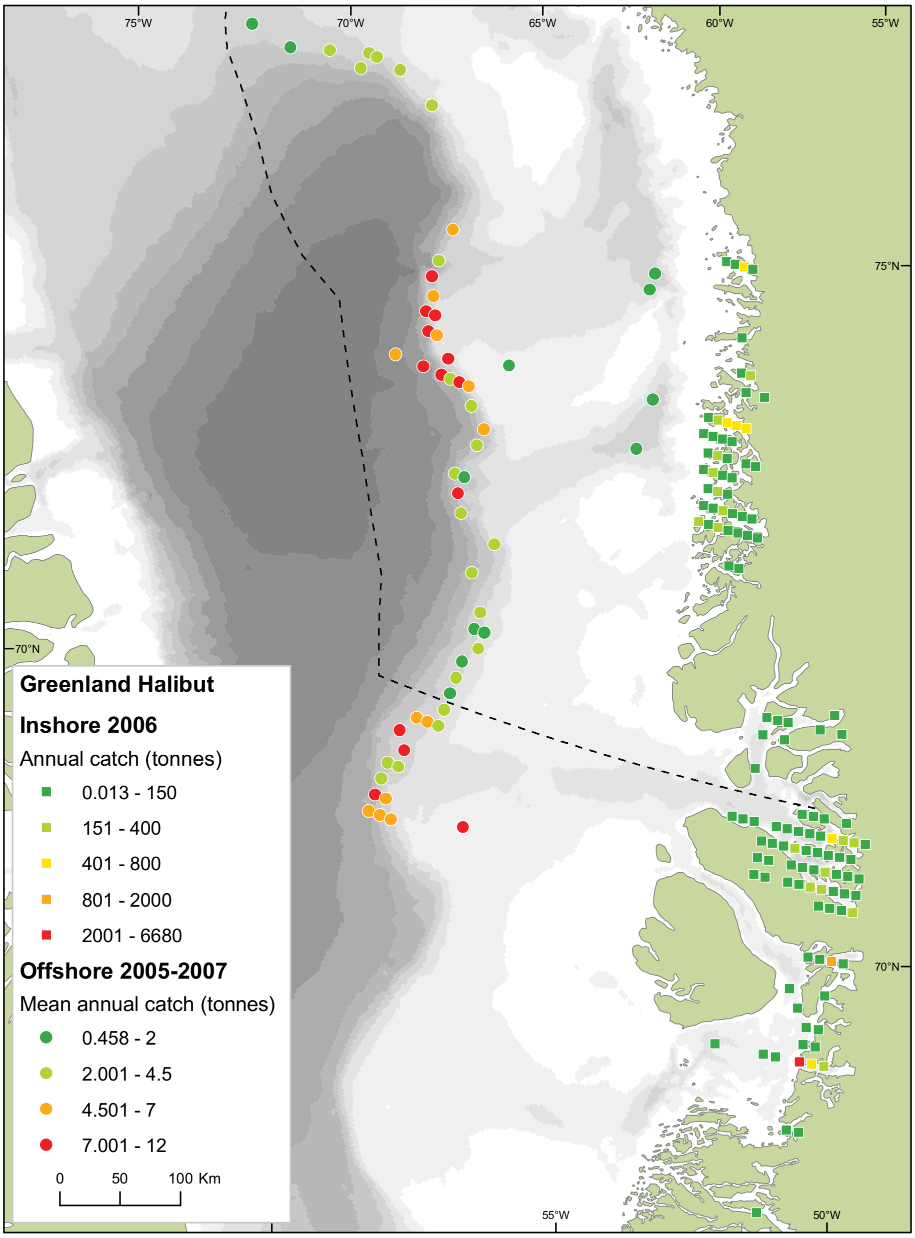
The offshore fishery for Greenland halibut takes place in summer and autumn on the shelf slope of Baffin Bay (Figure 38). In the past years the offshore catches north of 68° 50’ N increased from 575 tonnes in 2001 to 3,500 tonne in the years 2003–2005. Catches increased again in 2006 to 6,220 tonnes and stayed at that level in 2007 (6,300 tonnes). In 2006 about 3 % (~200 tonnes) of the offshore catch north of 68° 50’ was taken within the assessment are

In recent years fishing is performed by trawlers primarily at depths between 750 and 1450 m. The distribution of the catches (average 2005-2007) is shown in Figure 38.

Northern shrimp fisheries

The fishery for northern shrimp (*Pandalus borealis*) has in recent years been conducted in a small area offshore of Upernavik. In 2004–2006 less than 1 % of the total Greenland shrimp catch was taken in the area north of 71° N (Figure 39). However, in previous years (1985–1988) the area north of 71° N was very important and accounted for up to 30 % of the total catch. As a response to climatic changes with higher temperatures in Southwest Greenland it is likely that the area could regain its importance as the stock is moving further north. The biological survey has shown an increased biomass in the area offshore of Upernavik since 2003.

Figure 38. Distribution of Greenland halibut fishery and size of landings from the assessment area. Note the different scales on inshore and offshore landings. Inshore catches are illustrated by a single year: 2006, off-shore by annual average over the period 2005 to 2007.

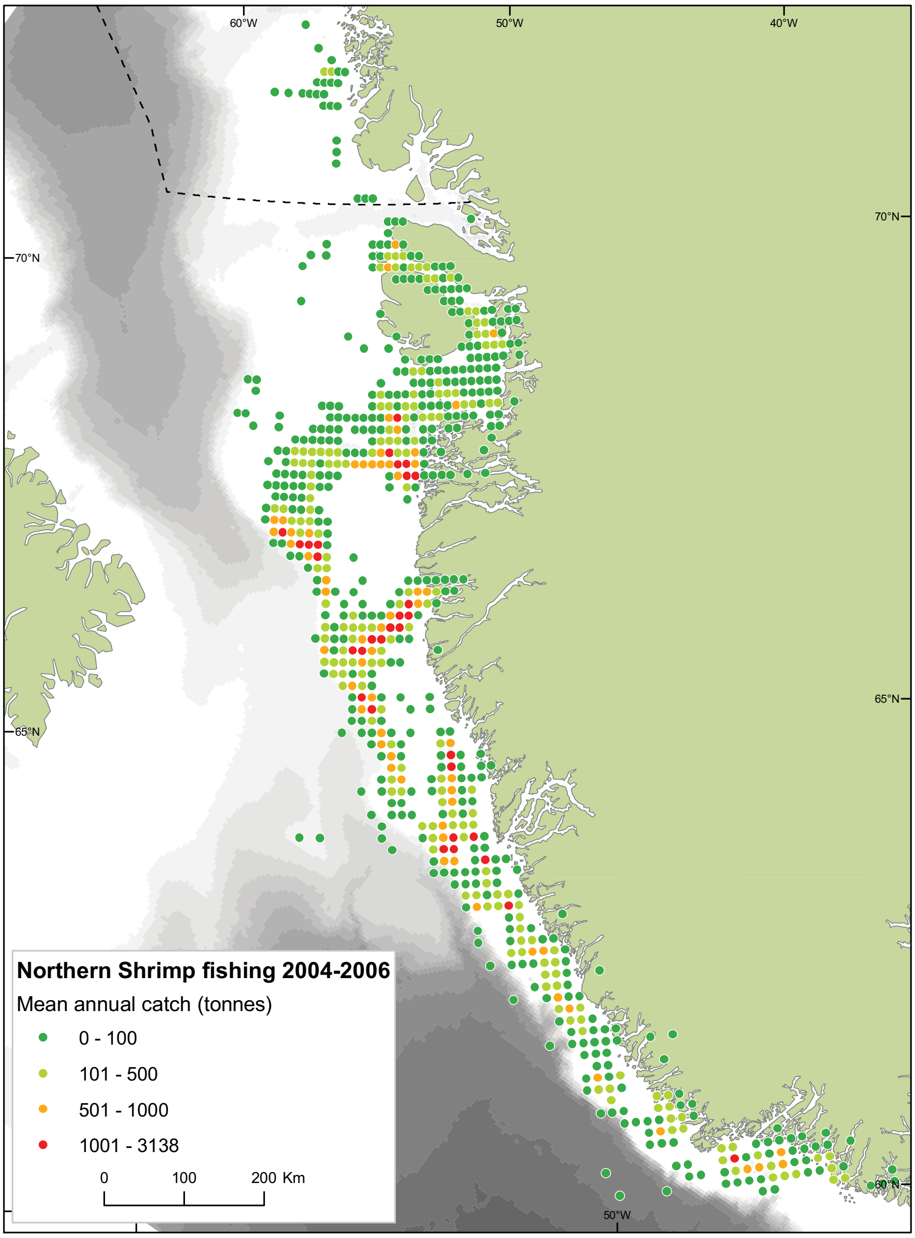


Other species

The commercial fishery for **snow crab** (*Chionoecetes opilio*) was initiated in 1996. Total landings peaked in 2002 at approximately 15,000 tonnes, and the snow crab at that time represented the third most important export for Greenland in terms of income. The stock has been decreasing since 2004 and total catch in 2007 was only 2,000 tonne. In the assessment area a catch of 65 tonnes (less than 1 % of total catch) was noted in 2004. Since then no fishery has been reported from the area. It is unlikely that a fishery for snow crab will develop in the near future in this area.

Iceland scallop (*Pecten islandica*) is caught in rather shallow water where currents are strong. Total catch in Greenland has been around 2,000 tonnes / year. In the assessment area almost no fishery (1 %) has taken place, with only 4 tonnes in 2000 and 53 tonnes in 2003. No fishery has taken place since then.

Figure 39. Distribution and size of northern shrimp catches in West Greenland. The fishing grounds cover only the southernmost part of the assessment area. Catch size calculated as annual mean over the period from 2004 to 2006.



5.2 Subsistence and recreational fisheries and hunting

Besides the commercial fishery, subsistence fishery and recreational fishery take place in the region. Hunting on subsistence basis and also as recreational activity is also important in the assessment area. Both fishing and hunting are important for the income of many families, particularly in the small settlements, and many are still dependent on these activities for their living. The catches are either used or manufactured by families themselves or sold at local outdoor markets (Kapel & Petersen 1982, Pars *et al.* 2001, Rasmussen 2005).

Fishery

Many fish species are utilised in these fisheries. The species that will be most vulnerable to an oil spill are those caught close to the shoreline: capelin (*Mallotus villosus*), lumpsucker (*Cyclopterus lumpus*) and Arctic char (*Salvelinus alpinus*). Fisheries for these species are restricted to spring and summer. Capelin and lumpsucker occur only in the southernmost part of the assessment area, although their ranges are moving northwards in these years. Arctic char occur throughout the assessment area, see section 4.5.2.

Many other species of fish are utilised on subsistence basis: spotted wolffish (*Anarchichas minor*), Greenland halibut (*Reinhardtius hippoglossoides*) redfish (*Sebastes* spp.), Atlantic cod (*Gadus morrhua*), polar cod (*Boreogadus saida*), Greenland cod (*Gadus ogac*), Greenland shark (*Somniosus microcephalus*), etc. Some of the species are also traded on a commercial basis in Uummannaq and Upernavik, particularly Greenland halibut (see section 5.1).

Important areas for fishery of capelin, lumpsucker and Arctic char were mapped by the oil spill sensitivity mapping project covering west Greenland as far north as 72° N (Svartenhuk Peninsula), but this overlaps only the southernmost small part of the assessment area (Olsvig & Mosbech 2003, Mosbech *et al.* 2000b, 2004).

Marine mammal species regularly hunted within the assessment area include all the seals, walrus, white whale, narwhal, minke whale, fin whale and polar bear.

In 2006, the following numbers of seals were reported to the official bag record for the former municipalities of Uummannaq, Upernavik and Qaanaaq (this includes the assessment area, plus the north of Qaanaaq and the south of Uummannaq): ringed seal 56,302; harp seal 19,963; hooded seal 1,373 and bearded seal 738 (Greenland Home Rule, unpublished data).

The catches of walrus, white whale, narwhal, polar bear and minke whale are regulated by quotas. The walrus quotas in 2008 were Qaanaaq 70, Upernavik 10 and 65 for west Greenland (23 for Uummannaq and Disko Bay, and the rest further south). White whale quotas for July 2008–June 2009 in the assessment area were Qaanaaq 20, Upernavik 44 and Uummannaq 10 (the rest of West Greenland 83). For the same season, narwhal quota for Qaanaaq north of Savisivik was 65, Melville Bay 93 and Uummannaq 79 (55 for the rest of West Greenland). Polar bear quota for 2008 for the Kane Basin population (Qaanaaq north of Savisivik) was 8 and for the Baffin Bay population was 73 (Savisivik 18, Upernavik 45, Uummannaq and south 10). Minke whale quotas for 2008 were Upernavik 5, Uummannaq 5 and the rest of West Greenland 190.

Seals are caught throughout the year, with ringed seals mainly when ice is present, and harp seal and hooded seal in the open-water season. Narwhals, white whales and walrus to the south of Melville Bay are caught when they migrate in spring and/or autumn, while in Qaanaaq and Melville Bay narwhals are caught in summer. In the Qaanaaq area walruses are caught mainly in May–June and September–October. Minke whales are caught in the open-water season in the southern part of the assessment area. Polar bears are caught during the period 1 September to 30 June.

In 2006 about 2,688 murres and 2,211 eiders were reported to the official bag record system from the region to the north of Disko Bay (= the assessment area + southern part of the former Uummannaq municipality). Reported bird catches were considerably reduced after new legislation came in force in 2001 (Greenland Home Rule unpublished).

A significant part of the hunt takes place along the spring ice edge, which usually is situated off the outer coast.

5.3 Tourism

The tourist industry is one of three major sectors within the Greenland economy, and the industry is increasing greatly in importance both nationally and locally in the assessment area. The most important asset for the tourist industry is the unspoilt, authentic and pristine nature.

There are no statistics on the number of tourists and their regional distribution in Greenland available, but hotels report the number of guests they have accommodated and how many ‘bed nights’ they have sold. Overall figures for Greenland as a whole in 2006 were approx. 82,000 guests and approx. 250,000 ‘bed nights’ (Statistics of Greenland 2008). By far the major part of these were in West Greenland outside the assessment area and only 5–10 % of the total number of ‘bed nights’ were in Northwest and East Greenland (= former municipalities of Qaanaaq, Upernavik, Uummannaq, Scoresbysund and Tasiilaq).

Besides the tourists staying in hotels and other accommodation on shore, cruise ships bring an increasing number of tourists to Greenland. According to the Danish Naval Authorities in Greenland, the number of visitors from cruise ships increased from 23,000 in 2006 to 55,000 in 2007 (Figure 40). The National Strategy of Tourism 2008–2010 plans a 10 % increase per year in the number of cruise tourists (Erhvervsdirektoratet 2007).

The cruise ships focus on the coastal zone and they often visit very remote areas that are otherwise almost inaccessible, and seabird and marine mammals are highlights on these trips.

A number of tourists also go to Greenland for outdoor leisure activities (mountaineering, kayaking, etc) or scientific expeditions (natural history) (Figure 41).

Tourist activities

The activities are centred in the main towns of the assessment area: Uummanaq (just outside the assessment area), Upernavik and Qaanaaq, where there are accommodation and tourist operators. The season starts in early spring when there are opportunities for dog sledding on the sea ice, but the main season is summer when it is possible to sail from the towns to attractions such as archeological sites, bird cliffs, whale habitats, glaciers, small settlements, hiking areas and areas with scenic views.

In Upernavik the following activities take place (Bo Albrechtsen, Director of Museum and Tourism in Upernavik, pers. comm.):

- Dog sledge trips. Takes place year round. Sled trips are mostly on sea ice in the coastal zone.
- Boat trips with local hunters. Summer season
- Kayaking. June to August. Kayakers explore the coastal zone and bring equipment and provisions on their own
- Cruise ships. Mainly August and September. Visitors in Upernavik town mostly walk around for sightseeing and visit the museum
- Fishing and hunting. Seal hunt on the ice in spring
- Hiking. Summer season. Land-based

Figure 40. Number of cruise ships and number of passengers 1994–2007 in Greenland overall. There is no data on the cruise ship activity available for the assessment area, but the trends are similar (Greenland Tourism pers. comm.).

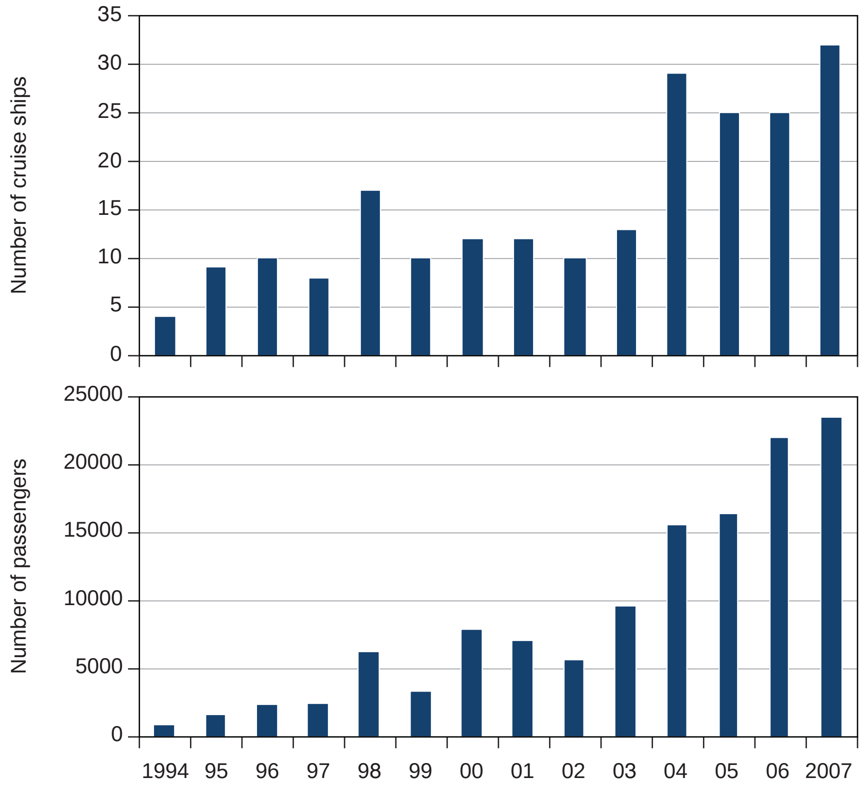
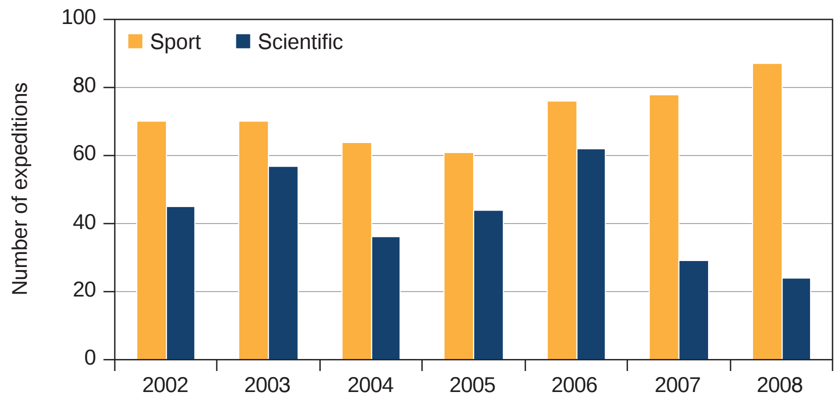


Figure 41. Number of expeditions in Greenland by year. Data provided by the Danish Polar Centre (DPC). It is not possible to filter out the expeditions visiting the assessment area.



In 2007 the number of visitors was in total approx. 800. Of this figure, 700 arrived from cruise ships, 50 were there specifically for kayaking, and the last 50 were independent travellers.

Due to the remoteness, Qaanaaq receives only a few independent travellers and these often as sport or scientific expeditions. The activities include dog sledge trips, hiking, kayaking and hunting. Most of the activities are related to the sea or the ice. A few of the independent travellers go there in winter. Cruise ships also bring an increasing number of tourists to Qaanaaq in the summertime.

Much of the tourist activity within the assessment area takes place in the coastal zone, which potentially is 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.

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. No Ramsar sites are found within the assessment area (Egevang & Boertmann 2001a).

6.2 National nature protection legislation

The Melville Bay Nature Protection Area is situated within the assessment area (Figure 42). This was designated primarily to protect polar bears. Although a nature protection area, traditional hunting is allowed in an outer part and exploration for petroleum and minerals is allowed throughout (Boertmann 2005).

There are six specific sites protected as seabird breeding sanctuaries according to the Bird Protection Executive Order within the assessment area (Figure 42). This order also states that in general, all seabird breeding colonies are protected from disturbing activities (*cf.* the maps showing the seabird breeding colonies within the assessment area (Figure 15). 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 and they also include the most important seabird breeding colonies (Figure 43). Moreover have some important narwhal-areas in the assessment area been designated as narwhal-protection areas (Figure 37).

Table 3. Red-listed species occurring in theKANUMAS West assessment area.

Species	Red List category
Polar bear	Vulnerable (VU)
Walrus	Critically endangered (CR)
Bowhead whale	Near threatened (NT)
White whal	Critically endangered (CR)
Narwhal	Critically endangered (CR)
Great northern diver	Near threatened (NT)
Greenland white-fronted goose	Endangered (EN)
Common eider	Vulnerable (VU)
Gyr falcon	Near threatened (NT)
Sabines 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)

Figure 42. Areas protected according to the Greenland Nature Protection Law (Melville Bay reserve and Bird Protection areas) and areas designated as Important Bird Areas (IBAs) by BirdLife International. There are no Ramsar-areas within the assessment area.

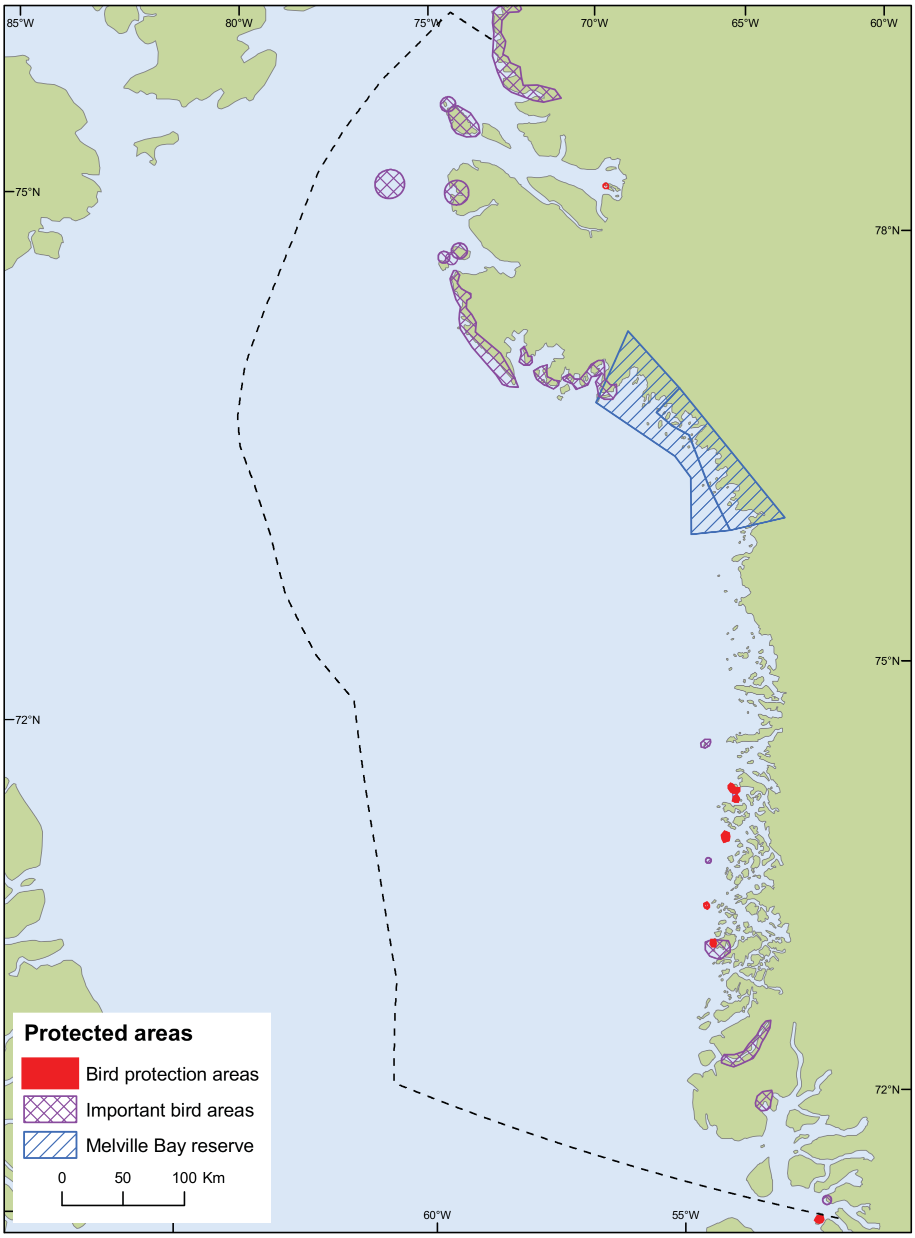


Table 4. National responsibility species (defined as more than 20 % of the global population in Greenland) and species listed as 'Data Deficient' (DD) occurring in the assessment area. Only species which may occur in marine habitats included.

National responsibility species	Species listed as Data Deficient (DD)
Polar bear	Bearded seal
Light-bellied brent goose	Harbour porpoise
Greenland white-fronted goose (endemic)	Blue whale
Black guillemot	Sei whale
Little auk	

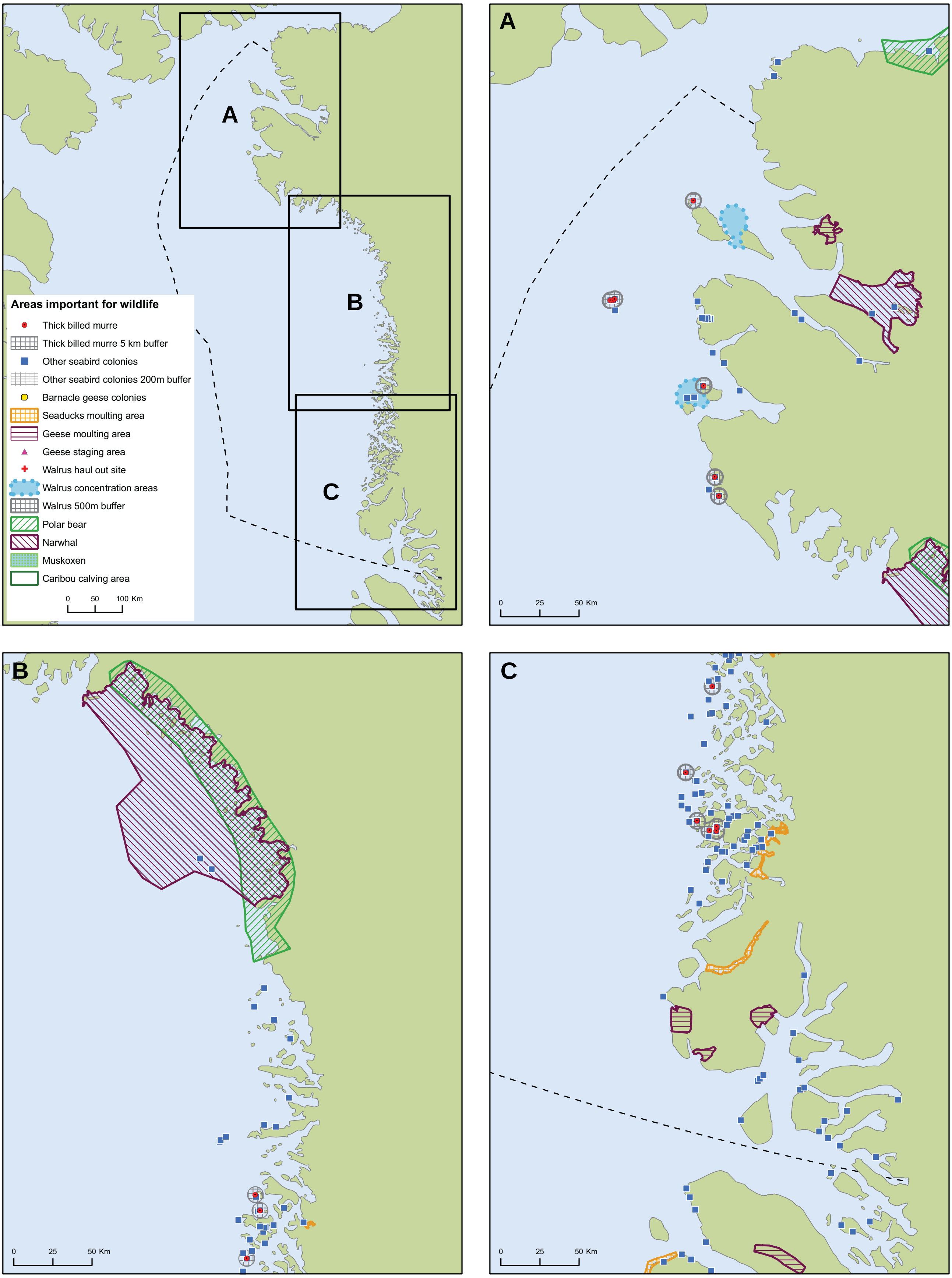
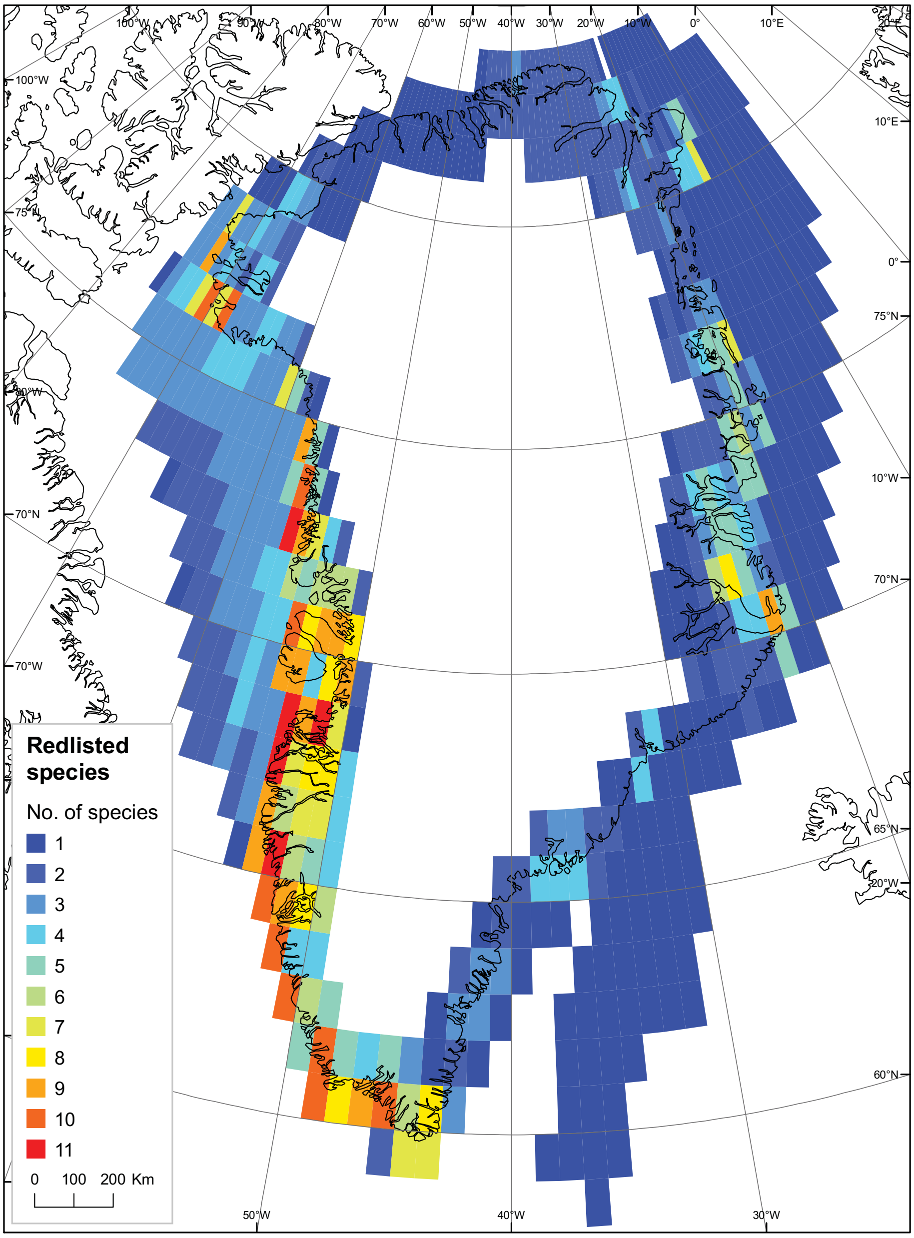


Figure 43. Areas designated as "important to wildlife" by Bureau of Minerals and Petroleum as a part of the field rules for prospecting and exploration activities.

Figure 44. Distribution of Red-listed species in Greenland shown as number of species in 1°× 1° squares.



6.3 Threatened species

Greenland has red-listed (designated according to risk of extinction) five species of mammals and eleven species of birds (Table 3) occurring in the assessment area (Boertmann 2007).

A few species have been categorised as 'Data Deficient' (DD) 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, narwhal may also be included here, but knowledge on numbers and fraction in Greenland is unknown.

Within the assessment area there are some hot-spots for threatened species (Figure 44) – particularly in the coast of the former municipality of Upernavik and the coasts of central part of the former Qaanaaq municipality.

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), of which eighteen are located within the assessment area (Figure 42). These areas 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 regulations e.g. as seabird breeding sanctuaries, but many are without protection or activity regulations, although they may be protected in the future.

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 the years in various regions and with 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. 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 (TAB) 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 TAB.

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 antropogenic 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 just south of the assessment area. Species included in the programme were the landlocked Arctic char, shorthorn sculpins (*Myoxocephalus scorpius)*, black guillemot (*Cepphus grille*) 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 (2006, 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 observed appear mainly to be related to natural geological differences in the occurrence of the minerals (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 peregrine falcons could indicate a change in the increasing trend (Dietz *et al.* 2006b).

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 (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 had 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 black 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, 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 (Skjoldal *et al.* 2007).

Over the years various studies on hydrocarbons, their patterns and sources have been performed mainly in Southwest Greenland (Mosbech *et al.* 2007b).

PAH levels in sediments, bivalves (Iceland scallop, Greenland cockle) and shorthorn sculpins were measured at dumpsites and reference sites around Thule Airbase in 2002. The PAH concentrations found in the bivalves were in the same range as in blue mussels from temperate marine environments but higher than in blue mussels from Disko Bay previously studied. PAH concentrations in shorthorn sculpins did not differ between dumpsites and reference locations. The levels were, however, only about half of those measured in specimens at the Disko area (Mosbech *et al.* 2007b).

Total petroleum hydrocarbons (TPH) and PAH levels were measured at possible natural seeps in the Marrat Disko Bay area in 2005. Sediments and biota (blue mussels, Sculpins, Greenland cod) were taken from the coast of Nuussuaq Peninsula from onshore and offshore areas (Mosbech *et al.* 2007b). TPH levels in the sediment were relatively low and therefore gave no real indication of oil seeps or other local petrogenic sources. The PAH levels ranged from low values up to approx. 1600 µg / kg dry weight but there was no clear spatial pattern. However, samples from greater depths (200–400 m) and further away from the coast showed 3–4 times higher levels than those closer to the coast. The reason for this is presently not clear (Mosbech *et al.* 2007b).

In 2006, sediments samples were taken off West Greenland between (64°N and 71°N). Only three samples from Aasiaat bay and two from Nuussuaq Basin displayed higher background levels than usual for the area.

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 dump sites 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, the 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, 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 KANUMAS West assessment area is still limited. Most of the studies have been carried out in certain areas, only covering the south and very north of the KANUMAS West assessment area.

Further studies are needed to fill in the gaps in order to better understand to 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 impairments.

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 level 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 level 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 observed 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 turn over 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 been raised. Based on laboratory and field studies performed at Bear Island (Bjørnøya) and in Svalbard it has been demonstrated that the present level 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 the 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 pointed out 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 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 the 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 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 date 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. Nevertheless, 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 mid-century and 4 to 7 ºC higher toward the end of the 21st century (ACIA 2005, Walsh 2008). Other changes predicted for 2050 are a general decrease of sea level pressure and an increase of 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 45). 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

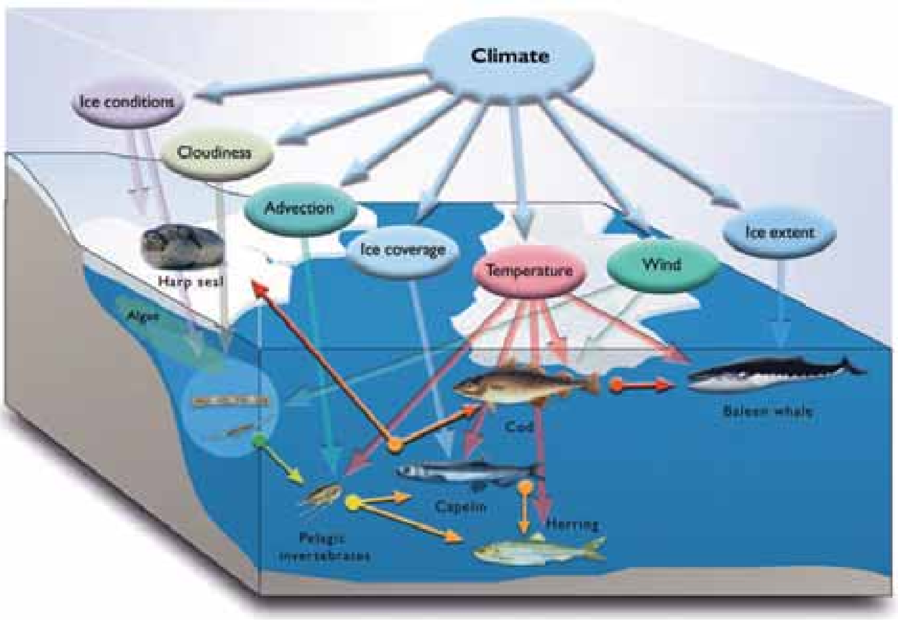


Figure 45. Different climate parameters that may impact the marine food chain, both directly and indirectly. From ACIA (2005).

effects could also occur through changes in the abundance of top-level 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 change 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 (*Cystophora cristata*), the polar bear (*Ursus maritimus*), and the narwhal (*Monodon monoceros*), 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 (*Phoca hispida*) and bearded seal (*Erignathus barbatus*), 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 (i.e. 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. According to Derocher *et al.* (2004) spatial and temporal sea-ice changes will lead to shifts in trophic interactions involving polar bears through reduced availability and abundance of their main prey: seals. In the short term, climatic warming may improve bear and seal habitat at higher latitudes over continental shelves if currently thick multi-year ice is replaced by annual ice with more leads, making it more suitable for seals. A cascade of impacts beginning with reduced sea ice will be manifested in reduced adipose stores, leading to lowered reproductive rates. As sea ice thins, it is likely to be more fractured and labile and more reactive to winds and currents. As a result, polar bears will need to walk or swim more and thus use greater amounts of energy to maintain contact with the remaining preferred habitats (Derocher *et al.* 2004).

Change in ice climate, therefore, has a large potential to modify marine ecosystems, either through a bottom-up reorganization of the food web by altering the nutrient or light cycle, or top-down reorganization by altering critical habitat for higher trophic level (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 affected by human releases of contaminants as indicated in Chapter 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; 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 the 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 West area

Annual mean temperatures for selected stations in West 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).

According to Parkinson and Cavalieri (2008) the Baffin Bay / Labrador Sea region experienced a cyclical rise and fall in winter sea-ice extent through two cycles of about 10 years each from 1979 through 1998. Continuation of this cyclical pattern would have yielded a rise in ice extent over the next several years; however, this did not occur, being replaced instead by continued, overall decreases in the extent of the ice. The net result includes statistically significant negative trends in the monthly deviations, yearly averages, and all four seasonal averages. Sea-ice area provides the total cumulative area of ice coverage and, similar to the case of ice extent, all annual trends are significantly negative for Baffin Bay / Labrador Sea.

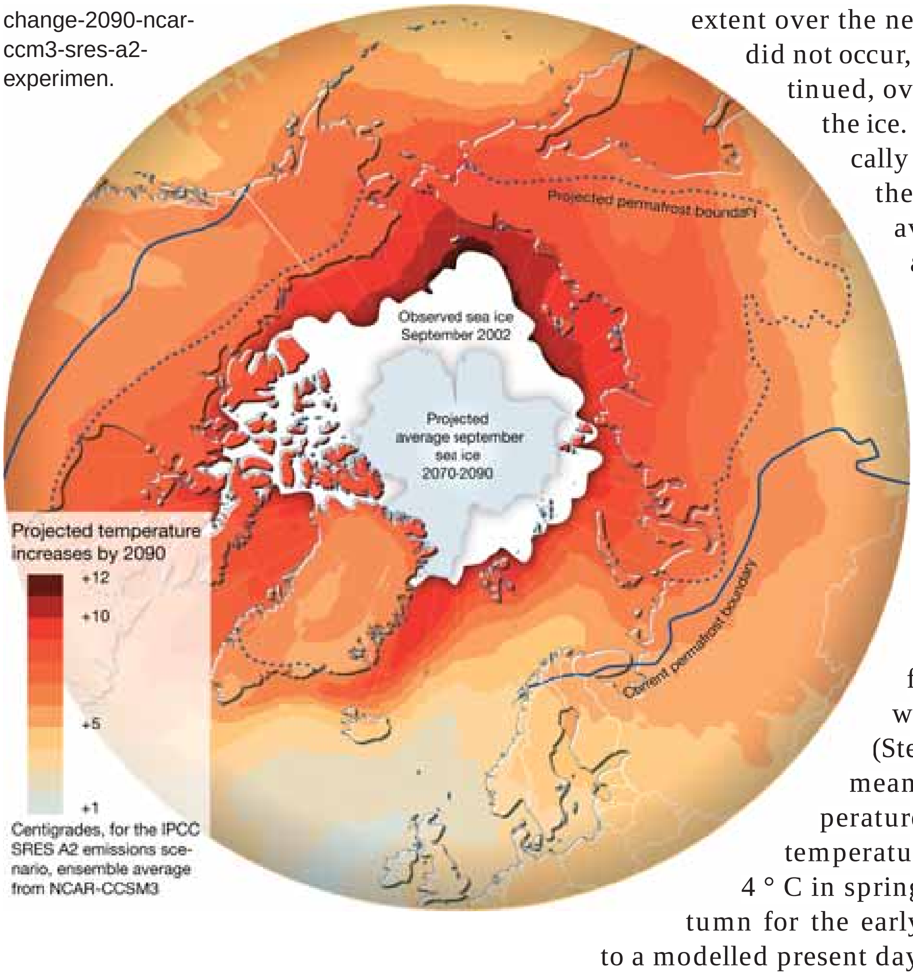


Figure 46. Projected temperature increases in the Arctic due to climate change, 2090 (NCAR-CCM3, SRES A2 experiment). UNEP/GRID-Arendal Maps and Graphics Library 2008. Available at: http://maps.grida.no/go/graphic/projected-temperature-increases-in-the-arctic-due-to-climate-change-2090-ncar-ccm3-sres-a2-experimen.

Based on a regional study using the HIRHAM4 model a clear increase in 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 general 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 a modelled present day situation (1961–1990). For the later period (2051–2080), winter temperature increases accelerate considerably, reaching 7–8 ° C throughout the Arctic and 12° C along the east coast (Figure 46). Precipitation is projected to increase by approx. 8 % by mid-century and by about 20 % towards the end of the 21st century.

8.3 Marine mammals

Vibe (1967) made the first quantitative observations of the impacts of climate change on the distribution and abundance of different types of sea ice and some of their consequences for Arctic marine mammals in the early 1900s. He noted that multi-decadal environmental fluctuations during 1810–1960 influenced the density and distribution of top predators such as eider, ringed seals, polar bears, harp seals, walrus or different whale species (Narwhal, white whale, Greenland whale) in West Greenland.

More recently, inter-annual and intra-annual trends in the ice concentrations and fraction of open water on narwhal wintering grounds have been studied using a 23-year time series of satellite-derived ice conditions between 1978 and 2001 ((Laidre and Heide-Jørgensen 2005). Satellite tracking studies show narwhals arrive on the wintering grounds no later than 10 November (Heide-Jørgensen *et al.* 2002a, 2003a). The results from this analysis suggest that obstruction by sea ice does not influence when or where whales terminate their migration, as the wintering grounds are >60 % open water when whales arrive and begin localised movements.

The interaction between changing climate and distribution of certain fish species has been documented for previous warming period off Greenland with consequences for the abundance of cod and halibut (Horsted 2000, Stein 2007, Drinkwater 2006), and distribution of other species (Jensen 1939, Jensen and Fristrup 1950). Ecosystem changes associated with the warm period during the 1920s and 1930s included a general northward movement of fish. Boreal species, such as cod, haddock and herring expanded farther north while colder water species such as capelin and polar cod retreated northwards. Higher recruitment and growth led to increased biomass of important commercial species (i.e. cod and herring).

During a period of decreasing air and ocean temperatures cod abundance (including cod larvae) in this region declined again (Horsted 2000, Drinkwater 2006). Coinciding with the decrease in cod was an increase in northern shrimp (*Pandalus borealis*) and Greenland halibut (*Reinhardtius hippoglossoides*). Meanwhile, the shrimp fishery has replaced cod as a dominant industry in West Greenland (Hamilton *et al.* 2003).

Jensen (1939) and Tåning (1949) documented changes in many other fish species (e.g. spotted wolffish and herring). Also benthic species such as mussels (*Mytilus edulis*) and common starfish (*Asterias rubens*) spread northward during the warming period. Some of these more temperate species including herring, coalfish and redfish reproduced successfully in areas north of their previous range. On the other hand, colder water species such as capelin no longer migrated as far south along the West Greenland coast and their abundance in southwestern Greenland decreased while it increased northward as far as Thule. Greenland shark (*Somniosus microcephalus*) retreated from the region off south-western Greenland while densities in the colder, more northern regions increased. In north-western Greenland, white whales (*Delphinapterus leucas*) and narwhals (*Monodon monoceros*) arrived earlier and left later on their annual migrations. New immigrants came to Greenland including tusk (*Brosmius brosme*), ling (*Molva vulgaris*), witch (*Pleuronectes cynoglossus*) and the jellyfish *Halopsis ocellata*. It was suggested that most of these new species probably arrived through advection from Iceland (Tåning 1949).

The examples document that the warming period resulted in a clear, radical shift in the abundance and occurrence of certain species with significant impact on community structure and thus functioning of the ecosystem off West Greenland. With the predicted increasing temperatures in the near future, similar changes and effects are likely to occur.

Presently, we do not know what the adaptation capacity of native species is and the extent to which they might be more sensitive to potential impact of oil exposure under these changing environmental conditions. Changes in species composition and occurrence of fish species with relevance for commercial fisheries are likely, resulting in increased fishing activities in the area. This has to be taken into account for future oil exploration activities.

9 Impact assessment

9.1 Methodology and scope

The following assessment is based on available information compiled from studies published in scientific journals and reports, from previous NERI technical reports (e.g. Boertmann *et al.* 1998, Mosbech 2002, Mosbech *et al.* 1996, 1998, 2007a) and information from the oil spill sensitivity atlas prepared for the southernmost part of the region (Mosbech *et al.* 2004). Several studies were initiated specifically for the present assessment (Nielsen et. al. 2008, Blicher *et al.* 2008, 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 covers the area described in the introduction (Figure 1). It is the region which potentially can be impacted by oil exploration related 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 also areas within the Canadian EEZ.

The assessment includes, as far as possible, all activities associated with an oil field, from exploration to decommissioning. Exploration activities will take place in the summer and autumn months due to ice cover in winter and autumn.

Production activities will, if decided upon and initiated, take place throughout the year. How potential production facilities will be constructed is presently not known, but setup is likely to be similar to that described for the Disko West area by the APA (2003) study, *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 ecological 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 (VEC) has been applied.

VECs can be species, populations, 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) and 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 or 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 scale – 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 not known 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 potentially 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 (Skjoldal *et al.* 2007), the extensive literature from 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 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 of the life cycle of a petroleum field.

10.1.1 Assessment of noise

Noise from seismic surveys
The main environmental impacts from the seismic sound generators can potentially 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 the potential impact 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 in an inshore reef did not move away from airgun sounds with peak pressure level 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 about 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, and it is not likely that seismic surveys will take place in the specific Greenland halibut fjords. 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 inshore 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 in the vertical distribution of the fish (Hirst & Rodhouse 2000).

The few studies available on seismic impacts on crustacean fisheries did not find any reduction in catchability (Hirst & Rodhouse 2000, Andriguet-to-Filho 2005, Parry & Gason 2006), why it is likely that the limited shrimp fisheries within the assessment area (Figure 39) will not be affected by seismic surveys.

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 damages. 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 sounds. 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, but occasionally came closer. 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, NMFS 2002, Brewer *et al.* 1993, Hall *et al*, 1994, 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. If alternative areas are available the impact 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 has indicated that humpback whales, which that had been satellite tracked, utilised extensive areas and moved between widely spaced feeding grounds (Dietz *et al.* 2002, Heide-Jørgensen & Laidre 2007); they therefore most likely still would have access to alternative foraging areas if they were displaced from one area by seismic activities.

White whales avoided seismic operation in Arctic Canada by 10-20 km (Lee *et al.* 2005).

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 white whale, narwhal and bowhead whale, and both white whales and bowhead whales are mostly absent from the area when seismic surveys usually are carried out (summer and autumn). There is however a risk of overlap with seismic operations in late autumn. Narwhals have a summer ground in Melville Bay, well-defined migration routes and winter quarters within the assessment area, and there is a risk of displacement from these areas. The summer and autumn grounds are those which may be exposed to seismic noise, whereas the winter quarters are the most critical; however no seismic surveys would take place in winter. Seismic activities are currently regulated in the assessment area in order to minimise overlap with the occurrence of narwhals, see Figure 37 (Mosbech *et al.* 2000a).

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, where 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, walruses (especially when hauled out on ice or land) may be disturbed and displaced by seismic activity and not so much by the siesmic noise.

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 (Tougaard in press). 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 (Figure 37; Mosbech *et al.* 2000a). 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 activities are taking place.

In Arctic Canada a number of mitigation measures were applied to minimise impacts from seismic surveys on marine mammals and the subsistence hunting on 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.* 2009), some important issues to consider when the impacts of a seismic surveys have to be assessed were listed:

- 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 species' annual cycles, e.g. the degree of sensitivity of animals engaged in mating and 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 bowhead whales, narwhals, white whales and walruses. The occurrence of bowhead whale, white whale and walrus do however not usually overlap with the season for seismic surveys and, if they do so it is only for a short period in the late autumn (October / November). However, the there is a risk for overlap

with the narwhal summer grounds in the Melville Bay, but here seismic activities are regulated in order to minimize impacts on the whales (Boertmann *et al*. 2009).

There is also a risk of displacement of other species, such as rorquals from important, if not critical habitat, especially in the southern part of the assessment area.

A temporary displacement will also impact the availability (for hunters) of whales and walrus (and seals) if the habitats include traditionally hunting grounds.

As seismic surveys are temporary, the risk for long-term impacts is low. But long-term impacts have to assessed if several surveys are carried out simultaneously or in the same potentially critical habitats during consecutive years (cumulative effect).

The only fishery which is at risk of impacts from seismic surveys is the Greenland halibut fishery in the southern part of the assessment area. There is a risk of a temporary displacement of fish and consequently reduced catches from the trawling grounds.

Table 5. Overview of potential impacts from a single seismic 2D survey on KANUMAS West VECs. The risk of long-term impacts on commercial fisheries are 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
Ringed seal	no	no	indv.	short term	local	none
Narwhal	pot. large	yes	pop.	short term	local	moderate*
White whale	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

*in Melville Bay

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 water depths 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 and 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).

As described in section 4.6 bowhead whales occur in the assessment area mainly during spring migration. The migration corridor across Baffin Bay seems to be wide enough to provide alternative routes (Figure 27), and displacement of single animals similar to that described from the Beaufort Sea probably has no significant effect here.

Also white whales and walrus will only overlap with the season for exploration drilling for a brief period in autumn, and no effects are expected.

Narwhals on the other hand occur throughout the year in the assessment area (section 4.7.3). Particularly during summer, displacement from critical habitats will be a risk if drilling takes place in the Melville Bay area.

Conclusion on noise from exploration drilling rigs

Exploration activities are temporary, and displacement of marine mammals caused by noise from drilling rigs will also be temporary. The most vulnerable species in the assessment area is narwhal, which occurs in the assessment area also in summer. 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 sea floor 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 gen-

Table 6. Overview of potential noise and discharge impacts from a single exploration drilling on KANUMAS West VECs.

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	no	pop.	short	Local	minor
Bearded seal	Small	no	short	short	Local	minior
Ringed seal	small	no	indv.	short	Local	neglig.
Narwhal	small	yes	pop.	short	Local	pot. major
White whale	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**
Comm. fisheries	small	yes		short	Local	minor
Hunting	small	no		short	Local	minor

eral 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 where 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, though less pronounced than 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 indicated 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 around 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.

Discharges of cuttings with water-based drill fluids are likely to disperse widely in seawater before reaching the benthos and thus may have a greater influence on pelagic organisms such as plankton (Røe & Johnsen 1999, Jensen *et al.* 2006).

More widespread effects on the benthos 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 instead 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 exploratorion 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, the 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 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 the other. 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 is it believed that the environmental impacts from produced water are small due to dilution. For example has the discharges during the 5 % 'off normal time' in Lofoten-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 particularly concern surrounding the hormone-disrupting phenols, the 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 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 the 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 the eggs and larvae of 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.

Table 7. Overview of potential impacts from discharges to the marine environment (primarily produced water) in relation to exploitation activities on KANUMAS West 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*	local	pot. moderate
Zooplankton	pot. large	yes	pop.	long term*	local	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.

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 least affected area 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 almost no knowledge on such sites in the assessment area; although some areas are important for bearded seal, walrus and king eider, which live on benthic mussels and other invertebrates (Figures 16, 21). 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. This is discussed below (section 2.1.1).

Illumination and flaring can attract birds migrating during the night. Under certain weather conditions (e.g. fog and snowy weather) on winter nights, eider ducks are known to be attracted to the light on ships sailing in Greenlandic waters. Occasionally hundreds of eiders are killed on a single ship and not only are eiders killed, but these birds are so heavy that they destroy antennae and other structures on the ships (Boertmann *et al.* 2006). The Greenland authorities have initiated a study to assess the quantitative significance of the current level of these events and the potential for mitigation.

A related problem occurs in the North Sea where millions of song birds cross on their night time autumn and spring migrations. Large numbers of song birds under certain weather conditions are attracted to light from illumination and flaring (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.

Placement of structures will affect the fisheries due to exclusion (safety) zones. These areas, however, are small compared with the total fishable area. A drilling platform with 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 the fisheries are generally estimated 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

Table 8. Overview of potential impacts from placement of structures (footprint) in the marine environment (incl. terrestrial coastal habitats) and on KANUMAS West 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
Ringed seal	small	no	indv.	long term	local	minor
Bearded seal	small	yes	indv.	long term	local	minor
Narwhal	small	no	indv.	long term	local	minor
White whale	small	no	indv.	long term	local	minor
Bowhead whale	pot. large	no	indv.	long term	local	minor
Polar bear	small	yes	indv.	long term	local/reg.	moderate
		Risk of impact on important sites				**Risk of income impacts**
Com. 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.

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).

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 polar bear females. Denning areas are critical to polar bear populations. Dens are apparently very rare in the assessment area and when they occur they are much dispersed 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 on land and in coastal habitats, aesthetic aspects must be considered in a landscape conservation context. The risk of spoiling the impression of pristine wilderness 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 placement 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 in the waters west of for example Upernavik town, the impacts of noise particularly on the migration of narwhals and white whales 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). This will probably not be a problem in the assessment area as the bowheads here are on migration towards their summer grounds. There will also be a risk of displacement of walruses from important feeding grounds.

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, 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

Table 9. Overview of potential impacts from disturbing activities during development and production in the KANUMAS West 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. moderate	yes	pop.	long term	regional	minor
Great cormorant	pot. moderate	yes	pop.	long term	regional	minor
Common eider	pot. moderate	yes	pop.	long term	regional	minor
King eider	pot. large	yes	pop.	long term	regional	moderate
Long-tailed duck	small	yes	indv.	long term	regional	minor
Ivory gull	small	no	indv.	long term.	local	minor
Arctic tern	pot. moderate	yes	pop.	long term	regional	moderate
Thick-billed murre	pot. large	yes	pop.	long term	regional	major
Atlantic puffin	pot. large	yes	pop.	long term	regional	moderate
Little auk	pot. moderate	yes	pop.	long term	regional	moderate
Walrus	pot. large	yes	pop.	long term	regional	major
Ringed seal	small	no	indv.	long term	regional	minor
Bearded seal	pot. large	yes	indv.	long term	regional	moderate
Narwhal	pot. large	yes	pop.	long term	regional	major
White whale	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	small	no				minor
Hunting	pot. large	yes				moderate

the noise; and in this respect white whales, narwhals and walruses which are hunted from motor boats will be expected to be particularly sensitive. 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 ice are sensitive to this activity, and there is risk of displacement of the walruses from critical feeding grounds. Walruses have a narrow foraging niche restricted to the shallow parts of the shelf. Activities in these areas may displace the walruses to suboptimal feeding grounds or to coastal areas where they are more exposed to hunting.

Seabird concentrations are also sensitive to helicopter flyovers. The most sensitive species is thick-billed murre 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). By far the majority of the Greenland breeding population is found within the assessment area (Figure 15). Also concentrations of feeding birds will be sensitive, as they may loose feeding time due to the disturbance.

Concentrations of moulting seaducks occur at several sites along the coasts of the assessment area (Figure 16). 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 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 2003) 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 CO_2 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) and it successor. 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 some 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 instance, 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. 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 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).

Seabird hunting is widespread and intensive in West Greenland and some of the populations have been declining, mainly due to unsustainable harvest. Tightened hunting regulations were introduced in 2001, which was followed by reduced numbers of birds reported to the hunting bag record. In particular, common eider and thick-billed murre colonies in and near the assessment area have decreased in numbers over the past decades. Both species rely on a high adult survival rate, giving the adult birds many seasons 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 (see also Figure 47) (Mosbech 2002). Within the assessment area the breeding colonies of thick-billed murres in the southern part of the former Upernavik municipality have declined considerably and a few have been completely exterminated. Thick-billed murres are particularly vulnerable during the swimming migration, which is performed by flightless adults (due to moult) and chicks still not able to fly (Box 2). This migration was studied in the Disko Bay in 2005 and 2006, and similar studies have been initiated in Qaanaaq in 2007 (Box 2).

10.2.7 Mitigating impacts from development and production

As a consequence of previous experience, e.g. from the North Sea, the Arctic Council in its 2002 guidelines (updated 2008) 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' (Arctic Council, 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):

1. Den concentrations should be indentified.
2. Winter activity should be minimised in suitable or traditional denning areas.
3. If winter activities are unavoidable, they should be around the time when bears naturally enter dens, so they can choose to avoid disturbed areas.
4. 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 hillsides.
5. Activity should avoid known bear dens by at least 1 km.
6. 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 from 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 impacts on the pristine landscape, which again may impact on the local tourism industry.

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 hunted species, because they 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 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.

10.3 Decommissioning

The impacts from decommissioning activities are mainly from noise at the sites and from traffic, assuming that all material and waste are taken out of the assessment area and deposited at a safe site. There will also be a risk of pollution from accidental releases. However, the 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 (Skjoldal *et al.* 2007). The probability of such an event is low, but 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 lack of infrastructure in large parts of the assessment area also contributes to difficulties associated with oil spill response in case of an oil spill, e.g. in the North Water polynya.

According to the AMAP (Skjoldal *et al.* 2007) oil and gas assessment tankers are the main potential spill source. Another potential risk is oil spills 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 (as the KANUMAS 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).

The only known previous oil spill in the assessment area was the result of a tanker accident in Melville Bay in August 1977. The U.S. Navy ship Potomac lost approx. 400 m^3 bunker-C fuel from a ruptured tank at a position of 74° 52’ N, 61° 13’W (Grose *et al.* 1979). An effect study was carried out during the following weeks, and only very slights effects were detected on the biota studied, e.g. ingested oil in 4 % of sampled copepods (*Calanus*) in a single sample (Grose *et al.* 1979).

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 subsea, 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 the ongoing SEA of oil activities in the assessment area, DMI 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 four hypothetical spill events located on the shelf areas in Baffin Bay. They 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 47).

For 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. The five first periods represent a predominant wind from different directions at moderate windspeeds; the sixth period has spells of a strong southerly wind.

A total of 24 one-month oil drift simulations have been carried out: 4 release sites, 3 simulations 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 is calculated. Oil end up on the shore in only three spill scenarios, while the oil remains offshore under all of the selected wind conditions during the other 21 scenarios. No nearshore spills from where the risk of shoreline pollutions is much higher, have been modelled.

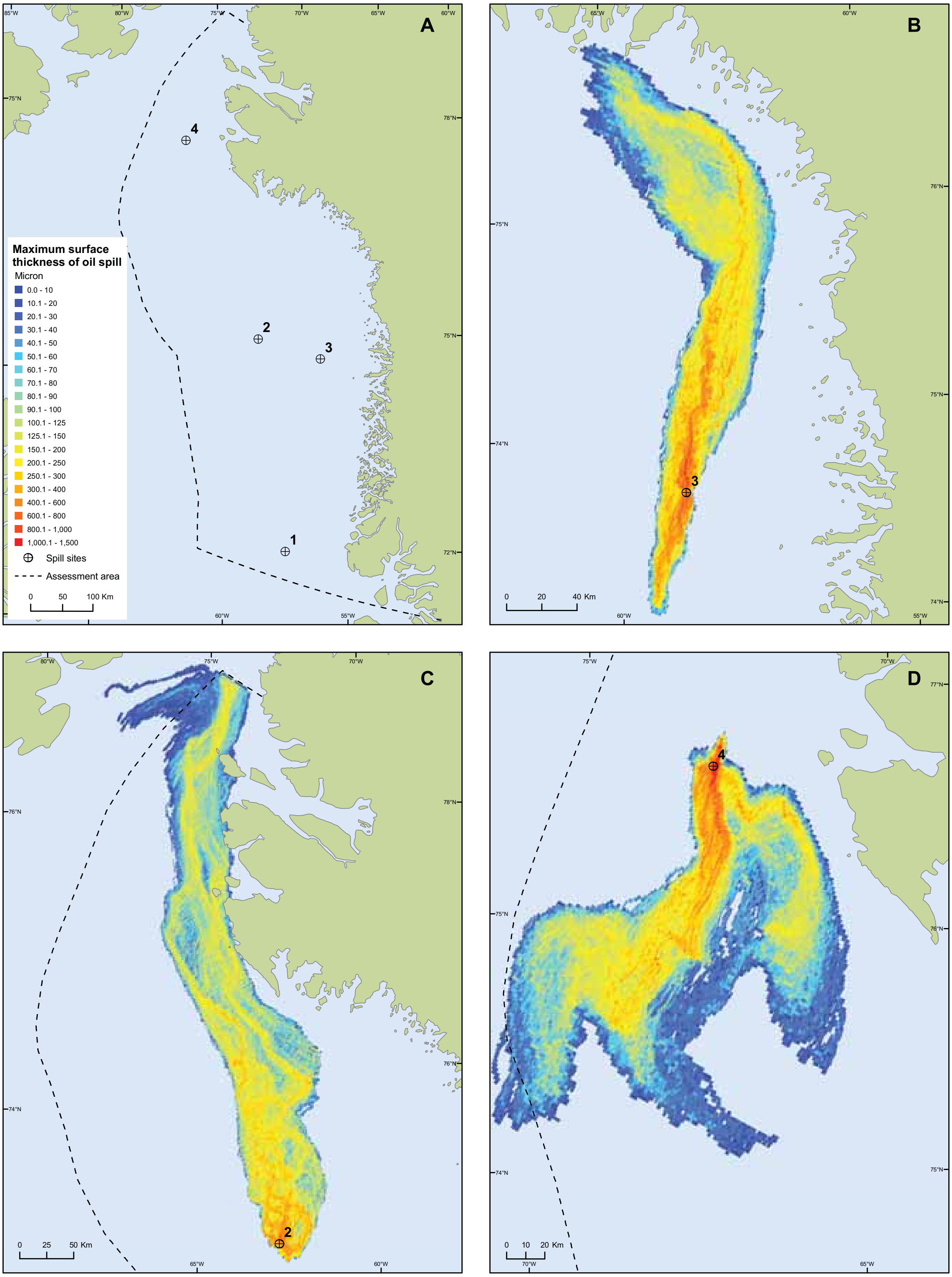


Figure 47. Examples of the DMI oil spill trajectory simulations (Nielsen *et al* 2008). The maps B-D show the entire area swept by three different surface spills. The scale indicates the maximum thickness of the sea surface oil layer attained in the different cells during the 30 day simulation periods. Map A shows the four spill sites. B is a continuous spill from site 3 in August 2004. Map C is a continuous spill from site 2 in April 2005. Map D is a continuous spill from site 4 in October 2004. Note that the oil spill in map C hits the coasts, the spill in map B almost does and that oil spill in map D is 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 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 with reference to the oil spill simulations in southern Baffin Bay (Nielsen *et al.* 2006, Mosbech *et al.* 2007b).

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.

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 incl. larvae of fish and shrimp

Adult fish and shrimp

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, many fish 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. The situation is different in coastal areas, where high and toxic oil concentrations can build up in sheltered bays and fjords resulting in high fish mortality (see below).

Adult shrimps live on and near the bottom in relatively deep waters (100–600 m), where oil concentrations from a surface spill will be very low, if detectable at all. No effects were seen on the shrimp stocks (same species as in Greenland) in Prince William Sound in Alaska after the large oil spill from Exxon Valdez in 1989 (Armstrong *et al.* 1995). Whether a subsea blowout may cause high concentrations in the water column near the shrimp habitats is not known, but a simulation study concluded that high oil concentrations would most likely occur only in a limited area (*cf.* Johansen 1999).

Fish and shrimp larvae

Eggs and larvae of fish and shrimp are more sensitive to oil than adults. Theoretically impacts on fish and shrimp larvae may be significant and reduce the 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 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 2 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 48).

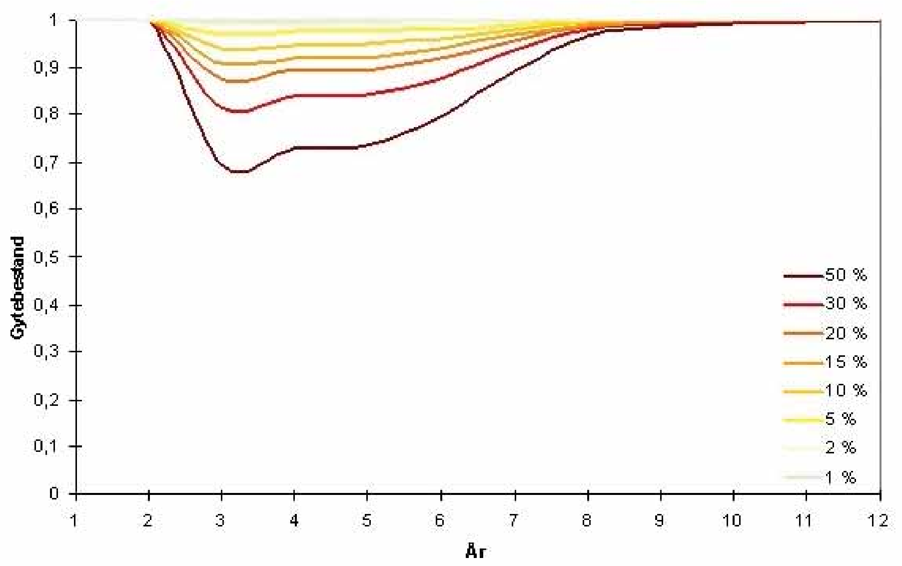


Figure 48. Estimated reduction and recovery in Barents Sea cod spawning biomass following large losses of egg and larvae due to large 'worst case' oil spills. Gydebestand = spawning stock, År = year. Source: Anonymous 2003, Johansen *et al.* 2003.

There is much less knowledge available on concentrations of eggs and larvae from West Greenland and particularly in the assessment area compared to Norwegian waters. However, the highly localised spawning areas with high concentrations of egg and larvae for a whole stock near the surface as seen in the Lofoten-Barents Sea are not documented in Greenland and will not occur in the assessment area. Here the overall picture is that fish larvae are widespread, although occurring in patches which may hold relatively high 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 shrimp and Greenland halibut also are found deeper and would therefore be less exposed to harmful oil concentrations from an oil spill.

The above implies that an oil spill will most likely impact a much smaller proportion of a season's production of eggs and / or larvae for Greenland halibut and northern shrimp than modelled for cod in the Barents Sea, and that impacts on recruitment to Greenland halibut and northern shrimp stocks will most likely be insignificant. However, a subsea blowout may have effects on these 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 spilled under ice will tend to accumulate in the same space, there is a potential risk for overlap and impacts on the recruitment to the polar cod population. Presently, we have no knowledge on possible 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 could have effects up through the trophic web, as polar cod is an ecological 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, 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 may 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 and shrimp larvae are 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 shrimp and 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.

A study of the density and distribution of chlorophyll (as a measure of primary productivity) in the Disko Bay area in spring 2006 (in the Disko West SEIA; Mosbech *et al.* 2007a) indicated large spatial and temporal variability in chlorophyll levels and that high chlorophyll levels (spring bloom) are distributed over large areas. Moreover, areas of high importance for primary production vary both between seasons and between years, depending for example on ice conditions. An oil spill therefore has the potential to impact small and localised primary production sites, while primary production as a whole will only be slightly impacted even during a large spill in open waters.

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 effect (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 break up and melt; weathering processes are inhibited which means that the 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, as in Baffin Bay.

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 capelin, because these fish spawn here and the sensitive eggs and larvae may be exposed to high oil concentrations. Arctic char may be forced to stay in oil-contaminated shallow waters when they assemble before they move up into their 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 occasionally inundated at high water levels. Salt marshes are particularly sensitive and they represent important feeding areas for geese.

The coastal areas of the southernmost part of the assessment area have been mapped and classified according to their sensitivity to oil spills (Mosbech *et al.* 2004).

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 northern shrimp and 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). However, some mussel fishing grounds were closed for more than 18 months after the *Braer* incident.

The offshore fishery for Greenland halibut within the assessment area is very small (annual catch 2006 approx. 600 tonnes) compared to the total for Greenland as a whole (total approx. 35,000 tonnes), so closure of the offshore fishery for a season will only have minor economic consequences, and none on the local communities in the assessment area as they do not participate in the fishery. However, the single fishermen participating in the offshore fishery, will be impacted. The inshore fishery is much more important; approx. 18 % of the total Greenland halibut catch was taken here in 2006. A closure here will have much more severe impacts on local fishing communities.

The tourism industry may be impacted by a large oil spill hitting the coasts. Tourist 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 attributable to their 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 small oil spills in such areas may cause very high mortalities among the birds present. The high concentrations of seabirds found at coasts, e.g. breeding colonies, moulting areas (Figures 14, 15) or in offshore waters at important feeding areas (Box 2) 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 from oiling. To assess this issue, extensive studies of the natural dynamics of the affected populations and the surrounding ecosystem are necessary (Figure 49).

The seabird species 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 year. This very low annual reproductive output is counterbalanced by a very long expected life of 15–20 years or more. These seabirds 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 the 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 former municipalities of Upernavik and Uummannaq, there will be no or only few birds available for re-colonisation of a site.

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.

Several breeding colonies of thick-billed murre are known from the assessment area. They are all situated at or close to the outer coast where they are exposed to oil spills from activities associated with the potential KANUMAS West licences. Moreover, adult birds often feed in concentrations far from the breeding site (Box 2), and also at these areas there is a high risk for contamination of many birds. A further risk situation is when the chicks and flightless adults leave the colony on a swimming migration. The satellite tracking studies of birds from a colony in Qaanaaq and another colony just south of the assessment area showed that these swimming birds move offshore towards the likely licence areas, but that they also disperse over extensive areas (Box 2). The population of thick-billed murres in southern Upernavik is most vulnerable to oil spills as all the colonies here have decreased due to excessive hunting. The colonies in Qaanaaq are not declining, and moreover there are several very large colonies within a relatively small area, increasing the regeneration potential for a colony depleted by an oil spill here.

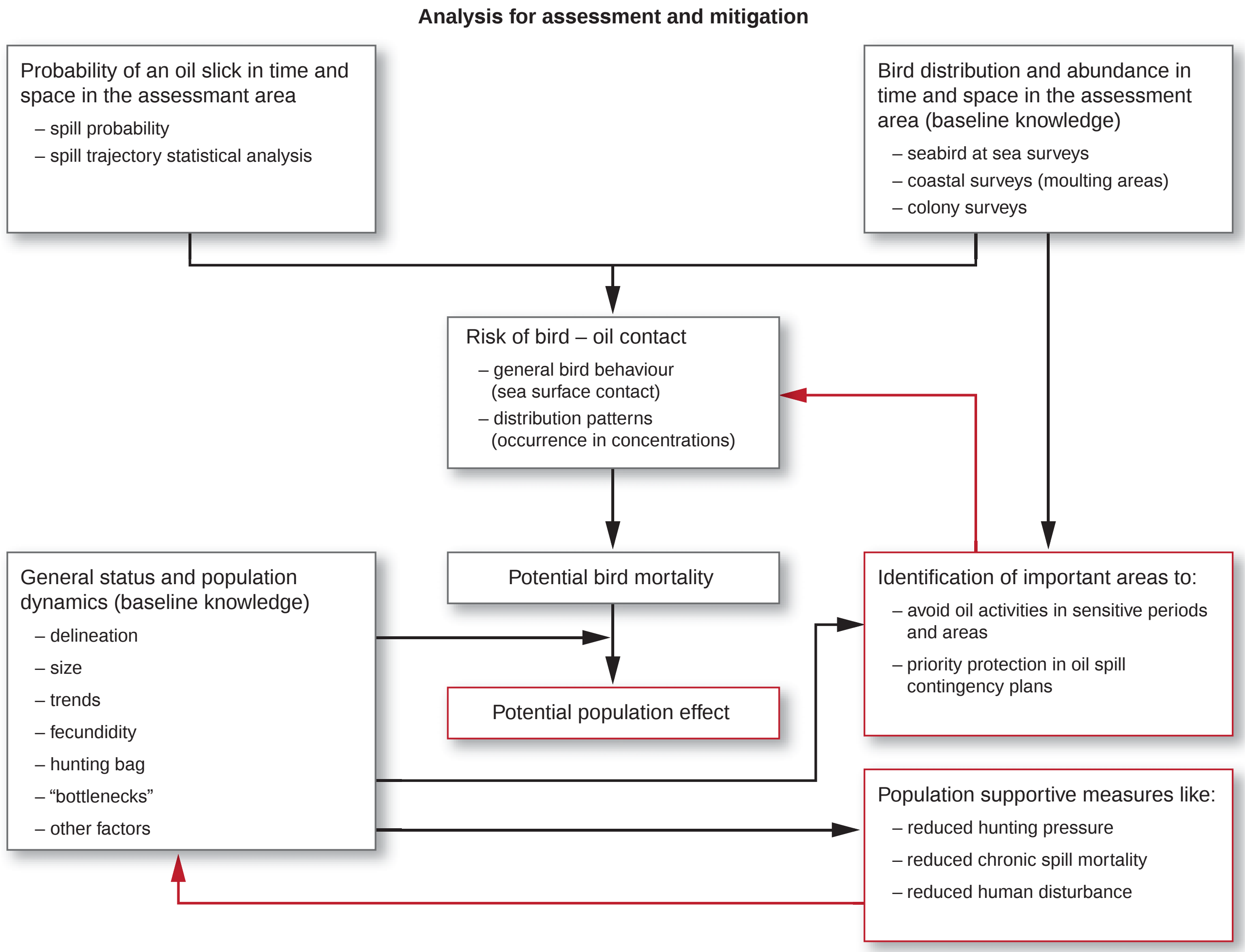


Figure 49. Basic principles of assessing a seabird populations vulnerability to oil spills. Black lines indicate main analysis of effects on bird populations, red lines analysis of potential mitigative measures. Indirect effects not included for simplicity.

There are several other important seabird colonies within the assessment where the population could be severely impacted by oil spills. The most significant are the substantial little auk colonies in Qaanaaq, where millions of birds breed each summer (Figure 15). But also remote bird island as the Sabine Islands in the central Melville Bay are important. These are often almost inaccessible to oil spill response due to their remoteness and the presence of sea ice during a large part of the year.

Moulting areas

There are many areas along the coast with concentrations of moulting seaducks, primarily common and king eiders (Figure 16). These are highly vulnerable to oil spills in the moulting period from mid-July until September.

Migration concentrations

Large numbers of thick-billed murres have been located south of the assessment area in April / May (Mosbech *et al.* 2007a). These birds most likely proceed northwards through the assessment area to breeding sites in Upernavik and perhaps further north. Such concentrations are particularly vulnerable to oil spills because they will rest and stage in the restricted (by ice) open-water area, where oil also will tend to accumulate in case of a spill.

The considerable numbers of seabirds migrating through the Baffin Bay in autumn (Figure 17) are also very vulnerable to oil spills, and significant numbers may be affected by a large oil spill.

Some of the bird populations which utilise the assessment area are particularly important and vulnerable: these include the king eiders moulting in the late summer and autumn, the thick-billed murres, little auks, razorbills, great cormorants, Atlantic puffins, common eiders, etc breeding in colonies holding significant proportions of the entire population. A large oil spill has the potential to severely deplete such assemblages of seabirds, which in the case of the little auk, for instance, could amount to millions of birds. Small and localised breeding colonies may be wiped out, and Atlantic puffin and razorbill are the most vulnerable in this respect. Healthy seabird populations will have a recovery potential, but if they are impacted by other anthropogenic factors such as hunting, by-catch or chronic oil spills in their winter quarters, recovery can be impaired.

11.2.7 Oil spill impacts on marine mammals

Marine mammals are generally less sensitive to oiling than many other organisms, because individuals (except polar bears) are rather robust in response to fouling and contact with oil. 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 the toxic effects and injuries 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.

Marine mammals species affected by an oil spill during winter and spring could include walrus, bearded seal, bowhead whale, narwhal, white whale and polar bear. Of these, walrus, white whale and narwhal are especially vulnerable because their populations are declining due to unsustainable harvest. The bowhead whale may also be considered as vulnerable because the population is very small and the survival of single individuals is crucial for the recovery of the population.

There is a special issue regarding the whale populations occurring in the assessment area in winter / early-spring. Preliminary evidence indicates that the assessment area is the primary feeding ground (on an annual basis) for narwhals and perhaps also white whales and bowhead whales (although these two are more transient in the area, wintering further south). Survival of these populations can therefore be dependent on the rich food resources in the assessment area. Consequently, oil spill effects on these food resources may have implications for the survival of the whale populations (Laidre *et al.* 2008).

Polar bears are particularly sensitive to oil spills. 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 displayed lower survival, their mortality rate was 22 % instead of 16 %; their body mass was smaller; 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 West Greenland have the same morphology as the coasts of Prince William Sound, where oil was trapped This indicates that similar long-term impacts must be expected in the assessment area if spilled oil strands on the coasts. The high Arctic conditions in the assessment area may even prolong the impact period compared to 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 through their diet (e.g. fishes and crustaceans) (Alonso-Alvarez *et al.* 2007, Perez 2008).

Table 11. Overview of potential impacts from a large oil spill in the KANUMAS West 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
Ivory gull	large	yes	pop.	long term	local	major
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
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
White whale	large	yes	indv.	short term	regional	minor
Bowhead whale	large	yes	indv.	long term	regional	minor
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		short	local	moderate
Tourism	large	yes		long term	regional	moderate

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 47).

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.

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 may 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 mainly depending on fish species. It is assessed that potential impacts of seismic activity on the commercially utilised Greenland halibut populations will be low and temporary and that shrimp distribution will not be affected by seismic activities.

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 must be expected. The main species concerned are narwhal, white whale and bowhead whale during autumn, winter and spring, but also narwhal and rorquals during summer. Walrus and bearded seals may also be displaced from areas where drilling activity taking place. There is therefore a risk of displacing populations from critical feeding grounds and also a risk for reduced availability of quarry 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). Walrus and whales, particularly narwhal, white whale and bowhead whale are sensitive in this respect and may be permanently scared away from specific habitats. This could also impact hunters if quarry species are scared away from traditionally hunting grounds.

Intensive helicopter flying also has the potential to displace seabirds and marine mammals from habitats (e.g. feeding grounds important for winter survival) as well as traditional hunting grounds, impacting on local people.

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 of 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 the 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 more than twice the total Greenland CO_2 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 aesthetical 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 comprised by 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 assessment area, as large and obvious industrial installation will compromise the impression of unspoilt Arctic wilderness, which is the main asset to tourist operators.

Cumulative impacts are a 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 environment terms would be a large oil spill. This has the potential to impact on all levels in the marine ecosystem from primary production to the top predators and the 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 in the major part of the year. Ice may protect coasts and it can also trap, conserve and transport oil over long distances. It 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 Oil and Gas assessment concludes 'that a large oil spill in ice-covered waters could represent a threat to populations and even to species' (Skjoldal *et al.* 2007).

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 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 / shrimp 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 spawning concentrations of capelin in spring, Arctic char assembling outside their spawning rivers, and many seabird populations both in summer and migration periods, with potential to 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 possible 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 highly 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 there is 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, in the assessment area there are some very concentrated and recurrent seabird occurrences in polynyas and in the shear zone. Such concentrations are extremely sensitive to oil spills and population effects may occur in case of oil in one of these open-water habitats in spring. The most vulnerable species are the thick-billed murre and the little auk. Several nationally red-listed species occur in the marine environment and will be exposed to potential oil spills. The little auk is a moreover a national responsibility species, because a vast majority of the world population is found within the assessment area, where a major oil spill could seriously affect the viability of the species.

Among the marine mammals the polar bear is sensitive to oiling, and several individuals may become fouled with oil in case of a large oil spill in the marginal ice zone. The impact of an oil spill may add to the general decrease expected for the polar bear stocks (therefore redlisted both nationally and internationally) as a consequence of reduced ice cover (global warming) and heavy hunting pressure.

Whales, seals and walruses are also vulnerable to oil spills, particularly if they have to surface in oil slicks. Baleen whales may get their baleens smothered with oil and ingest oil. The extent to which marine mammals actively will avoid an oil slick and also how harmful the oil will be to fouled individuals is not known. White whales, narwhals, bowhead whales and walruses are especially sensitive because they all have small or declining populations. These species are also listed on the Greenland Red List. Effects from oil spills (and disturbance) may therefore have disproportionably high impacts on the populations.

The assessment area is probably particularly important to many of whales because it appears to be where they their main food intake takes place (on an annual basis). Effects from oil spills (and disturbance) may therefore have disproportionably high impacts on the populations.

Recent studies indicate that whales and seals are very sensitive to inhaling oil vapours, and this may particularly apply to narwhals, white whales and bowhead whales during winter when the availability of open waters is limited by the sea ice. Walruses and other seals living in the ice may also be vulnerable to this impact.

There is also a risk of 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 oil spill mortality can to some extent be compensatory, while for others it will be largely addititive to natural mortality. 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 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 of quarry species.

An oil spill in the open sea will affect fisheries mainly by means of temporary closure in order to avoid contamination of catches. Closure time will depend on the duration of the oil spill, weather, etc. The offshore fishery for Greenland halibut is however small and a closure will only have minor economic impacts. The northern shrimp fishery is presently also very small and similar small economic consequences are expected in case of closure.

Oiled coastal areas would also be closed for fisheries for a period – the duration of the closure would depend on the behaviour of the oil. There are examples of closure for many months due to oil spills, particularly if oil is caught in sediments or on beaches. The inshore fishery for Greenland halibut is important on a national scale and closing these fishing areas will have economic consequences for the fishery.

The tourist industry in the assessment area will probably also be impacted negatively by a large oil spill.

Long-term effects of 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 (November–March/April)

This is the season when ice covers most of the assessment area, except for polynyas and the shear zone off the Greenland coast, where more or less open waters are present. Narwhals, white whales, bowhead whales, walrus, ringed seals and bearded seals are in these open-water areas. Polar bears walk over the sea ice and swim across open water in search of seals. These marine mammals are highly dependent on the open-water areas and sensitive to disturbance and highly exposed to oil spills.

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.

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 50 shows a preliminary, regional designation of particularly important and sensitive winter areas in the assessment area.

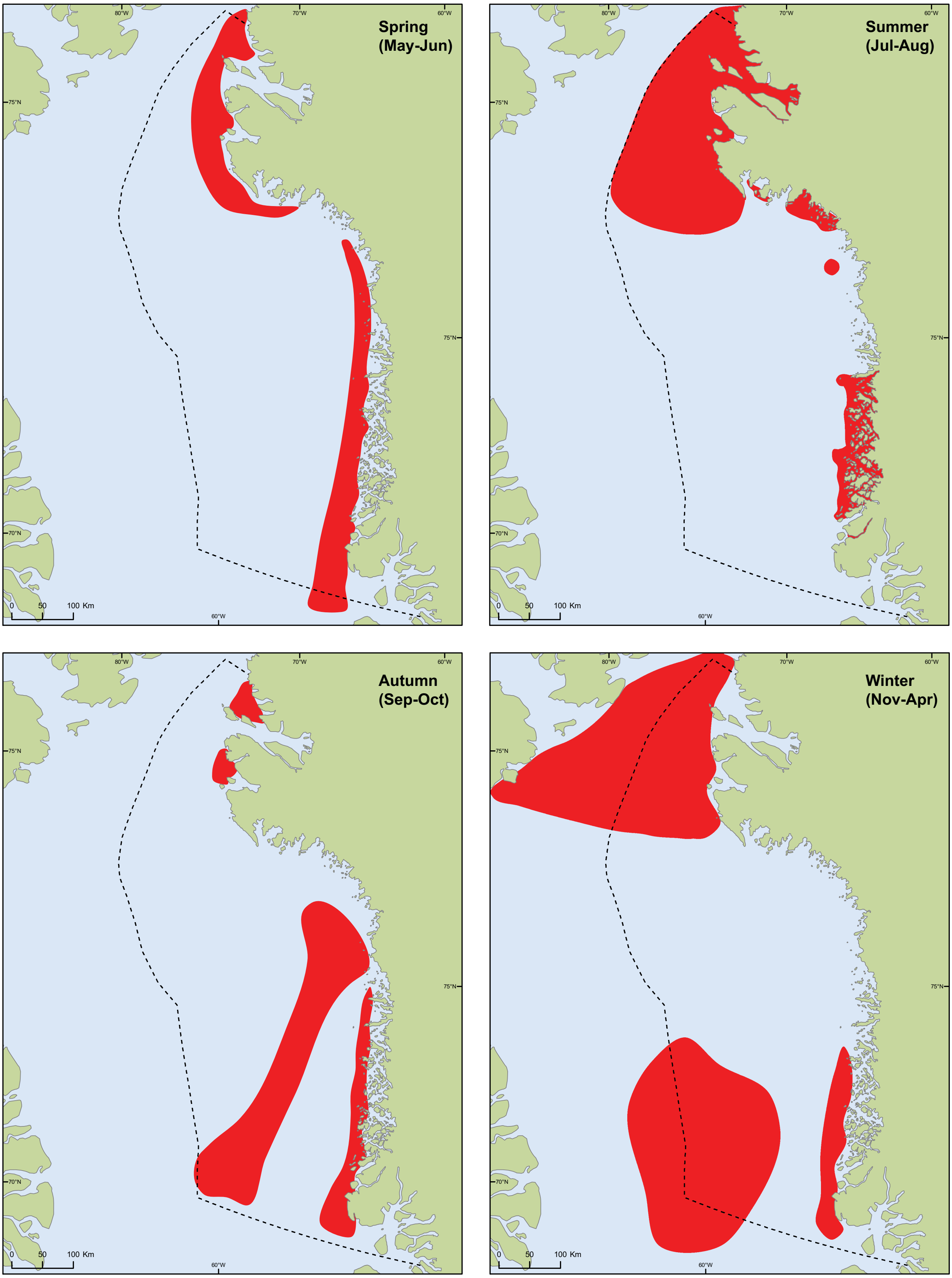


Figure 50. A preliminary designation of the most oil spill sensitive areas in the assessment area. The background data for this designation is not always adequate and future analyses may change the number, extend and placement of the areas, particularly when all data from the associated projects have been analysed.

12.4.2 Spring (April/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 giving access to open waters.

The spring bloom is initiated in these open waters, and many seabirds assemble in the open waters along the fast-ice edges and other open waters, especially close to the large breeding colonies. Bowhead whales, white whales, narwhals, walrus, ringed seals and bearded seals move northwards in the leads and cracks which opens. As open water becomes available; rorquals, harp seals and hooded seals move in from the south.

At the coasts of the southern part large schools of capelin spawn in the intertidal zone

Figure 50 shows a preliminary, regional designation of particularly important and sensitive spring areas in the assessment area.

12.4.3 Summer July–August

This is the open-water season, when the assessment area usually is ice free except for icebergs.

Seabirds occur at the many breeding colonies, often in large concentrations and they feed throughout the offshore part of the assessment area, often in large concentrations. Bowhead whales, white whales, walrus and several narwhal stocks leave the assessment area following the ice towards Smith Sound and Arctic Canada. Other narwhals assemble in the interior parts of Melville Bay and in Inglefield Bredning. Rorquals feed in the southern and central parts of the assessment area.

Arctic char assemble at the river mouths before moving into the freshwater spawning and wintering grounds.

Figure 50 shows a preliminary, regional designation of particularly important and sensitive summer areas in the assessment area.

12.4.4 Autumn September–October

Seabirds move southwards from the large breeding colonies and may occur in concentrations far offshore. Narwhals and white whales move southwards, the white whales often close to the coast. Rorquals retreat south out of the assessment area.

Figure 50 shows a preliminary, regional designation of particularly important and sensitive autumn areas in the assessment area.

13 Ongoing studies

To support this SEIA a number of background studies have been initiated. They are still in progress and will be completed in 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 West area.

It should be noted that the ecology of the assessment area is dependent on several biophysical factors (e. g. hydrograhphy, currents) that are manifested on a larger geographical scale. Thus 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 a hydrodynamic model and oil spill trajectories (by DMI)
Report finished in 2008 (Nielsen *et al.* 2008).

An evaluation of oil spills in the Baffin Bay ice (by SL Ross, Canada)
Report finished in 2008 (SL Ross 2008).

Thick-billed murre, breeding biology and migration pathways
This aim of this project is to document the migration patterns and as far as possible identify important staging areas for thick-billed murres, between the breeding sites in Northwest Greenland, through Baffin Bay to the winter quarters in Davis Strait and off Labrador / Newfoundland. This will be carried out by equipping birds with satellite transmitters and data loggers (to be retrieved after a full season away from the breeding site). Furthermore, information on breeding biology, colony attendance and information on other breeding seabirds will be collected. The project was initiated in the field season of 2007 and continued into 2008. Preliminary results are presented in Box 1. The project will be finalised in 2009.

Benthos in ecological key areas in Northwest Greenland
The shallow coastal areas of the Arctic seas are highly productive and extremely important to the marine food web. The benthic fauna in coastal areas is characterised by high diversity and biomass combined with an abundance of very old individuals. The long life span of several species and their slow growth makes the benthic community particularly vulnerable. The benthos in general and bivalves in particular constitute an important food source for fish, birds and marine mammals. In order to gather information on biodiversity, community structure and identify key species a benthic survey was performed in August 2008. The study on the benthic community was linked to areas that are ecologically important to higher trophic levels and attract high concentrations of sea birds and / or mammals. During the cruise a larger set of benthic samples was taken. In the coming months these samples will be analysed. Species diversity will be estimated as well as biomass, and key species will be identified. During the field study, the microbial activity of the sediment was also measured and bioturbation of the fauna will be quantified for selected stations. In addition, samples have been taken for later chemical analysis of the

hydrocarbon content in the sediments. Preliminary results are shown in Figures 12 and 13. The project will be completed in 2010.

White whale migration and habitat use in the assessment area

White whales pass through Baffin Bay on their autumn migration from the Canadian High Arctic archipelago to their wintering grounds in West Greenland. The routes and timing of this migration are known primarily from records of coastal subsistence hunting. However, few details are available on exact routes, variability and sex or age differences in timing, or corridor use. White whales are sensitive to underwater noise pollution. Gaining insight into the timing of their migration across northern Baffin Bay will allow a better mitigation of the effects of oil activities. White whales overwinter in the highly mobile pack ice on the banks of West Greenland. Disturbance from underwater noise may divert these whales away from their critical winter feeding grounds. The effects of disturbance are unknown but could be severe, given that the whales have few other options for wintering areas than the open-water microhabitats. The surrounding areas are completely covered with dense pack ice, a poor habitat for white whales and sites where they endure high risk of ice entrapment.

The major part of the annual food intake for white whales occurs during winter on the banks of West Greenland, areas they share with a number of other species (e.g. walrus, bearded seal, bowhead whale, common eider, king eider and guillemots). The High Arctic summering grounds in North Canada are less productive and are primarily of importance for moult of the white whales. Thus, anthropogenic disturbance in this winter feeding site may impact survival, body condition, and reproductive success. Given this risk it is important to quantify the potential conflicts between white whales and oil activities to reduce the negative effects on the population. This project will study the migration and habitat selection of white whales in West Greenland using satellite telemetry. Important habitat variables like sea-ice coverage, bathymetry and food resources will be included in a statistical treatment of habitat selection for white whales.

The plan was to catch ten white whales in West Greenland and tag them with satellite transmitters. Catch was attempted in November 2007 and April 2008 without results. Fieldwork is planned again for November 2008 and April 2009.

14 Data gaps identified during the preparation of the SEIA

There is a general lack of knowledge on many of the ecological components and processes in the KANUMAS West 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 (Skjoldal *et al.* 2007), and it is hoped that international research will be initiated. A more extensive 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

Benthos
Information on diversity, biomass and distribution is missing for larger parts of the offshore areas

Fish
Polar cod, biology, concentration areas, importance

Birds
Seabird breeding colonies in the Melville Bay area

Spring concentration areas in the shear zone

Migration pathways of little auks breeding in the former Qaanaaq Municipality

Marine mammals
Year-round seasonal occupancy, distribution and abundance of whales

Relationship of polar bears and sea ice in Baffin Bay

Stock identity and movements of narwhal

Whale (in particularly narwhal) reactions to seismic noise

Stock identity and movements of walrus

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

PAH levels in the environment

Biological effects of PAHs on key species under Arctic conditions

Produced water

Behaviour and toxicity of produced water in ice-covered waters

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