

Environmental Oil Spill Sensitivity Atlas

for the

West Greenland Coastal Zone

CD-version

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Data sheet

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| Abstract: | <p>This oil spill sensitivity atlas covers the shoreline and the offshore areas of West Greenland between 62° N and 68° N. The coastal zone are divided into more than 250 areas, and the offshore zone into 12 areas. For each area, a sensitivity index value is calculated and each area is subsequently ranked according to four degrees of sensitivity. Besides this general ranking, a number of smaller sites are especially selected as they are of particular significance, they are particularly vulnerable to oil spills and because an effective oil spill response can be performed. The shoreline sensitivity ranking are shown on 34 maps (in scale 1:250,000), which also show the different elements included. These maps also show the selected areas. Coast types logistics and proposed response methods along the coasts are shown on another 34 maps. The sensitivities of the offshore zones are depicted on 4 maps, one for each season. Based on all the information, appropriate oil spill response methods have been assessed for each area.</p> |
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Ministry of Environment and Energy

Bureau of Minerals and Petroleum
Government of Greenland

2 Preface

This Atlas was produced as a part of the preparations for exploratory drilling offshore Greenland. The Danish Energy Agency (DEA) initiated the Atlas in consultation with the Government of Greenland's Bureau of Minerals and Petroleum (BMP). A study team consisting of Danish and Greenlandic institutions and two Canadian companies was put together to prepare the Atlas.

The National Environmental Research Institute, Department of Arctic Environment (NERI-AE) was designated as prime contractor responsible for co-ordinating, editing and producing the Atlas.

NERI further provided the biological information in the Atlas, and prepared the shoreline and offshore sensitivity maps.

The Geological Survey of Denmark and Greenland (GEUS) prepared the coastal morphology maps and the basic map layout. GEUS also developed a CD presentation solution and an Internet version of the Atlas.

The Institute of Geography, University of Copenhagen, was responsible for shoreline morphology classification based on air photo interpretation.

AXYS Environmental Consulting Ltd. provided consultancy on their existing sensitivity model, and developed the software of the Greenland Oil-spill Sensitivity Application. This application was used to generate shoreline and offshore sensitivity scores and supported the development of the Atlas.

SL Ross Environmental Research Ltd. developed the sections on countermeasures, access and safe havens on the Physical Environment and Logistics maps.

The Danish Meteorological Institute (DMI) reviewed and compiled data regarding ice, oceanography and climate, mainly the chapters 8.1 (part), 8.4, 8.5, 8.6, 8.7 and Appendix C.

The Greenland National Museum and The Greenland Secretariat of the Danish National Museum compiled and reviewed the archaeological information.

The Greenland Institute of Natural Resources (GINR) contributed with information regarding living resources (fish, shellfish, birds and whales) and their use in Greenland, and the Greenland Ministry of Environment and Nature supplied information and commented on an early draft of the Atlas.

A draft version of the Atlas was presented at community consultations in April 2000 in Nuuk, Paamiut, Qeqertarsuatsiaq (Fiskenæsset), Atammik, Napasoq, Maniitsoq, Kangaamiut, and Sisimiut. We thank the residents here for constructive participation.

The Study Team

Anders Mosbech (NERI) headed the study team producing the Atlas, and the team consisted of (in alphabetic order):

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The team conducting the community consultations consisted of Anders Mosbech and Søren Nielsen (NERI), and Kennet Larsen and Johannes Kyed (BMP).

The Steering Group

A steering group for the Atlas project was headed by Uffe Danvold (DEA) and consisted of Joe Nazareth (DEA), Uffe Strandkjær (DEA), Finn Frøstrup (DEA), Kennet M. Larsen (BMP), Poul Johansen (NERI) and Anders Mosbech (NERI).

The Danish Energy Agency funded the Atlas project.

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Photos of shore types Fig. 7.1-13 by NERI-AM.

3 Summary

Environmental Oil Spill Sensitivity Atlas for the West Greenland Coastal Zone

This Atlas was produced as a part of the preparations for exploratory drilling offshore Greenland. The objective of the project is to produce an overview of resources vulnerable to oil spills, for example biological resources (fish, birds etc.), and a tool to respond to an oil spill. The project covers the region between 62° N and 68° N in West Greenland.

The following elements are included in the project

- coast types,
- oceanography, ice and climate,
- biological resources (fish, birds etc.),
- fishing and hunting,
- selected areas (e.g. seabird breeding colonies),
- archaeological sites,
- logistics and oil spill response methods.

As the oil spill sensitive resources are very different in character (e.g. seabird breeding colonies, important fishing areas, and archaeological sites), it has been common practice to calculate an index value of the sensitivity of a specific area, in order to compare areas with different characteristics. The index calculations are based on a Canadian system, which has been used in Lancaster Sound. An overview of the methods used in the Atlas is given in Chapter 6.

The coastline is divided into areas (coastlines and groups of islands) approx. 50 km long. Each area has been ranked in one of four degrees of sensitivity based on the index calculation that includes abundance and sensitivity of a number of environmental or community elements (e.g. different birds and marine mammals, hunting areas, and archaeological sites).

Besides the general classification of coastal sensitivity, the maps of the Atlas also show smaller selected areas. They have been selected as being of particular significance, particularly vulnerable to oil spills, and as being of a size where an effective oil spill response can be performed.

As a part of the project, classification of the coastline morphology has been conducted from aerial photographs, e.g. the occurrence of rocky shores and beaches. An index value of the self-cleaning ability of the coast after an oil spill has been calculated, based on this classification in combination with shoreline exposure to waves and ice. For example, oil on a rocky coast exposed to wave action will be cleaned faster than oil on a beach in a protected lagoon.

Based on all the information, appropriate methods to respond to oil spills in the different areas have been assessed.

Chapter 8 in the Atlas contains overview information, primarily in 1: 3.5 million scale maps, and Chapter 9 contains detailed information in 1: 250,000 scale maps. Chapter 7 is a users guide common to Chapter 8 and 9.

Chapter 8 contains maps showing the sensitivity of the offshore areas and with each of the elements used in the classification (fishing areas, fish, birds, and marine mammals). A number of maps show ice conditions and the most important biological resources and their use, e.g. deep sea shrimp and Greenland halibut.

Chapter 9 contains 34 maps in the scale 1: 250,000 showing index values for coastal sensitivity and symbols for the elements of the classification (hunting and fishing areas, fish, birds, marine mammals and archaeological sites). The maps also show the selected areas. Each map has a description of biological resources and human use of the area.

Chapter 9 also contains 34 maps showing coast types, logistics, and proposed methods to oil spill response for each area.

A community consultation phase was carried out during the project. A draft version of the Atlas was presented and discussed with local communities and user organizations in April 2000, and new information was incorporated.

The Danish Energy Agency initiated the Atlas in consultation with the Government of Greenland's Bureau of Minerals and Petroleum.

The project was carried out by the National Environmental Research Institute, the Geological Survey of Denmark and Greenland, the Greenland Institute of Natural Resources, the University of Copenhagen (Institute of Geography), the Greenland National Museum, The Greenland Secretariat of the Danish National Museum, Danish Meteorological Institute, AXYS Environmental Consulting Ltd. and SL Ross Environmental Research Ltd.

4 Eqikkaaneq

Kitaata imartai kangerluilu - Uuliaarluernermi piffiit immikkut sunnertiasut pillugit atlassi

Ukioq 2000-ip aasaanerani uuliasioqatigiiffik Statoil Kitaani Fyllap imartaata kitaani uuliamik/gassimik ujarlerluni qillerissaaq. Kalaallit Nunaanni 1977-mili imaani qillerisoqaaqarmat qillerinerit taanna siullersarissavaat. Avatangiisinut sunniuteqarlussinnaasut annersaraat qillerisoqartillugu uuliaarluerujussuarneq, uulialu aqunneqarsinnaanngitsumik imaanut siaruaappat. Taamatulli pisoqarsinnaanerata ilimanassusaa anikitsuararsuuvoq.

Pilersaarusiornermut atatillugu pisortat una atlassi pilersissimavaat. Suliap siunertaraa uuliaarluernermi pinngortitami sunnertiasut tamakkerlugit suunerisa nalunaarsorneqarnissaat. Tamakku ilagaat uumasut (aalisakkat, timmissat il.il.) kiisalu aalisarnermut piniarnermillu soqutigisaqatigiinnut attuumassuteqartut. Uuliaarluertoqartillugu suut siulliullugit illersortariaqarnersut aalajangiisoqartariaqalernissaa pisariaqalissappat uuliasioqatigiiffik pisortallu ilisimasat nalunaarsorneqarsimasut tunngavigalugit siumut nalilersuisinnaapput. Suliap Kitaata kujataani allorniusat sanimukaartut 62⁰ aamma 68⁰ N akornanni ingerlanneqarsimavoq.

Suliami immikkoortut maku ilaapput

- sinerissap ilusaanik allaaserisat
- imaq, siku silalu
- uumasut pisuussutit (timmissat, aalisakkat il.il.)
- piffiit immikkut illersorneqartut (soorlu timmissat inaat)
- itsarnitsat eriagisariaqartut
- angallannermut tunngasut uuliaarluernermillu akiueriaatsit

Pisuussutit assigiinngeqisunik pissuseqarmata (soorlu timmissat ineqarfii, aalisarfiit pingaartut itsarnitsallu eriagisariaqartut), nunani allani nalinginnaavoq piffiup ataatsip qanoq sunnertiatiginaera kisitsinngorlugi nalilersuisarneq, taamaalilluni piffiit assigiingitsut imminnut assersuunneqarsinnaanngorlugit pingaarnertitallu tullerriaarneqarsinnaanngorlugit. Tamanna siunertaralugu nalilersuerialaatsit assigiinngitsut inerisarneqarsimapput. Suliami uani canadamiut nalilersuerialaasiat aallaaviuvoq, taannalu Canadap kangiata avannaani Lancaster Sound-imi aamma atorneqarsimavoq.

Sineriak immikkoortunut 50 km-rit missiliorlugit isorartutigisunut agguarneqarsimavoq malussarissutsinullu immikkoortunut sisamanut agguarneqarsimallutik. Immikkoortiterneranullu atatillugu qanoq sunnertiatiginerisa nalilersorneranni avatangiisinut inuiaqatigiinnullu tunngassuteqartut ilanngunneqarsimapput (timmissat imaanilu uumasut miluumasut eqimattat assigiinngitsut, piniarfiit, aalisarfiit, itsarnitsanik eriagisariaqartut il. il.). Tamakku ataasiakkaat uuliaarluernermut qanoq sunnertiatiginerat, kiisalu immikkoortut ataasiakkaat qanoq amerlatiginerat/pingartiginerallu nalilerneqarsimalluni. Umaasut immikkuutaartut uuliaarluernermut malussarissusaa taakku uuliaarluertoqartillugu uuliamik sunnerneqarsinnaanerata ilimanassusaa uuliamullu malussaritsiginerat tunngavigalugu nalilerneqarsimavoq. Uumasut immikkoortut taakkulu atorneqarnerat immikkoortut ataatsimut katillugit malussaritsiginerata naatsorsorneqarnerani pingaartinneqarnerpaasimavoq.

Sineriak tamakkerlugu piffiit annertungaatsiartut malussaritsiginerisa nalinginnaq nalilersorneqarnerisa saniatigut nunap assingini piffiit minnerusut immikkut toqqarneqarsimasut nalunaarsorneqarsimapput. Piffiit tamakku immikkut naleqassusaat, uuliaarluernermit immikkut malussarissusaat kiisalu annertussusaat naapertorlugu uuliaarluertoqartillugu pitsaasumik siaruatsaaliorsinnaanerit tunngavigalu immikkoortinneqarsimapput.

Suliamut atatillugu timmisartumit assiliasat tunngavigalugit sinerissat nalunaarsorneqarsimapput (ilusaat sunillu sananeqaateqarnerat, soorlu qaarsoqarfiunersut sioraqarfiusulluunniit). Ilisimasaq taanna aallaavigalugu aammalu mallinut sikunullu qanoq sunnerneqartigisarnerat tunngavigalugu uuliaarluernermit imminut salissinnaassusaat kisitsisinngorlugu nalilerneqarsimavoq. Soorlu sineriak qaarsorisoq mallinit sunnerneqartuortoq sissamat kangerliumanermit oqquartamiittumut naleqqiullugu uuliamik sukkanerusumik akuiarneqartarpoq.

Paasisat katersorneqarsimasut tunngavigalugit piffinni assigiinngitsuni uuliaarluernermit siaruatsaalioriaatsit naleqquttut nalilersorneqarsimapput.

Atlassi aamma nassuiaatinik immikkoortortaqqarpoq (kapitali 8), nunap assinganut uuttuut 1:3.5 million tunngavigalugu nalunaarsorneqarsimasunik kiisalu sukumiinerusumik nassuiaatalimik immikkoortortaqqarpoq (kapitali 9) nunap assinganut uuttuut 1:250.000 tunngavigalugu nalunaarsorneqarsimasunik. Kapitali 7 kapitalit 8-mi 9-milu nunap assingisa atomissaannut ataatsimut ilitersuummik imaqqarpoq.

Kapitali 8 nunap assinginik imaani piffiit sunnertiatigineri tunngavigalugit immikkoortut ataasiakkaat ilisarnaataannik nalunaaqutserneqarsimasunik (aalisartarfiit, aalisakkat, timmissat imarmiullu miluumasut) imaqqarpoq. Taassuma saniatigut piffiup sikosarneranut tunngasunik nunap asseqarpoq kiisalu uumasut pisuussutit arlallit sumiissusaat taakkulu atorneqarneri nalunaarsorneqarsimallutik, soorlu kinguppaat qalerallillu.

Kapitali 9 nunap assinginik uuttut 1:250.000 tunngavigalugu sananeqarsimasunik 34-nik imaqqarpoq taakkunanilu sinerissat sunnertiatiginerat nalilerneqarsimavoq sumullu atorneqartarnera ilisarnaaserneqarsimalluni (piniarfiit aalisarfiillu, aalisakkat, timmissat imaanilu uumasut miluumasut itsarnitsallu eriagisariaqartut). Nunap assingi piffiit immikkut pingaaruteqartut ilanngunneqarsimapput. Nunap assiginut ataasiakkaanut piffiup sumut atorneqartarneranut kiisalu sunik uumasogarneranik paasissutissat allaaserineqarsimapput.

Kapitali 9 nunap assingi 34-it saniatigut aamma nunap assinginik 34-nik sinerissap qanoq ilusaanik, periarfigitsigineranik kiisalu piffinni ataasiakkaani uuliaarluernerup qanoq akiorneqarsinnaaneranik siunnersuutit imaqqarpoq.

Paasissutissat pissarsiarineqarsimasut suliap ingerlanerani kommuninut soqutigisaqaqatigiinnullu ataasiakkaanut saqqummiunneqarsimapput oqallisigineqarsimallutillu.

Suliaq Energistyrrelse-mit aningaasaliiffigineqarsimavoq suliffeqarfiillu makku ingerlatsisuusimapput: Qallunaat Nunaanni Avatangiisinut Misissuisoqarfik (Danmarks Miljøundersøgelser), Pinngortitaleriffik (Grønlands Naturinstitut), Qallunaat Nunaanni Kalaallit Nunaannilu Ujarassiut Misissuisoqarfiat (Danmarks og Grønlands Geologiske Undersøgelse), Københavns Universitet, Grønlandssekretariatet (Nationalmuseet), Danmarks Meteorologiske Institut kiisalu canadamiut siunnersuisoqatigiiffii marluk AXYS Environmental Consulting LTD. aamma S.L. Ross Environmental Research Ltd.

5 Sammenfatning

Vestgrønlandske havområder og fjorde – Atlas over områder der er særligt følsomme for oliespild

I sommeren 2000 udfører olieselskabet Statoil en boring efter olie/gas til havs vest for Fyllas Banke ved Vestgrønland. Det bliver den første boring til havs i Grønland siden 1977. Den alvorligste miljømæssige påvirkning vil kunne opstå, hvis der sker et stort oliespild fra en boring, og olien spredes ukontrolleret i havet. Der er dog en meget lille risiko for, at dette sker.

Som led i forberedelserne til efterforskningsboringen har myndighederne iværksat dette atlasprojekt. Hensigten med projektet er at få et samlet overblik over de ressourcer, der er følsomme over for et oliespild. Det drejer sig bl.a. om de biologiske ressourcer (forekomst af fisk, fugle m.v.) og om fiskeri- og fangstinteresser. Med en kortlægning af denne viden vil såvel selskabet som myndighederne på forhånd kunne vurdere, hvor der primært skal sættes ind mod et oliespild, hvis det er nødvendigt at prioritere indsatsen. Projektet omfatter områderne mellem 62° N og 68° N ved Vestgrønland.

I projektet indgår følgende elementer:

- kysttypebeskrivelser,
- oceanografi, is og klima,
- biologiske ressourcer (fugle, fisk o.s.v.),
- fiskeri og jagt,
- særligt beskyttede områder (f.eks. fuglefjelde),
- fortidsminder,
- logistiske forhold og metoder til at bekæmpe oliespild.

Da ressourcerne har meget forskellig karakter (f.eks. fuglekolonier, vigtige fiskeriområder og fortidsminder), er det almindeligt i andre lande at udregne indexværdier som udtryk for et områdes følsomhed, således at forskellige områder kan sammenlignes og prioriteres. Der er udviklet en række forskellige indexsystemer til dette formål. I dette projekt tages udgangspunkt i et canadisk system, der bl.a. er brugt i Lancaster Sound i det nordøstlige Canada.

Kysten er inddelt i segmenter (områder) af ca. 50 km's længde, der er blevet klassificeret i fire grader af følsomhed. Klassifikationen er sket ved hjælp af en index-beregning, hvor der indgår et antal miljø- og samfundselementer (forskellige fugle og havpattedyrgrupper, jagtområder, fiskeriområder, fortidsminder m.v.). Disse elementer er givet dels en værdi for følsomhed overfor oliespild, dels en værdi for, hvor talrig/vigtig forekomsten er på hvert segment. De biologiske elementers følsomhed overfor oliespild beregnes ud fra, hvor sandsynligt det er, at den pågældende art kommer i kontakt med olie under et oliespild, samt hvor følsom arten er overfor olie. De biologiske elementer og deres udnyttelse indgår med den største vægt ved beregningen af segmenternes samlede følsomhed.

Udover den generelle klassificering af hele kystens følsomhed er der på kortene angivet en række særligt udvalgte mindre områder. Disse områder er udvalgt ud fra at de er særligt værdifulde,

særligt følsomme overfor oliespild samt at de har en størrelse der generelt gør det praktisk muligt at gennemføre en effektiv oliespildsbekæmpelse.

Som en del af projektet er der ud fra luftfotografier foretaget en morfologisk kortlægning af kysterne (deres opbygning og materialesammensætning, f.eks. om de består af klippeflader eller sand). Ud fra denne viden og hvor udsatte de er overfor påvirkning fra bølger og is, er der udregnet et mål (index) for deres selvrensende evne efter en eventuel olieforurening. For eksempel vil en klippekyst, der er meget udsat for bølgeslag, hurtigere blive "vasket ren" for olie end en strand i en beskyttet lagune.

På baggrund af det samlede materiale er der lavet en vurdering af egnede metoder til bekæmpelse af oliespild i de forskellige områder.

Atlas'et indeholder en sektion med oversigtsinformation (kapitel 8), der hovedsageligt er angivet på kort i målestoksforholdet 1: 3,5 million, og en sektion med detaljeret information (kapitel 9) på kortblade i målestoksforholdet 1: 250 000. Kapitel 7 indeholder en fælles brugervejledning til kortene i kapitel 8 og 9.

Kapitel 8 indeholder kort, der viser offshoreområdernes følsomhed med symboler for elementerne i klassifikationen (fiskeriområder, fisk, fugle og havpattedyr). Desuden er der en række kort over isforholdene i området samt kort over de vigtigste områder for en række biologiske ressourcer og deres udnyttelse, bl.a. for rejer og hellefisk.

Kapitel 9 indeholder 34 kortblade i målestoksforholdet 1: 250 000 med angivelse af indexværdier for kysternes følsomhed og symboler for elementerne i klassifikationen (jagt og fiskeriområder, fisk, fugle og havpattedyr samt fortidsminder). Kortene viser også særligt udvalgte områder. Til hvert kortblad er der udarbejdet en beskrivelse med oplysninger om områdets udnyttelse og biologiske forekomster.

Kapitel 9 indeholder derudover 34 kortblade med angivelse af kysttyper og logistiske forhold samt forslag til metoder til bekæmpelse af oliespild for hvert område.

Projektets resultater er undervejs blevet præsenteret for og diskuteret med berørte kommuner og interesseorganisationer i en høringsfase.

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6 Introduction

6.1 Objectives

This environmental oil spill sensitivity Atlas has been prepared to provide oil spill response planners and responders with tools to identify resources at risk, establish protection priorities and identify appropriate response and clean-up strategies.

The Atlas is designed for planning and implementing year-round oil spill countermeasures in both coastal and offshore areas on the west coast of Greenland between 62° N and 68° N latitude. An important component of the Atlas is a sensitivity ranking system which is used to calculate an index value describing the relative sensitivity of coastal and offshore areas. The sensitivity index value is calculated based on information on resource use (human use), biological occurrences, and physical environment. The sensitivity ranking system is based on a Canadian system used in Lancaster Sound (Dickins et al. 1990) and modified to meet the specific requirements of the Greenland study area (see Chapter 6.3). As a supplement to the Canadian ranking system, a number of smaller areas has been selected for priority in case of an oil spill (see Chapter 6.4). The selection of these areas is based on the principles from a Norwegian system (Anker-Nilssen 1994), which gives priority to oil spill sensitive areas for oil spill contingency planning.

The west coast of Greenland between 62° N and 68° N latitude is the most populated area in Greenland. It is extremely important for fisheries and it is ecologically highly important for a number of seabird and marine mammal species. It is therefore essential that all possible measures are taken to minimise the environmental risk of oil activities in the area. The objective of this Atlas is to contribute to that effort.

6.2 Contents and organisation

The study area covers the west coast of Greenland between 62° N and 68° N including offshore areas as far west as the Canadian border. Moreover, it includes most of the information regarding the physical environment further north to 71° N.

All fjords between 62° N and 68° N are included in the Atlas, although the coastal morphology has not been mapped in the easternmost inner part of the long fjords.

This Atlas is produced both as a pdf-document on CD and as a paper version. The pdf-document on CD has, compared to the paper version, a number of extra maps, figures and tables. Furthermore the CD contains a series of air photos covering the area, and the shoreline sensitivity map and physical environment and logistics maps are included in a GIS application, which makes it possible to produce seamless maps at various scales.

The information in the Atlas is organized by map scale moving from summary information (Chapter 8) in a scale of approx. 1: 3.5 million to operational information (Chapter 9) in a scale of 1: 250,000 (G/250 Vector copyright Danish Survey & Cadastre 1998).

Chapter 7 contains a users guide to the maps which supplement the legend.

Chapter 8 contains the summary maps, which include:

- bathymetry,
- sea surface currents,
- overall distribution of important species,
- overview of extreme and high sensitivity areas and special status areas,
- offshore sensitivity (winter, spring, summer and autumn),
- ice conditions.

Chapter 9 contains the operational maps, which include Shoreline Sensitivity Maps with:

- shoreline species,
- resource use (human use),
- archaeological sites,
- sensitivity rankings,
- selected areas.

and Physical Environment and Logistics Maps with:

- shoreline geomorphology,
- anchorage's and safe havens,
- access by boat or aircraft,
- descriptions of potential countermeasures.

Further information on the physical environment is given in Appendix C: Climatic data for logistics.

Detailed accounts of methodology and data documentation and limitations are given in Appendix D.

6.3 Sensitivity index system

An environmental sensitivity ranking system is used in the Atlas to determine and illustrate the relative sensitivity of shoreline and offshore areas of West Greenland to the effects of an oil spill. This pre-spill ranking allows spill responders and on-scene planners to do a quick evaluation of which areas and environmental components that are most susceptible to an oil spill, and thus provides the information to consensus regarding protection priorities during a spill event.

Through the use of the sensitivity ranking system, each shoreline and offshore area receive a single numeric value, which represents the relative sensitivity of that area to a marine oil spill. This numeric value is ranked as extremely high, high, moderate or low and is illustrated on the summary, regional and operational maps by the use of a colour code.

This ranking system is based on the scheme developed for the Canadian Atlases (e.g. Lancaster Sound) with some modifications to account for the different biological and physical features of the region. The sensitivity ranking system incorporates the biophysical and social elements of the region that are important from an oil spill perspective. These elements are assigned to and ranked on a relative scale within three major categories: (1) resource (human) use; (2) species occurrence; and (3) oil residence. The latter category considers the oil residence periods associated with various coastal types, and the differences in ice and open water zones for the shoreline and offshore areas of West Greenland, respectively. Each of the categories are assigned a weighting factor, which is based on their relative importance within the region. The elements within each of the categories are ranked based on their relative sensitivity to potential effects of oil spills. These

assigned values are then multiplied by the weighting factor to produce a single numeric value the PI (priority index). It is the sum of the priority indices that determines the overall sensitivity of a specific shoreline or offshore area.

$$PI = AV \times WF$$

and

$$S = \text{sum of PI}$$

where:

AV = assigned value of the element

WF = weighting factor of the category

PI = priority index

S = relative sensitivity of an area: the **sensitivity value**

Criteria for ranking the relative sensitivity of the human use elements are based on their importance to local residents from a cultural/historic and economic perspective, and the replaceability of the resource.

Biological elements (species or species group) selected for the sensitivity index are listed in Table 6.1. They are selected based on their sensitivity to oil spills, their ecological importance and their importance to biodiversity and the local human population.

The following formula is used to calculate the AV (assigned value) for each biological element (species or species group):

$$AV = (RS \times RA \times TM \times ORI) / C$$

Where:

RS = relative sensitivity of the species

RA = relative abundance of the species

TM = temporal modifier

ORI = oil residence index

C = constant used to reduce the maximum possible score

The relative sensitivity (RS) for the species rely on available information regarding the vulnerability, recovery potential, potential for lethal and sublethal effects, which are summarised in Table 6.1. The relative sensitivity for the selected species range from 7 to 25. The relative abundance and timing of occurrence of the selected species (biological elements) is extracted from available knowledge and encoded for each shoreline and offshore area.

Table 6.1 The relative sensitivity (RS) and characteristics of the selected species or species groups in relation to oil spills.

| Species Name | Vulnerability | Mortality potential | Sublethal potential | Recovery period | Relative sensitivity |
|---------------------|---------------|---------------------|---------------------|-----------------|----------------------|
| Alcids | Very High | Very High | Very High | Very High | 25 |
| Arctic char | Moderate | Low/Short | Moderate | Moderate | 14 |
| Baleen whales | Low | Very Low | Very Low | Moderate | 9 |
| Bearded seal | Low | Very Low | Low | Short | 9 |
| Capelin | Very High | High | High | Moderate | 21 |
| Cormorants | High | High | High | Moderate | 19 |
| Deep sea shrimp | Very Low | Very Low | Low | Short | 7 |
| Greenland halibut | Very Low | Very Low | Low | Short | 7 |
| Gulls | Moderate | High | Very High | Short | 17 |
| Harbour seal | Moderate | Moderate | High | No Recovery | 18 |
| Hooded seal | Moderate | Moderate | Moderate | Moderate | 15 |
| Lumpsucker | Moderate | Moderate | High | Short | 15 |
| Scallop | High | Low | High | Long | 18 |
| Seaducks | Very High | High | Very High | Long | 23 |
| Seaducks breeding | Very High | High | Very High | Long | 23 |
| Snow crab | Very Low | Low | Moderate | Short | 9 |
| Tubenoses offshore | Moderate | High | High | Moderate | 17 |
| Tubenoses shoreline | Moderate | High | High | Long | 18 |
| Walrus | High | Moderate | Low | No Recovery | 18 |
| White whale | Low | Low | Low | No Recovery | 13 |

The biological resource constant "C", refers to a value which is used to limit the maximum possible biological resource score, and thus to balance the importance of the biological components with the other components.

The oil residence index (ORI) provides a relative estimate of the potential residence period of oil stranded within the shore zone under normal conditions. The index is only an approximation, because many aspects of a spill are unknown until the time of the spill incident (e.g. the volume of spill, oil type, degree of weathering). The oil residence is ranked from 1 to 5 mainly based on the shorelines exposure class and the shoreline substrate. Table 6.2 shows the basic relation. A few minor modifications to the basic classification of the ORI value are made to account for slope (where steep shorelines are less vulnerable) and to account for a few geomorphological coast types considered to have longer residence times (archipelagos, pocket beach, barrier beach and delta).

Table 6.2 Basic Oil Residence Index (ORI) ranking based on a combination of shoreline substrate and exposure class.

| Substrate / Exposure class | Protected | Semi-protected | Semi-exposed | Exposed |
|----------------------------|-----------|----------------|--------------|---------|
| Coarse sediment | 4 | 3 | 1 | 1 |
| Fine sediment | 4 | 3 | 1 | 1 |
| Ice | 1 | 1 | 1 | 1 |
| Not classified | 4 | 3 | 2 | 1 |
| Rock | 4 | 3 | 1 | 1 |
| Rock and coarse sediment | 5 | 4 | 2 | 1 |
| Rock and fine sediment | 5 | 4 | 2 | 1 |

6.4 Selected areas

In particular, a total of 78 areas along the coast and within fjords have been selected for priority in an oil spill situation. These areas are identified by a black polygon border and a number with the prefix, 's'. The basis for their selection is that they are, relative to the shoreline in general: i) of high value either environmentally or for resource use; ii) sensitive to oil spills; and iii) of a size and form that may allow effective protection in an oil spill situation with a manageable amount of manpower and equipment.

6.5 Countermeasure overview

Oil spill countermeasure considerations are described for each of the 34 operational maps in Chapter 9. The following is an overview of their basis and content.

The low level of industrial and marine activity in the waters of West Greenland leads to a very limited number of spill possibilities, both currently and in the foreseeable future. The main possibilities at present are those related to fuel re-supply to the communities, and fuel carried by fishing vessels and other small ships. A small but finite risk will be added with the advent of exploration drilling for crude oil, which is planned for the year 2000 in an area approximately 150 km west of Nuuk. More exploration drilling is anticipated on the offshore area in the coming years.

If a significant spill occurs, there would be severe limits to the response, particularly during the critical initial stages of the incident. The remoteness of the region, the distance of existing response bases, and, most importantly, the low marine activity practically eliminate the possibility of an effective initial marine-based response unless dedicated response plans and equipment are available as is the case for offshore exploration drilling. The main countermeasure activities that could be carried out are described in general terms below, with specific local notes where applicable on each of the operational maps. These countermeasures could include surveillance and tracking, in situ burning of spills in ice conditions, dispersant-use in offshore areas, and the protection and clean-up of important coastal entities, such as the "selected areas" (see Chapter 6.4).

Surveillance and tracking activities will be critical in determining the location and extent of spilled oil. This will be particularly important in establishing clean-up priorities and adjusting strategies

when a long-term and geographically widespread response is required. Aircraft-based remote sensing and surveillance overflights could be mounted from airports at Kangerlussuaq, Maniitsoq, Nuuk, or Sisimiut. A program to track oiled ice would be required for spills that occur among pack ice or for open water spills that reach the pack ice edge or persist through freeze-up in protected inshore waters.

Conventional containment and recovery techniques will be severely limited by the lack of vessels with which to deploy and operate equipment unless vessels and equipment are available on standby in the area as part of a response plan for specific activities such as offshore drilling. Spills that are not contained within the first few days of a response will likely be too thin and widespread to allow effective recovery.

In situ burning may be applicable as an initial response measure for spills in ice conditions. Pack ice concentration of 6 tenths or greater will limit the spread of an oil spill and may allow the opportunity for burning until some time after an incident. For inshore areas and fjords that freeze over winter, oil that persists through the freezing season may be available for burning the following melt season when released into leads and melt pools. This would require a tracking and monitoring program through the winter to delineate oiled areas and to prepare for the likely release period.

Dispersant-use should be considered for use in offshore areas to prevent or reduce surface oil from contaminating more sensitive inshore areas. This technique will be particularly applicable for slicks that threaten to approach nearshore bird and marine mammal habitats, and for which containment and recovery countermeasures may not be fully effective due to the size of the spill, the limited logistical support for a large-scale clean-up, the prevailing weather and sea conditions, or a combination of the three.

Shoreline protection countermeasures will also be limited by a lack of logistical support. There is, however, limited need for shoreline protection through much of the areas that are exposed to marine transportation risks, as described further below. The main exceptions to this generalisation are the "selected areas" within each map area that have been identified as priorities for protection. These areas are particularly vulnerable to oiling, can generally be protected with a relatively modest effort, and in some cases, could be difficult to clean if heavily oiled. In many cases, deflection rather than containment booming will be preferred because the tidal currents exceed 1 knot. While deflection booming may not offer complete protection of the "selected area" it will be valuable in limiting the extent and degree of contamination and lead to faster and more complete post-spill recovery. Deflection booming strategies will require monitoring and perhaps repositioning periodically to account for changes in current strength and direction.

A more significant limitation for shoreline protection countermeasures will be that dictated by the water currents and topography. Little water current information is available for the area; the few data available indicates that tidal currents are strong in most areas - as high as 7 knots in one instance. This coupled with steep, rocky shorelines and bottom contours may preclude effective booming. As noted above, for areas that can be boomed, the most effective strategy may be to use deflection booming to limit the extent of shoreline oiling and thereby hasten recovery.

It should be noted that there are many areas, including some of the "selected areas" for protection, for which effective containment operations are not likely to be possible. In many areas, offshore countermeasures present the only realistic option for effective protection. For spills that may affect these areas, strong consideration should be given to dispersant-use (and in situ burning for spills in ice conditions).

Much of the coastline in this Atlas consists of high-relief rocky shoreline that is moderately or highly exposed to prevailing weather and sea conditions as well as some ice action. In many areas, fjords, bays, and other inshore areas may also be somewhat protected from extensive contamination by the flushing action of tidal currents and by the natural outflow of streams and rivers. As a result, much of the shoreline may not require a widespread active cleaning effort unless it is heavily contaminated. Where active shoreline clean-up is required, priorities for restoration can be established based on both the environmental sensitivity and oil persistence factors. Preference should be given to in situ cleaning techniques such as in-place washing of rocky shores, use of shoreline cleaning agents, in situ burning, and bioremediation. Use of these techniques will minimise the amount of oily material collected and subsequent hauling requirements. Disposal site selection was beyond the scope of this study, and would require extensive study involving technical, logistical, environmental, and political factors. An alternative to land disposal within the region would be the trans-shipment of collected oily materials from temporary stockpiles to disposal sites and/or incineration elsewhere.

Marine access for shoreline clean-up may be limited in some areas by shoaling and offlying rocks and islets. In some areas, locally forming ice and the encroachment of seasonal pack ice may also limit access. The steep shorelines in many areas will rule out the use of remote staging areas and may necessitate ship- or barge-based clean-up operations.

7 Users Guide

Offshore sensitivity information is given in Chapter 8. This information covering the entire study area is presented on one page maps with an approximate scale of 1: 3.5 million.

Detailed shoreline information is given in Chapter 9 on maps with a smaller scale. The entire study area is covered by a total of 34 separate maps with a scale of 1: 250,000 (A4 size). The name of each map reflects the northern latitude (degrees N) of the area covered, and the position of the area from west to east, where numbering starts from west to east. For example, the western-most map (map number 1) that covers the area at 62° N, is named Map 6201, and the next to the east is named Map 6202. Note that there are two rows for each latitudinal degree, thus the map to the north of Map 6201 is at 62.5° N and is named Map 6251.

In Chapter 9, there are two series of 34 detailed maps: **Shoreline Sensitivity Maps** and **Physical Environment and Logistics Maps**. The Shoreline Sensitivity Maps are on the left-hand side, and Physical Environment and Logistics Maps are on the right. Descriptive text appears on the pages between these maps.

7.1 Shoreline and Offshore Sensitivity Maps

7.1.1 Sensitivity Index and Icons (animal and other symbols)

The shoreline zone in the study area has been divided into 279 shoreline areas, each consisting of approximately 50 km of shoreline or in the archipelagos a group of islands and skerries having roughly 50 km shoreline. The 279-shoreline areas are numbered from south to north and the numbers are given on the map.

The offshore zone in the study area has been divided into 12 offshore areas (including 1 major fjord). The boundaries of the offshore areas are based on bathymetry and ice conditions during the winter.

An oil spill sensitivity index value has been calculated for each of the 279 shoreline and 12 offshore areas based on:

- i) the abundance and sensitivity of selected species (or species groups);
- ii) resource use (human use), mainly fishing and hunting;
- iii) the potential oil residency on the shoreline (Oil Residency Index) based mainly on wave exposure, substrate and slope of coast;
- iv) the presence of towns, settlements and archaeological sites (for shorelines).

The sensitivity index value for each of the 279-shoreline areas and 12 offshore areas is given on the opposite page to the corresponding map. All areas are ranked as extreme, high, moderate and low sensitivity areas and a corresponding colour code has been used. Detailed index value calculations for each shoreline and offshore area are given in Appendix A and Appendix B, respectively. These can be accessed by links on the opposite pages in the pdf-document.

The importance of resource use, and the abundance of a number of biological occurrences in each of the 279-shoreline and 12 offshore areas, has been rated on a scale from 0 to 5 (see legend or Chapter 6.3 for a list of species and species groups included in the index). Where an areas importance for resource use, or the abundance of a particular species or species group is significant

(rated 3, 4 or 5), it is indicated with a **black icon** (and a letter code) on the map after the shoreline or offshore area number.

Blue icons (animal symbols) indicate a site-specific significant habitat. For example, such sites include important bird colonies and terrestrial haul-out for harbour seals. Photos of the coastal setting for about 50 bird colonies have been included in the pdf-document and can be accessed from links on the opposite page to the shoreline sensitivity map.

7.1.2 Selected Areas

To supplement the rather general mapping of shoreline sensitivity using the 50 km long shoreline areas, a number of small sensitive localities have been selected. A total of about 80 areas along the coast and within fjords have been selected as priority areas in the case of an oil spill situation. These areas are identified by a black polygon border and a number with the prefix, 's' for **Selected**. The basis for their selection is that, compared to the coastline in general, they are:

- i) of high value either environmentally or for resource use;
- ii) sensitive to oil spills; and
- iii) of a size and form that may allow effective protection in an oil spill situation with a manageable amount of manpower and equipment.

7.1.3 Season Information

Offshore sensitivity is presented on seasonal maps reflecting the changes in sensitivity during winter (January - March), spring (April - May), summer (June - August) and autumn (September - December).

Seasonal occurrence of species and resource use in the Shoreline Areas is presented on Species and Resource Occurrence graphs, corresponding to each of the Shoreline Sensitivity maps.

7.1.4 Resource Use Data

Data on resource use was extracted from NERI's interview survey (Nielsen et al. 2000) regarding fishery for capelin, lumpsucker and arctic char, as well as from unpublished material collected by (Petersen 1992, 1993 a,b,c,d). Additional information of resource use, especially shrimp, halibut, snow crab and scallop fisheries, and hunting of seabirds (mainly guillemots and eiders) seals, and whales were derived from Greenland Institute of Natural Resources (GINR). Finally, unpublished material from NERI have also been included.

A preliminary Atlas with all the data available on human use was presented to hunters and fishermen in settlements and towns between Paamiut and Sisimiut in spring 2000. New and supplementary information was gathered during these sessions, and are included in the present Atlas.

7.1.5 Species distribution and abundance data

Information on species distribution and abundance is mainly derived from a number of NERI reports reviewing data on biological resources and resource use in the area (Boertmann et al. 1996, (Boertmann et al. 1999, Mosbech et al. 1996, Mosbech et al. 1998). In these reports relevant aspects of the species status and ecology are further described.

7.1.6 Archaeological and historical sites included

All known prehistoric and historic sites are included in the background database to the present Atlas. However, only sites that are likely to be endangered during a marine oil spill are included on the maps (as purple squares). In order to protect the sites, only the most basic information is given.

To illustrate what archaeological sites in the coastal zone look like, seven photos are presented in the pdf-document. [\[Link\]](#)

In the event of a marine oil spill or a more general need, further information on the sites are available from either the Greenland National Museum or the Greenland Secretariat at the Danish National Museum.

All man made relics more than 100 years old are protected according to ""Landstingslov nr. 5/1980 af 16 oktober 1980 om fredning af jordfaste fortidsminder og bygninger" (The Conservation Act). The Greenland National Museum & Archives manages the legislation is responsible for recording the sites concerned.

7.2 Physical Environment and Logistics Maps

7.2.1 Coastal Types Description

The shores in the study area are classified into eleven different shore types on the Operational Maps of Physical Environment and Logistics. Shore type definitions are given in Table 7.1 and photos of shore types in Fig 7.1-13.

This classification is based on aerial photo interpretation of stereo images using a stereoscope. A full coverage of aerial photos are included in the pdf-document and can be accessed from the opposite page to the Maps of Physical Environment and Logistics.

The coastline was subdivided into segments with minimum segment length of approx. 2 km. Shore types with a shore length of less than approx. 2 km were not categorised separately, but were included in the neighbouring segments. Generally, the segments were drawn as lines coincident with the shoreline. However, during the classification, the shore type "Archipelago" was classified as polygons with varying area and form and including a varying number of islands. On the final maps, each island within the archipelago shore type polygons was reclassified as individual line segments (encircling each island). Small islands (perimeter < 6 km), that were not part of an archipelago, were not classified separately as segments but were attached to the nearest segment.

7.2.2 Access

For each operational map, access information is provided to cover the following areas:

- **Marine access:** navigational information, prevailing currents, tides, local ice conditions, shoal hazards, identified anchorages, beach landing sites;
- **Air access:** size, surface, and seasonality of airstrips within the area.

Marine information is taken from the nautical charts for the area and from the corresponding descriptions in the Arctic Pilot, Volume III published by the British Admiralty.

Table 7.1: Classification of shore types in West Greenland between 62° N and 68° N.

Shores developed in solid rock

| Shore type | Characteristics |
|---------------|--|
| Rocky coast | <ul style="list-style-type: none"> - Coast developed in bedrock of varying morphology, elevation and gradient. - Narrow beach with coarse sediment consisting of boulders, cobbles and pebbles might occur. - The occurrence of abraded inter-tidal platforms is indicated by the gradient. |
| Archipelago | <ul style="list-style-type: none"> - Several smaller islands, normally developed in solid rock. - Rocky coasts and pocket beaches might occur, but have only been classified individually if the perimeter of the island exceeds 6 kilometres. |
| Glacier coast | <ul style="list-style-type: none"> - Occurrence of a glacier in the intertidal zone. |

Shores developed in sediments of glacial, alluvial or colluvial origin

| | |
|--------------|---|
| Moraine | <ul style="list-style-type: none"> - Shore developed in unconsolidated glacial sediments. - Narrow beach with coarse sediment consisting of boulders, cobbles and pebbles might occur. - The occurrence of abraded intertidal platforms are indicated by the gradient. |
| Alluvial fan | <ul style="list-style-type: none"> - Shore developed in alluvial fan. - Narrow beach with sediment consisting of boulders, cobbles, pebbles, gravel and sand might occur. - The occurrence of intertidal platforms is indicated by the gradient. |
| Talus | <ul style="list-style-type: none"> - Shore developed in talus (colluvial fan) of varying gradient. - Narrow beach with coarse sediment consisting of boulders, cobbles and pebbles might occur. |

Shores developed in marine sediments

| | |
|------------------------------|--|
| Beach | <ul style="list-style-type: none"> - Long, linear depositional beaches of well-sorted sand, gravel, pebbles, cobbles or boulders. - Beach ridge plains often occur landwards the beach. |
| Barrier beach | <ul style="list-style-type: none"> - Coastal environment consisting of coastal barriers and lagoons with beaches, dunes, salt marsh and tidal flats. - Spits often occur near tidal inlets. - Washover fans might occur on barriers. - Beaches consisting of well-sorted sand, gravel, pebbles or cobbles. |
| Salt marsh and/or tidal flat | <ul style="list-style-type: none"> - Wide salt marshes with or without salt marsh cliff and/or wide intertidal flats. - Consisting of relatively fine sediments (mud, sand, silt and clay). |
| Pocket beach | <ul style="list-style-type: none"> - Beach developed in the inner part of an embayment in solid rock. - No larger rivers run into the embayment. - Beaches normally consist of well-sorted sediments consisting of sand, gravel, pebble or cobbles. |

Shores developed in deltaic sediments

| | |
|-------|--|
| Delta | <ul style="list-style-type: none"> - Low gradient intertidal platform developed by fluvial sediments in front of a river valley. - Braided river channels often occur within the inter-tidal zone. - Sediment normally fine grained ranging from clay to fine sand. |
|-------|--|

Others

| | |
|----------------|--|
| Not classified | <ul style="list-style-type: none"> - The shore has not been classified due to lack of air photo information (cloud cover, shadow, etc.) |
|----------------|--|



Figure 7.1. Rocky coast, Tuno (Hamborgersund).



Figure 7.2. Rocky coast.



Figure 7.3. Archipelago near Paamiut.



Figure 7.4. Archipelago.



Figure 7.5. Glacier coast in Nuuk Fjord (Godthåbsfjorden).



Figure 7.6. Moraine coast.



Figure 7.7. Alluvial fan.



Figure 7.8. Talus.



Figure 7.9. Talus with erosional cliff.

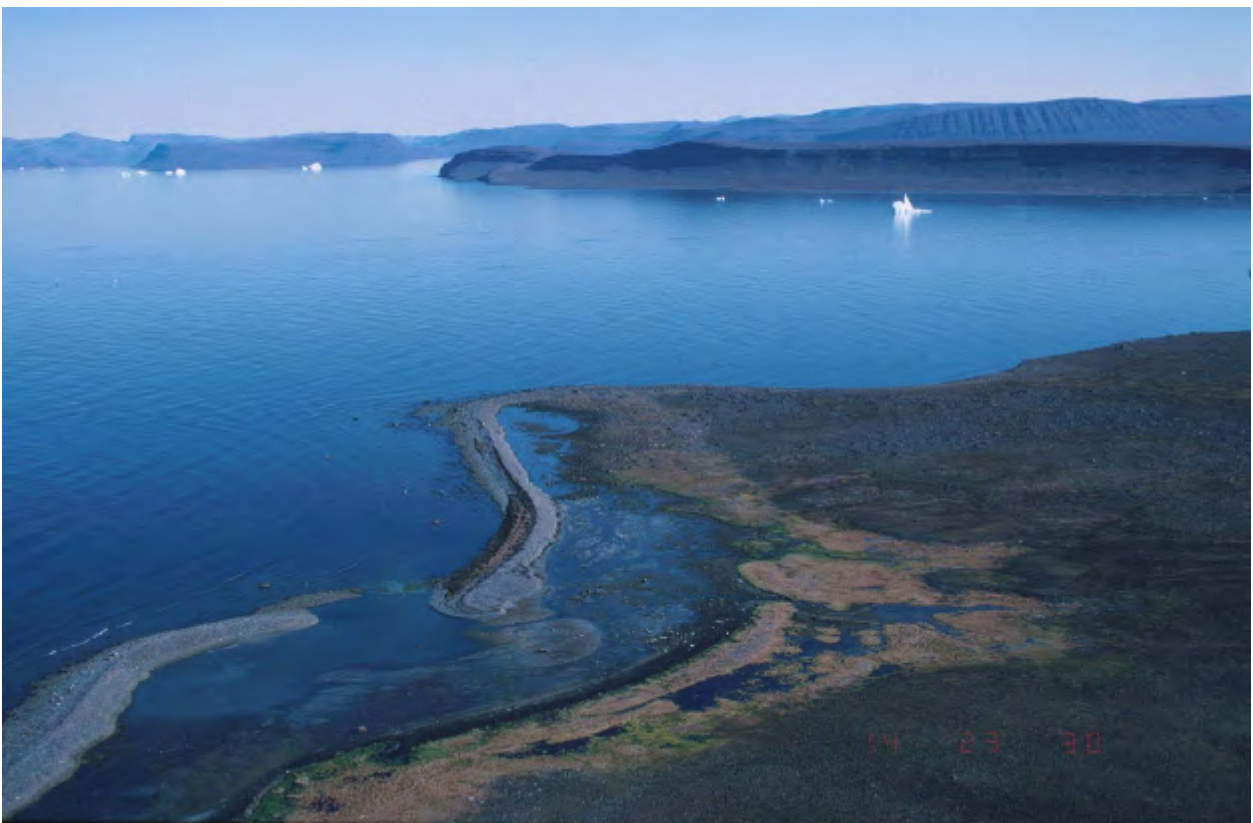


Figure 7.10. Barrier beach.



Figure 7.11. Barrier beach.



Figure 7.12. Pocket beach surrounded by rocky coast.

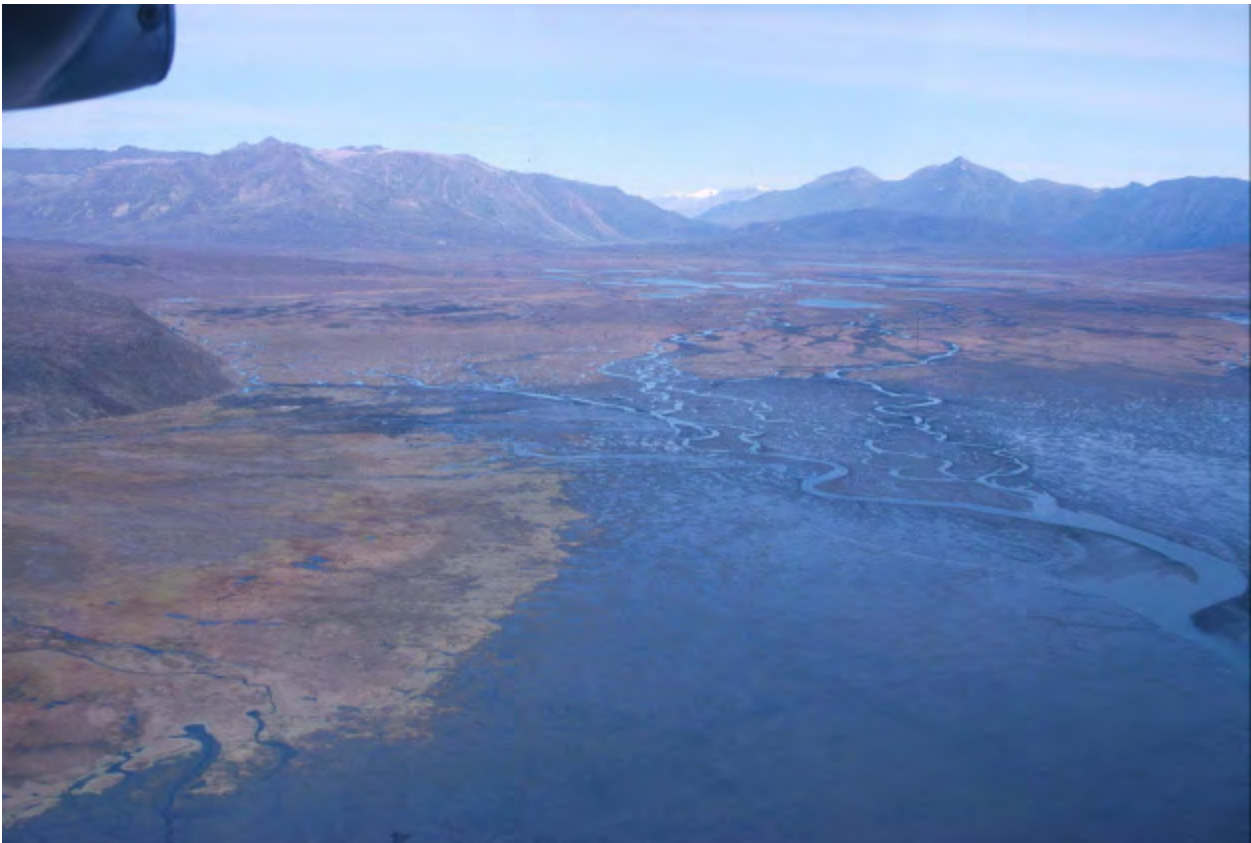


Figure 7.13. Delta with tidal flat.

7.2.3 Potential Safe Havens

An attempt was made to identify potential safe havens where unloading and/or stabilisation operations could be carried out on a stricken vessel within the areas depicted by each map. The criteria for selecting such sites were that the area was classified as having low to moderate sensitivity, allows access by deep draft vessels, provides shelter from weather and seas, and preferably is in an area that would allow an opportunity to contain any escaping oil.

7.2.4 Countermeasures

Countermeasure information is given for each map. Potential sites for booming, and inshore containment lengths are indicated on the maps.

7.2.5 Topographic Maps and Nautical Charts

Topographic map no. (at a scale of 1: 250,000) and Nautical Chart no. (at a scale of 1: 80 000) are given for each map. Topographic maps and nautical charts are available from The Danish National Survey and Cadastre.

8 Summary Information

8.1 Study Area Introduction

8.1.1 The offshore area

The sea of the study region (62° N - 68° N) are in eastern Davis Strait. The shelf is the rather shallow (less than 200 m) waters between the coast and the steep break to the deep sea. This shelf includes several large shoals or banks which typically ranges between 20 and 100 m in depth (Figure 8.1). In the southern part of the study area the shelf is narrow, while it is much wider up to 120 km in the northern part. There is deep water down to 2500 m to the west of the shelf.

As a result of the current pattern, the waters between 62° N and 67° N are normally free of ice cover all year round, although drift ice sometimes occur during winter. Thus, this area is called the Open Water Region, in contrast all other West Greenland offshore waters, where ice covers the water during winter.

The banks off the study region (62° N - 68° N) are considered to be among the most productive regions in Greenland waters. This high production are the basis for high densities of small schooling fish and large plankton organisms, which again are important food for large numbers of marine mammals and seabirds as well as for larger fish species, which all (including the deep sea shrimp) constitute important resources to the Greenland human population through hunting and fishing. The high production is nourished by upwelling of nutrients from the deep sea west of the banks, and it last throughout the summer. In contrast, the productivity of the waters in the central and western Davis Strait is low.

8.1.2 Currents

Along West Greenland the West Greenland current flows with two principal components. Closest to the shore brings the East Greenland Current component water of polar origin northward along the West Greenland coast. On its way, this water is diluted by run-off water from the various fjord systems. The East Greenland Current component loses its momentum on the way northward and at the latitude of Fylla Bank (64° N) it turns westward towards Canada where it joins the Labrador Current. West and below the Polar water of the East Greenland Current, another water component originating from the Irminger Sea and the North Atlantic Current is found. This relatively warm and salty water can be traced all the way along West Greenland from Cape Farewell to Thule (Avanersuaq). (Figure 8.2).

The oceanographic conditions off West Greenland are dominated by the following water masses:

Polar Water, originating from the Arctic Ocean and carried to West Greenland by the East Greenland Current

Irminger Water, Irminger Mode Water and North Atlantic Mode Water, all originating from the North Atlantic Current.

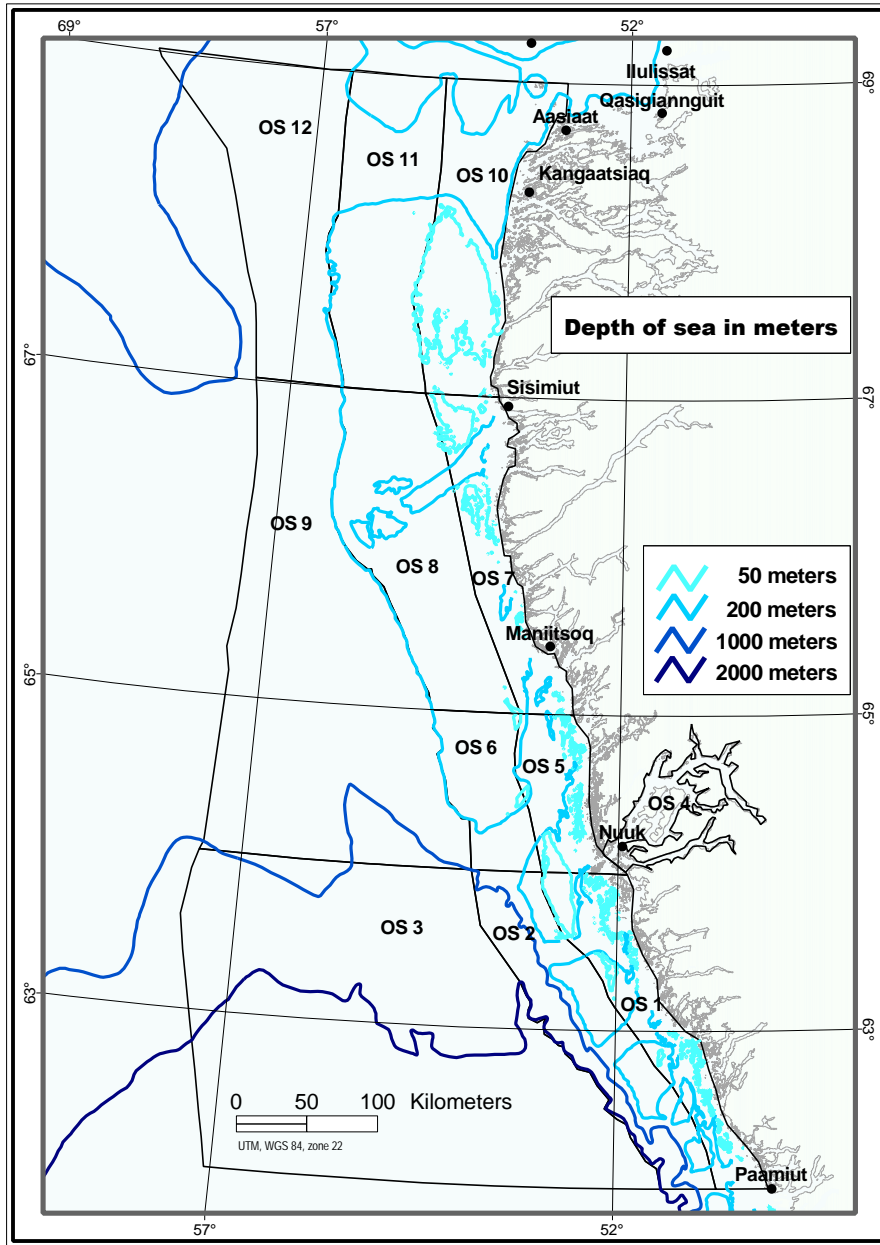


Figure 8.1. Bathymetry of the waters off West Greenland.

The Polar Water inflow is strongest during spring and early summer (May - July), and since the East Greenland Current carries large amounts of Polar Ice with it, the distribution of Polar Ice along the coasts of West Greenland will attain its maximum during the same period. The inflow of Atlantic water masses is strongest during autumn and winter explaining why the waters between 62° N and 67° N normally are ice free during wintertime.

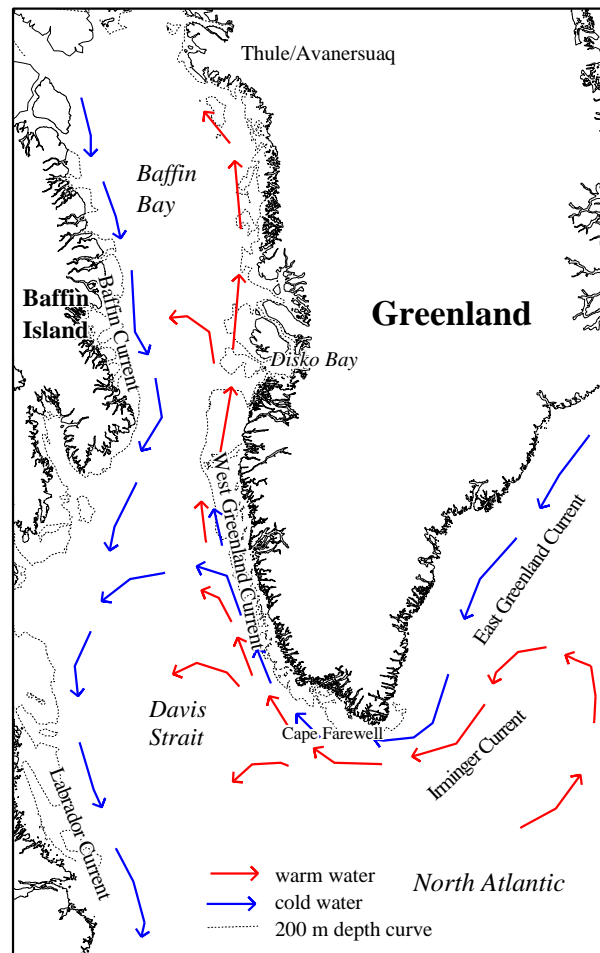


Figure 8.2. Surface current patterns in the waters off South and West Greenland.

A fifty year long time-series of temperature and salinity measurements from West Greenland oceanographic observation points, reveal strong inter-annual variability in the oceanographic conditions off West Greenland. Moreover, some distinct climatic events are obvious, of which three cold periods within the recent thirty years are the most dominant. The inter-annual variability is caused by changes in the atmospheric circulation or by variation in the strength of the ocean currents transporting water to the West Greenland area, and both seem to be related to the North Atlantic Oscillation Index (NAO-index) reflecting the difference in mean sea level air pressure between the Icelandic Low and the Azores High. (further information)]

8.1.3 Ice and weather

Sea ice is normally present in the Davis Strait, particularly in the western parts, from November to mid-summer, in Disko Bay from January to May and in the Cape Farewell area from mid winter to late July. The waters off Southwest Greenland are normally free of sea ice, but can be covered with sea ice during late winter for short periods or during spring and early summer months where multi-year ice originating from the Arctic Ocean drifts into the area.

Icebergs and growlers originating from glaciers occur in the entire region, but the density of icebergs is normally low in the eastern Davis Strait area. It increases towards Disko Island to the north and towards the Cape Farewell area to the south. However, the drift and distribution of glacial ice at sea have never been investigated systematically, and therefore are only known roughly known.

The meteorological conditions in the area are influenced by the North American continent and the North Atlantic Ocean, in addition the Greenland Inland Ice and the steep coasts of Greenland have a significant impact on the local climate. Many Atlantic depressions develop and pass near the southern tip of Greenland and cause frequently very strong winds off Southwest Greenland. Small scale phenomena such as fog or polar lows are also common features near the West Greenland shores. The probability of severe winds increases close to the Greenland coast and towards the Atlantic Ocean.

8.1.4 Coastal zone geomorphology

The coastal zone in the study area (62° N - 68° N) is dominated by bedrock shorelines with many skerries and archipelagos. Small bays with sand or gravel are found between the rocks in some sheltered areas. Sandy beaches are found in the Marraq-Sermilik area and off the Frederikshåb Isblink glacier, where this shore type is particularly extensive.

The tidal amplitude is 3-4 m and a rich intertidal and subtidal flora and fauna exists on the bedrock shorelines.

The geomorphology of the coasts in the study area has been classified regarding shore type, sediment type, slope and exposure. The total shore line length between 62° N and 68° N is app. 19,000 km. The inner parts of the fjords, except for Godthåb Fjord, are however not included in this classification. This reduces the total length of investigated shoreline to app. 15,000 km.

The division of the shoreline into shore type segments is based on the geomorphology of the coast. A lower shore type segment length of app. 2 km has been applied. Therefore, shore types with a shore parallel extent less than app. 2 km are not categorised separately, but have been included in the neighbouring shore type. Therefore, shore types with an extent of less than 2 km, are underrepresented in the classification. For example, the widespread pocket beaches are typically less than 2 km, and therefore have been classified as their surrounding shore type, rocky coast or archipelago.

The total number of segments identified is 12,961. Of these, 1,285 segments (5,491 km) are on the mainland coast, 493 segments (3,067 km) are on bigger islands (perimeter > 6 km) and 11,183 segments (5,564 km) are on smaller islands (perimeter < 6 km).

The segmental distribution of shore type, sediment type, slope and exposure categories respectively are given in Tables 8.1 - 8.4. In terms of shore line length, the 'Rocky coast' is the dominant shore type (59.9%), 'Rock' is the dominant substrate (87.9%), 'Inclined' is the dominant slope (81.6%) and 'Semi-protected' is the dominant exposure type (51.1%). The majority of the

coasts within the 'Archipelago' shore type are rocky coasts. Together the 'Archipelago' and 'Rocky coast' shore types by length constitute 92.3% of the total investigated shoreline.

Table 8.1. Shore type statistics.

| Shore type | No. of segments | km | % |
|---------------------------|-----------------|--------------|--------------|
| Rocky coast | 3311 | 8462 | 59.9 |
| Archipelago | 9118 | 4577 | 32.4 |
| Glacier coast | 32 | 25 | 0.2 |
| Moraine | 137 | 234 | 1.7 |
| Alluvial fan | 4 | 5 | 0.0 |
| Talus | 139 | 347 | 2.5 |
| Beach | 70 | 149 | 1.0 |
| Barrier beach | 29 | 43 | 0.3 |
| Salt marsh/ tidal flat | 36 | 153 | 1.1 |
| Pocket beach | 1 | 1 | 0.0 |
| Delta | 20 | 25 | 0.2 |
| Not classified | 15 | 27 | 0.2 |
| Total: | 12962 | 14122 | 100.0 |

Table 8.2. Sediment type statistics.

| Sediment type | Substrate, specific | km | % |
|---------------|-----------------------------|-------|------|
| 1 | Ice | 146 | 1.0 |
| 2 | Rock | 12414 | 87.9 |
| 3 | Rock and coarse sediment | 77 | 0.5 |
| 4 | Rock and fine sediment | 318 | 2.3 |
| 5 | Coarse sediment | 558 | 4.0 |
| 6 | Fine sediment | 511 | 3.6 |

Table 8.3. Slope statistics.

| Slope type | Slope | km | % |
|------------|----------|-------|------|
| 1 | Steep | 1776 | 12.6 |
| 2 | Inclined | 11522 | 81.6 |
| 3 | Flat | 723 | 5.1 |

Table 8.4. Exposure statistics.

| Exposure type | Exposure | km | % |
|---------------|----------------|------|------|
| 1 | Protected | 1114 | 7.9 |
| 2 | Semi-protected | 7215 | 51.1 |
| 3 | Semi-exposed | 2119 | 15.0 |
| 4 | Exposed | 3575 | 25.3 |

8.1.5 Marine fish and invertebrates

The offshore fish fauna in the area is dominated by bottom fish. The most important fish and invertebrate species in the study area are listed in Table 8.5. Major changes in the fish assemblage have occurred in last few decades. The most noteworthy is the disappearance of the offshore Atlantic cod stock. There are important fisheries for deep sea shrimp (Figure 8.3) and Greenland halibut (Figure 8.4) in the area. A stationary stock of sand eel is believed to be the most important prey species for marine mammals and seabirds on the banks.

Table 8.5. Important fish and large invertebrate species in the area (62° N - 68° N).

| Species | Main habitat | Spawning area | Spawning period | Exploitation |
|-----------------------------|--|--|--|----------------------------|
| Blue mussel | Subtidal, rocky coast | | | s |
| Scallop | Inshore and on the banks, in area with high current velocity, 20 -60 m depth | | July-August | c & s |
| Deep sea shrimp | Mainly offshore, 100 -600 m depth | Larvae released at relatively shallow depth (100-200 m), larvae in middle water-column | (July -September) larvae released March to May | Important c |
| Snow crab | Coastal and fjords, 180-400 m depth | | Larvae released April-May | c |
| Atlantic cod offshore stock | On banks north to 64° N | Pelagic eggs and larvae in upper water column (Former)western slope of banks | March-April, | See text |
| Inshore stock | Fjords | Inner fjords | April-May | |
| Greenland cod | Inshore/fjords | Inshore/fjords, demersal eggs | February-March | c & s |
| Arctic cod | Pelagic | Mainly N of 68° N | | No |
| Sand eel | On the banks at depths between 10 and 80 m | On the banks, demersal eggs, larvae in the water column | June-July south of 66° N later in the north | No, important prey item |
| Wolffish | Inshore and offshore | Hard bottom, one area known outside Maniitsoq, demersal eggs | Peaks in September | c & s |
| Atlantic salmon | Offshore and coastal | Freshwater | - | c & s |
| Arctic char | Coastal, fjords | Freshwater | - | c & s |
| Capelin | Coastal | Beach, demersal eggs | April-June | c & s, important prey item |
| Atlantic halibut | Offshore and inshore, deep water | ? western slope of banks south of 66° N, pelagic eggs and larvae, deep water | Spring | c & s |
| Greenland halibut | Offshore and inshore, deep water | Offshore south of 66° N, deep water, pelagic eggs and larvae | Winter | Important c & s |
| Redfish | Offshore and in fjords, 150-600 m depth | Main spawning south-west of Iceland, larvae drifts to West Greenland banks | | |
| Lumpsucker | Pelagic coastal, demersal eggs | May-June | - | c & s |

Exploitation of the species are categorised in c: commercial and s: subsistence fishery.

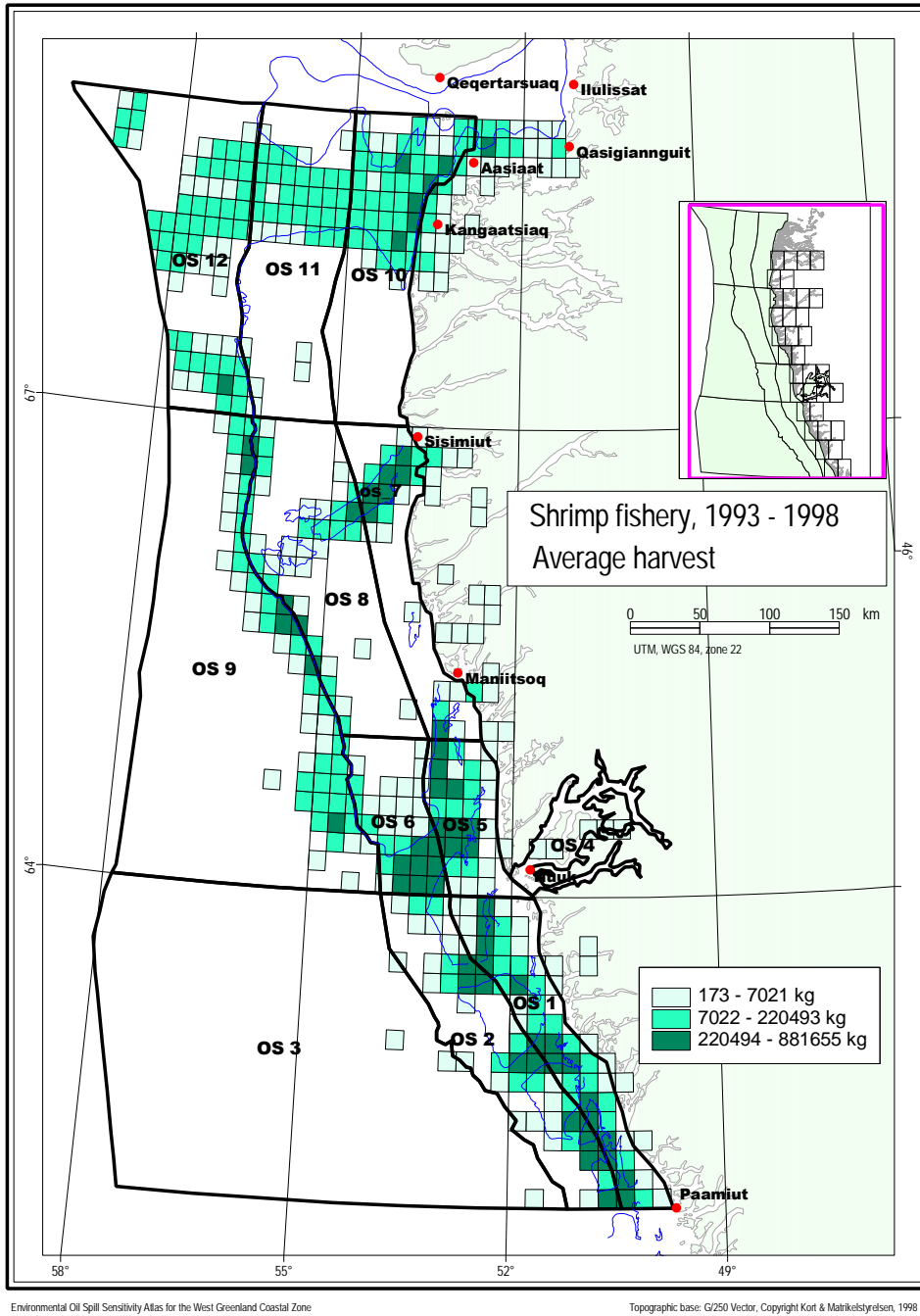


Figure 8.3. Distribution of deep sea shrimp catches off West Greenland. Average annual catches 1993 - 1998. Based on data from GINR.

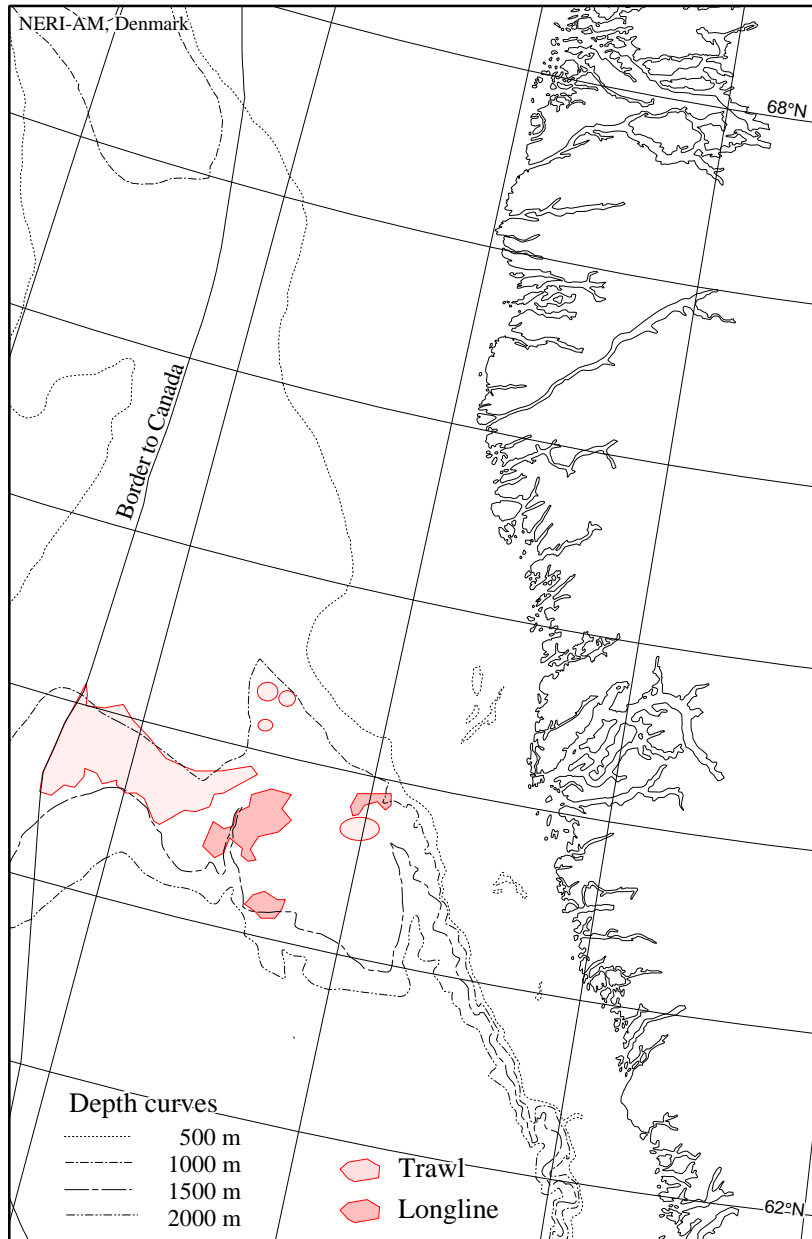


Figure 8.4. The offshore trawl and longline fishing areas for Greenland halibut in 1998. Based on data from GINR.

Lumpsucker and capelin are coastal spawners, and capelin are found inshore during most of the year. During summer, Arctic char also feed in coastal waters. **[Capelin maps]**
[Lumpsucker maps] **[Arctic char maps]**

In recent years, new resources have been exploited, and the most successful are scallop **[fishery]** and snow crab **[fishery]**, which both are utilised in several areas now.

8.1.6 Seabirds

The study area (62° N - 68° N) is rich in seabirds with many species adapted to different ecological niches.

Some species feed predominately on fish, such as the Brünnich's guillemot (during summer, outer coast and offshore) and cormorants (coastal and fjords), some are surface plankton feeders like the kittiwakes, and some are bottom feeders like eiders (hard bottom) and king eiders (soft bottom). The largest seabird populations are present in the area during winter, therefore the significance of the open water area during the winter season is unique.

Spring

From April through to June, when the ice starts to break up further north, large numbers of birds which winter in the Open Water Area move out of the study area. King eiders head for breeding areas mainly in the western Canadian Arctic, common eiders to breeding areas along the Canadian and Greenland coast, little auks to the huge colonies in Thule (Avanersuaq) and Brünnich's guillemots to the large colonies in the northern Baffin Bay as well as Svalbard, Canada, Russia and possibly Iceland.

Large numbers of kittiwakes and fulmars, which winter to the south of Greenland, also pass through the area on their way to colonies further north, leaving the area to local breeders and summering non-breeders.

Summer

There are 14 species of colony breeding seabirds in the area (62° N - 68° N) (Figure 8.5). The most important colonies in the outer coastal zone are the Brünnich's guillemots colony and a number of puffin colonies in the area south of Godthåb Fjord. More than half of the Greenland razorbill population breeds in small colonies (< 100 pairs) in the coastal zone in the area. The most numerous breeding species in the study area are the kittiwake. The kittiwake colonies are mainly situated in fjords some distance from the outer coast, like most of the glaucous gull and especially Iceland gull colonies. There are many small colonies of black guillemot along the outer coast. There are also small colonies of cormorant, arctic tern, razorbill and eider near the outer coast, as well as dispersed breeders of common eider and great black-backed gull.

In July/August, post-breeders of several duck species gather in the coastal zone for moulting and feeding. **[distribution]**. They remain unable to fly in these areas for 3-4 weeks. Small common eider flocks, both females and immatures and flocks of moulting males, are scattered in the archipelagos along the outer coast. Ikkatooq fjord, in the southern Nuuk municipality, supports a large concentration of moulting red-breasted mergansers **[distribution]**. A surprisingly high number of harlequin ducks use the rocky shores south of the Godthåb Fjord mouth in the post-breeding season **[distribution]**.

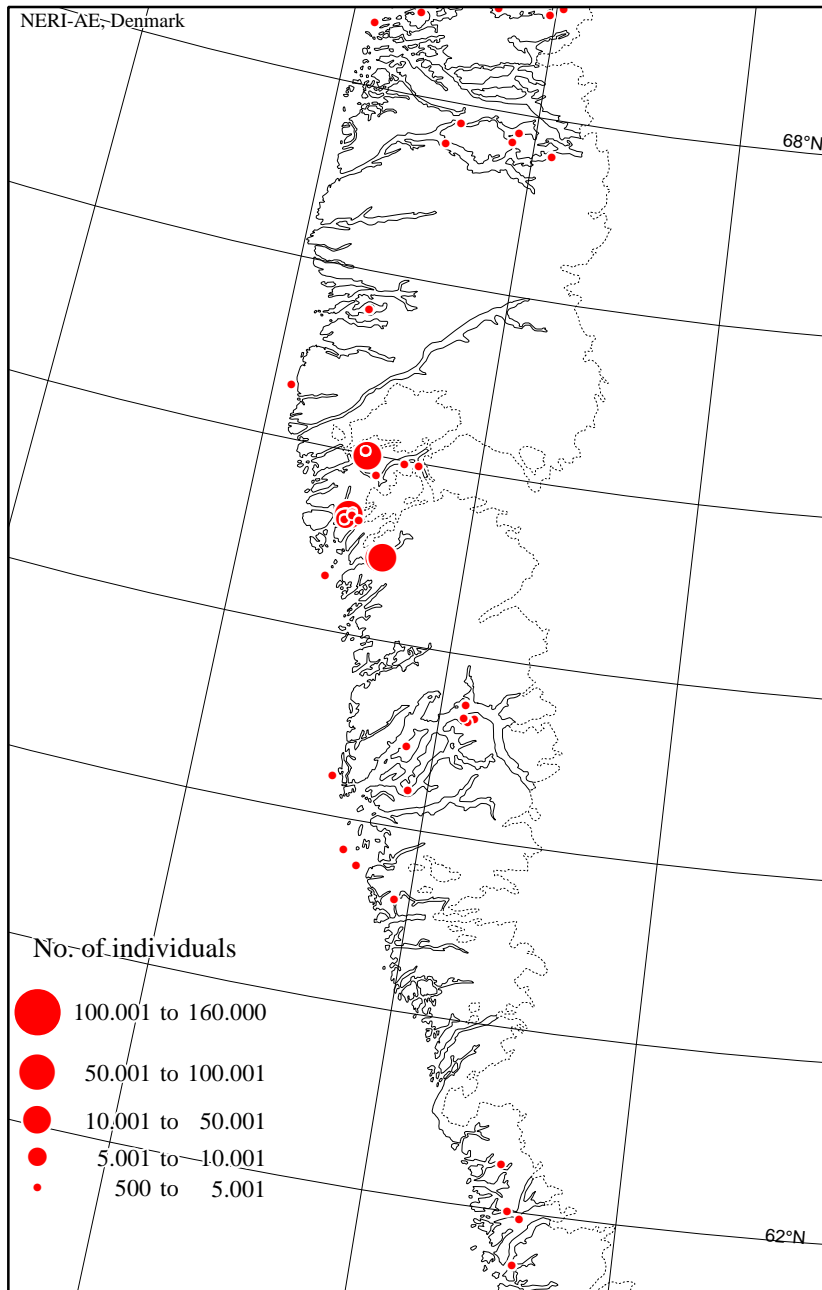


Figure 8.5. Distribution and size of seabird breeding colonies in West Greenland. Only colonies with more than 500 individuals included.

During the summer, the offshore density of seabirds is low compared to the autumn and winter period. In the summer, it is mainly long-range-foraging or non-breeding fulmars and gulls (kittiwake, glaucous gull and Iceland gull) which occur offshore. Brünnich's guillemots and puffins from local colonies and non-breeders also forage outside the fjord mouth and on the banks. Flocks of several thousand great shearwaters may occur on the banks and along the coast from July; they breed in the southern hemisphere and spend the southern winter in the North Atlantic.

Autumn and winter

During the autumn, concentrations of different seabird species build up on the banks of the study area. Brünnich's guillemots arrive from the colonies further north and little auks from the colonies in Thule (Avanersuaq), supplemented with large numbers of Brünnich's guillemots from breeding colonies in Svalbard, Canada and possibly Iceland.

Table 8.6. Seabird occurrence and activity in the coastal zone and offshore areas between 62° N and 68° N.

| Species | Occurrence | | Distribution |
|-------------------------|---------------|---|--------------------------------------|
| Fulmar | b/s/w | Year-round | c & o |
| Great shearwater | s | July-October | c & o |
| Cormorant | b/s/w | Year-round | c, mainly northern part in summer |
| Common eider | b/s/m/w | Year-round | c |
| King eider | (m, few) w | August - September October - May | c c & banks in w |
| Long-tailed duck | b/m/w | Year-round | c & banks in w? |
| Red-breasted merganser | b/m/w | Year-round | c |
| Harlequin duck | m w | August - September September - April | c (rocky shores) c (rocky shores) |
| Kittiwake | b/s/(w) | Year-round, few in winter | c & o foraging |
| Glaucous gull | b/s/w | Year-round | c & o |
| Iceland gull | b/s/w | Year-round | c & o |
| Great black-backed gull | b/s/w | Year-round | c & o |
| Arctic tern | b | May - September | c |
| Brünnich's guillemot | b/s/w | Year-round | c & o |
| Atlantic guillemot | b/w | Year-round | c & o |
| Razorbill | b/w | Year-round | c & o |
| Puffin | b/w | Year-round | c & o |
| Black guillemot | b/w | Summer Winter | c c & o |
| Little auk | (b) w | May - August September - May | c & o o |
| White-tailed eagle | b/w | Year-round | c |

Categories of occurrence: b: breeding, s: summering, m: moulting, w: wintering. **Categories of distribution:** c: coastal, o: offshore.

As the ice covers the sea in Baffin Bay and Disko Bay in December, common eiders and king eiders from Arctic Canada and high arctic Greenland move south to the Open Water Area for the winter. Both species occur in large concentrations: king eiders (Figure 8.6) mainly in shallow water (< 50 m) on the banks, particularly Store Hellefiskebanke, while common eiders are found along the coasts.

Generally, the largest seabird populations are believed to be present in the area during winter.

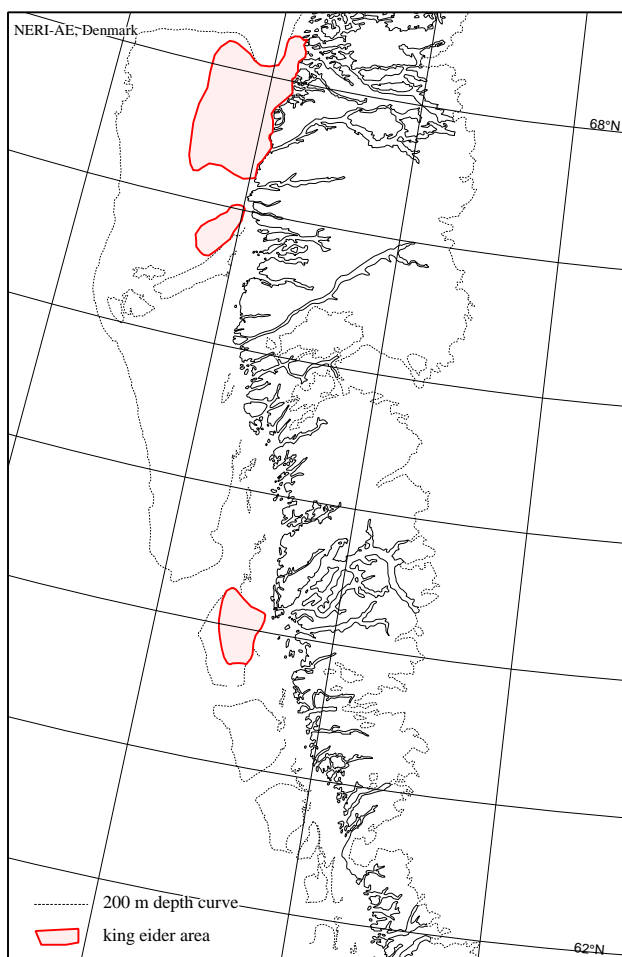


Figure 8.6. Important winter habitats for king eider in West Greenland.

8.1.7 Marine mammals

The study area (62° N - 68° N) is important to many marine mammal species. Table 8.7 gives an overview of the species. Bowhead whales **[distribution]**, narwhals, white whales **[distribution]** and walrus **[distribution]** inhabit the pack ice as late as March and April. Late March the hooded seals give birth to their young on the ice on whelping grounds in the central Davis Strait between 62° N and 65° N **[whelping]**. Bearded seals concentrate during winter in the northern part of the area **[concentration]**. As the ice starts to break up, the ice associated animals moves further north. In May-June, minke, humpback, fin whale and blue whale arrive in the area from the south. Ringed seals occur throughout the year, but are usually associated with ice. Harp and hooded seals start their migration along the West Greenland coasts in May-June and stay until October, although many harp seals stay throughout the winter. Details on these patterns are summarised in Table 8.7.

Table 8.7. Overview of marine mammals present in the study area in the eastern Davis Strait (62° N - 68° N).

| Species | Period | Main habitat | Stock size in the area/ occurrence | Protection / exploitation | Species status (IUCN 1996 categories) |
|------------------|------------------|------------------------------------|------------------------------------|---------------------------|---------------------------------------|
| Bowhead whale | Dec – June | Drift ice/ice edge | Few tens | Protected (1940) | Vulnerable* |
| Minke whale | April -November | whole area | 4600 | Hunting regulated | Lower risk |
| Sei whale | July - October | offshore waters | rare | Protected (1977) | Endangered |
| Humpback whale | July -November | Edge of banks | 400 | Protected (1986) | Vulnerable |
| Fin whale | June - October | Edge of banks | <2 000 | Hunting regulated | Endangered |
| Blue whale | June - October | Edge of banks | Few | Protected (1966) | Vulnerable* |
| Harbour porpoise | Whole year | Whole area | Common | Hunting unregulated | Vulnerable |
| Bottlenose whale | (June - August) | Deep water | Few | Protected (1978) | Lower risk |
| Narwhal | December - April | Pack ice/deep water | Few | Hunting unregulated | Unknown |
| White whale | November - May | Drift ice on banks | Some thousands | Hunting regulated | Vulnerable |
| Pilot whale | July - October | Deep waters, edge of banks | Fluctuating | Hunting unregulated | Lower risk |
| Killer whale | Whole year | Whole area | Rare | Hunting unregulated | Lower risk |
| Sperm whale | May -November | Deep water | Few | Protected (1985) | Vulnerable |
| Harp seal | June-October | Whole area | 2-3 mill. | Hunting unregulated | Lower risk |
| Hooded seal | March -October | Whole area | Unknown | Hunting unregulated | Lower risk |
| Ringed seal | Whole year | Whole area, mainly fjords with ice | Common | Hunting unregulated | Lower risk |
| Harbour seal | Whole year | Coastal waters | Rare | Hunting regulated | Lower risk** |
| Bearded seal | Mainly winter | Drift ice | Common | Hunting unregulated | Lower risk |
| Walrus | February -May | Drift ice on banks | <500 | Hunting regulated | Lower risk |
| Polar bear | February -May | Drift ice, central Davis Strait | Rare | Hunting regulated | Lower risk |

* apply to the Northwest Atlantic stock, ** local population vulnerable

Some of the marine mammals, such as walrus and bearded seals feed on the bottom fauna. Ringed seals, harp seals and harbour seals feed on a broad range of pelagic prey items, whereas hooded seals mainly feed close to the bottom at great depths. Baleen whales feed on krill and smaller schooling fish species, which often are present in the productive upwelling areas of the banks at depths less than 200 m. Toothed whales cover a broader depth range. Harbour porpoises feed on fish in the upper water layers whereas some whales e.g. sperm whales and narwhals are deep divers capable of going down to depths more than 1,000 m to feed.

The only seal which hauls out on land in the study area is the harbour seal. Harbour seals occur in archipelagos, on remote skerries and also on the sand banks in the head of undisturbed fjords during summer time [important areas]. The harbour seal is, however, rare today.

8.1.8 Archaeological and historic sites

Based on our present knowledge, Greenland seems to have been inhabited almost continuously since 4500 BP. Evidence of the various prehistoric cultures and settlements and use of resources are found almost everywhere along the Greenland coasts. Between 62° N and 68° N - approximately 700 km's in direct line - around 1400 archaeological "sites" are recorded close to the coast. In the present context, "sites" are defined as any evidence of prehistoric and historic man's activities that are protected by the Greenland Conservation Act.

The environment along the mapped coastline is highly diverse. These varying conditions provide very different possibilities for human settlement and patterns of use depending on the particular groups traditions and cultural preconditions.

While the outer coastal areas and the mouth of the large productive fjords provided the survival basis of the early Inuit hunting societies, the relatively mild (in terms of climate) and fertile areas along the fjords in south Greenland were the prerequisite for the existence of Norse farms during several centuries. The Thule-people migrated from Canada into Greenland around AD 1300 and constitute the direct ancestors of the present day Inuit of Greenland. The earliest Thule-people, who were primarily whale hunters, were far more mobile than the earlier Inuit inhabitants of Greenland. Soon after their arrival to Greenland their activities encompassed all of Greenland's west coast and the majority of the east coast. The complex settlement-patterns of the Thule-people, the historic Inuit and their predecessors are reflected in the archaeological record and their distribution can be seen on the shoreline sensitivity maps.

The sensitivity to oil spills of archaeological interests are expressed on a scale from 1 to 3:

- #1 Sites unlikely to be directly or indirectly vulnerable to marine oil spills: In total 375 sites, which are not included on the sensitivity maps,
- #2 Sites that are either directly or indirectly vulnerable to marine oil spills: In total 883 sites,
- #3 Sites of significant importance, directly or indirectly vulnerable to marine oil spills, and demanding special measures taken in case of an oil spill: In total 96 sites.

8.2 Areas of Extreme and High Sensitivity

Figure 8.7 shows an overview of the shoreline areas of extreme (red) and high (yellow) sensitivity to marine oil spills. In total there are 40 areas of extreme sensitivity and 72 of high sensitivity.

The map includes also the special status areas which can be affected by a marine oil spill. These comprise only the so called Ramsar-areas, wetlands of international importance especially as waterfowl habitats designated according to the Ramsar convention ((National Forest and Nature Agency 1996).

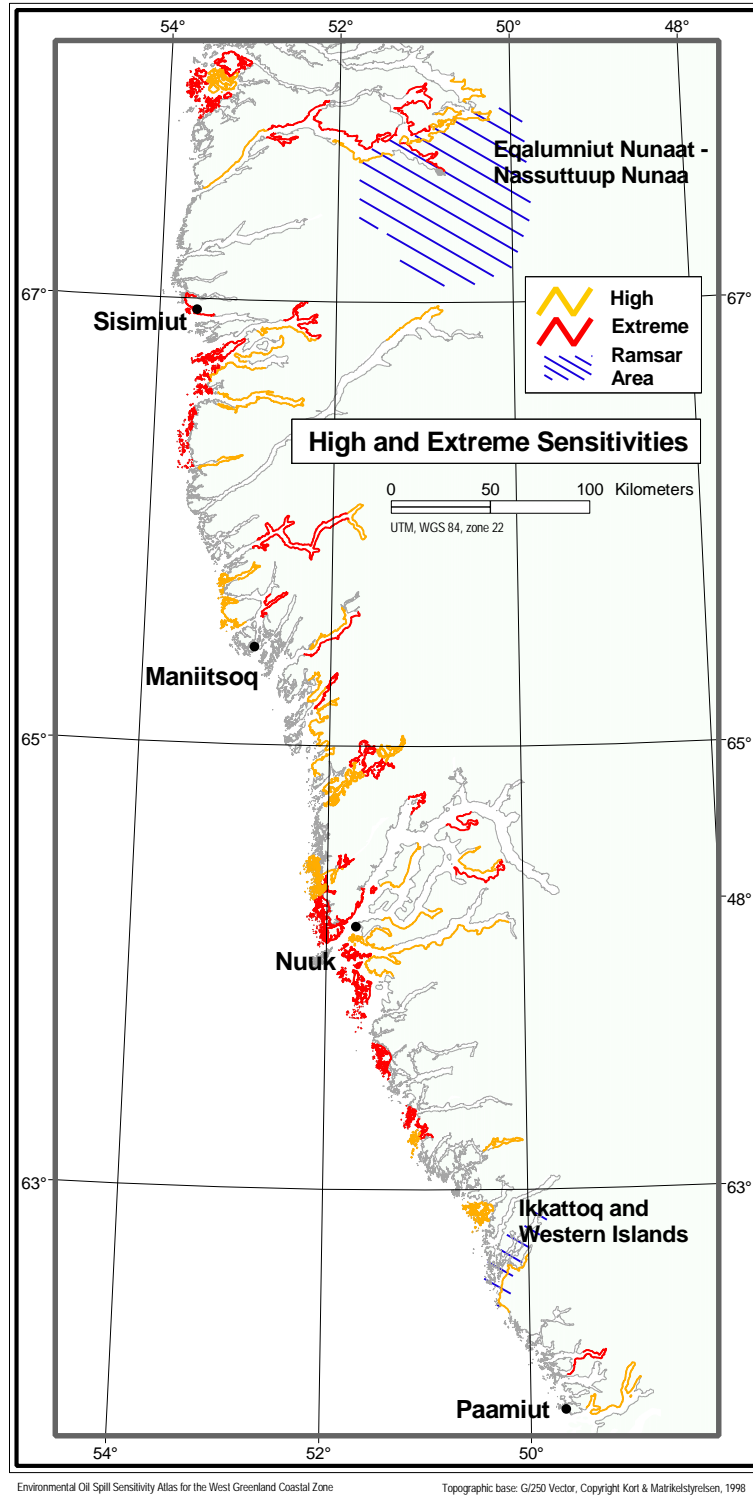


Figure 8.7 Areas of extreme and high sensitivity, and special status areas (Ramsar)








8.3 Offshore sensitivity

This chapter presents the four maps showing the sensitivity of the offshore areas between 62° N and 69° N for each of the seasons, winter, spring, summer and autumn.




See Chapter 7, Users Guide for further information on map interpretation.

Legend to the offshore maps (Figures 8.8-8.11):





Offshore Species

-  Al Alcids
-  Ba Baleen whales
-  Be Bearded seals
-  Co Cormorants
-  De Deep sea shrimps
-  Gh Greenland Halibuts
-  Gu Gulls
-  Sc Scallops
-  Se Seaducks
-  Tu Tubenoses
-  Wh White whales
-  Ho Hooded seals
-  Wa Walrus

Offshore Resources Use

-  R Human Use
-  Communitites
-  Sea depth (200 meters)

Offshore Areas Sensitivity Ranking

-  Extreme (> 70)
-  High (50 - 70)
-  Moderate (35 - 50)
-  Low (< 35)

Offshore Sensitivity Winter (January - March)

Environmental Description (Figure 8.8)

Offshore area 1 (os 1): *Resource use (R os 1):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months; hunting for Brünnich's guillemots takes place near the coast. *Species occurrence:* Seabirds occur with alcids (**Al os 1**) mainly Brünnich's guillemots, which may occur in large concentrations and also little auks; with gulls (**Gu os 1**); with king eiders (**Se os 1**) in areas with water depths less than 50 m; and with northern fulmars (**Tu os 1**). Large stocks of deep sea shrimp (**De os 1**) occur in waters 100 to 600 m deep.

Offshore area 2 (os 2): *Resource use (R os 2):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 2**) mainly Brünnich's guillemots and little auks; and with gulls (**Gu os 2**) which are widespread in the area. Large stocks of deep sea shrimp (**De os 2**) occur in waters 100 to 600 m deep.

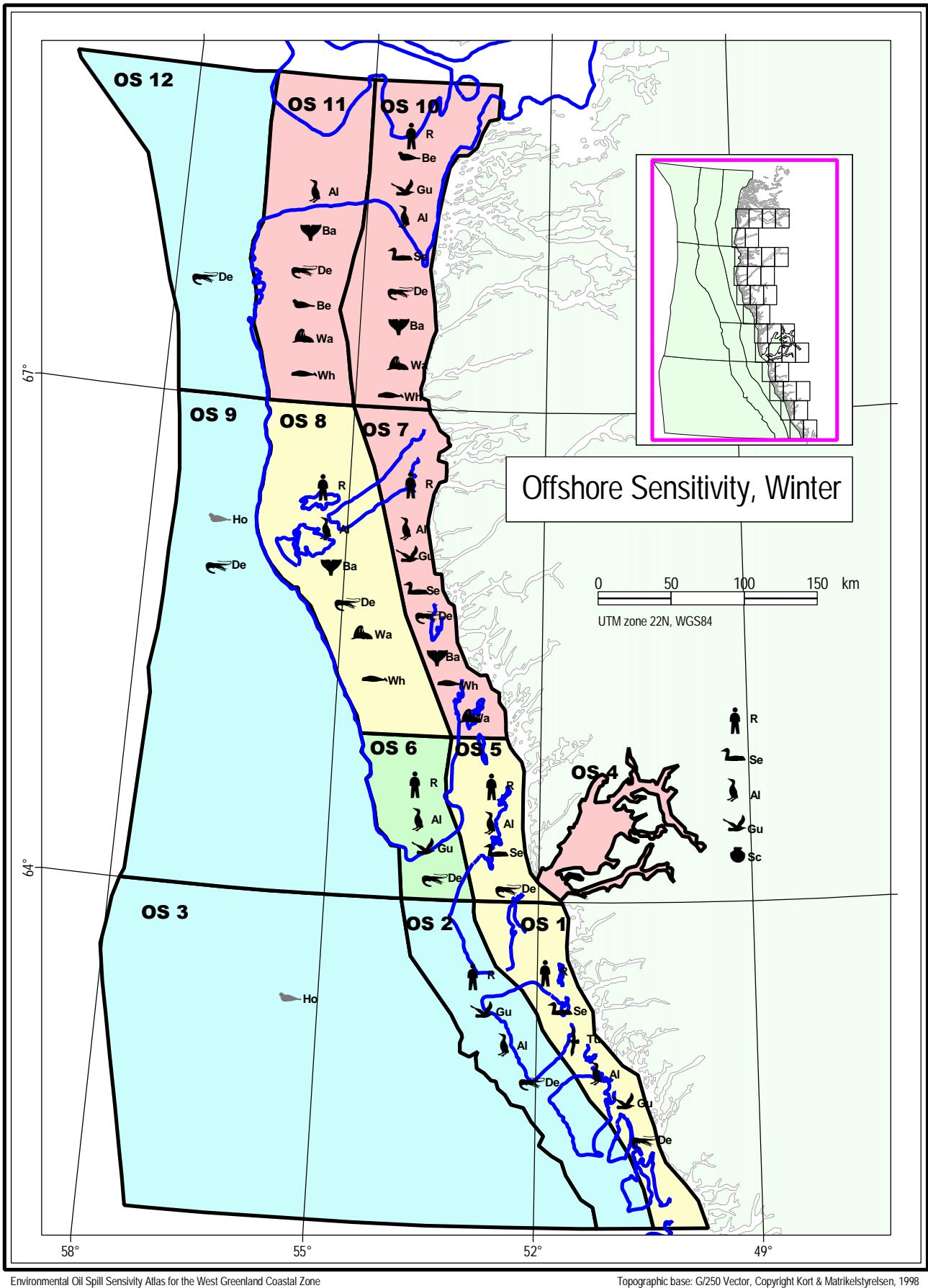
Offshore area 3 (os 3): *Resource use:* Not significant, why no icon on map. Longline and trawl fishery for Greenland halibut takes place in the northern part of the area; some fishery for deep sea shrimp takes place along the eastern border of the area. *Species occurrence:* Among the marine mammals hooded seals (**Ho os 3**) assemble in a whelping area in the driftice from March; the position of this area is highly dynamic and follows the movements of the ice. The whelping area may occur as far south as 61° 45' N.

Offshore area 4 (os 4): *Resource use (R os 4):* Extensive fishery for scallop takes place among the islands south of Nuuk, most extensively January to May and September to December; fishery for halibut and redfish takes place at several sites in the fjord system, important hunting areas for both seals and seabirds (Brünnich's guillemots and eiders) are located in the mouth of Godthåb Fjord. *Species occurrence:* Seabirds occur with alcids (**Al os 4**) mainly Brünnich's guillemots and little auks; and with gulls (**Gu os 4**) which are widespread in the area; and with seaducks (**Se os 4**) of which common eiders, king eiders and long-tailed ducks are widespread in the fjord. Large scallop banks (**Sc os 4**) are found in areas with strong currents.

Offshore area 5 (os 5): *Resource use (R os 5):* Important deep sea shrimp fishery takes place, most extensively during the summer months. Hunting areas for Brünnich's guillemots are located near the coast during autumn and winter. *Species occurrence:* Seabirds occur with alcids (**Al os 5**) mainly Brünnich's guillemots, which may occur in large concentrations, also little auks; and with gulls (**Gu os 5**) which are numerous and widespread in the area; with seaducks (**Se os 5**) mainly king eiders in areas with water depths less than 50 m. Large stocks of deep sea shrimp (**De os 5**) are found in waters between 100 and 600 m deep.

Offshore area 6 (os 6): *Resource use (R os 6):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 6**) mainly Brünnich's guillemots, which may occur in large concentrations and also little auks; and with gulls (**Gu os 6**) which are widespread in the area. Large stocks of deep sea shrimp (**De os 6**) are found in waters between 100 and 600 m deep.

Offshore area 7 (os 7): *Resource use (R os 7):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months; hunting areas for Brünnich's guillemots are located near the coast during autumn and winter. *Species occurrence:* Seabirds occur with alcids (**Al os 7**) mainly Brünnich's guillemots and black guillemots; with gulls (**Gu os 7**); and with concentrations of king eiders (**Se os 7**) in areas with water depth less than 50 m. Among the marine mammals, bowhead whales (**Ba os 7**) occur in the northwestern part; white whales (**Wh os 7**) may occur in important concentrations in the central and northern part of the area; and walrus (**Wa os 7**) have an important winter habitat in the northwestern part from February. Large stocks of deep sea shrimp (**De os 7**) are found in waters 100 to 600 m deep.



Environmental Oil Spill Sensitivity Atlas for the West Greenland Coastal Zone

Topographic base: G/250 Vector, Copyright Kort & Matrikelstyrelsen, 1998

Figure 8.8. Offshore sensitivity in winter. Legend to map on page 8-17.

Offshore area 8 (os 8): *Resource use (R os 8):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 8**) mainly Brünnich's guillemots and black guillemots. Among the marine mammals, bowhead whales (**Ba os 8**) occur in the northwestern part; and white whales (**Wh os 8**) may occur in important concentrations in the central eastern and northeastern part of the area; and walrus (**Wa os 8**) have an important winter habitat in the northeastern part. Stocks of deep sea shrimp (**De os 8**) are found in waters 100 to 600 m deep.

Offshore area 9 (os 9): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Among the marine mammals, hooded seals (**Ho os 9**) assemble in a whelping area in the driftice in March and April in the southeastern part of the area; the position of this area is highly dynamic, as it follows the movements of the ice and may be situated as far north as 64° 45' N. Stocks of deep sea shrimp (**De os 9**) are found in waters 100 to 600 m deep.

Offshore area 10 (os 10): *Resource use (R os 10):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 10**) mainly Brünnich's guillemots and black guillemots; with gulls (**Gu os 10**); and with concentrations of king eiders (**Se os 10**) in areas with water depth less than 50 m. Among the marine mammals, bowhead whales (**Ba os 10**) occur mainly in the northern part; white whales (**Wh os 10**) may occur in important concentrations throughout the area; bearded seals (**Be os 10**) assemble in the central part of the area; and walrus (**Wa os 10**) have an important winter habitat in the central and southern part of the area from February. Large stocks of deep sea shrimp (**De os 10**) are found in waters 100 to 600 m deep.

Offshore area 11 (os 11): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Seabirds occur with alcids (**Al os 11**) mainly Brünnich's guillemots and black guillemots; Among the marine mammals, bowhead whales (**Ba os 11**) occur mainly in the northern part; white whales (**Wh os 11**) may occur in important concentrations mainly in the central eastern and southeastern part of the area; bearded seals (**Be os 11**) assemble in the central part of the area; and walrus (**Wa os 11**) have an important winter habitat in the central and southern part of the area from February. Stocks of deep sea shrimp (**De os 11**) are found in waters 100 to 600 m deep.

Offshore area 12 (os 12): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Stocks of deep sea shrimp (**De os 12**) are found in waters 100 to 600 m deep.

Offshore Sensitivity Summary, Winter

| Area | Sensitivity value | Ranking |
|-------|-------------------|----------|
| os 1 | 62 | High |
| os 2 | 32 | Low |
| os 3 | 32 | Low |
| os 4 | 97 | Extreme |
| os 5 | 56 | High |
| os 6 | 36 | Moderate |
| os 7 | 97 | Extreme |
| os 8 | 62 | High |
| os 9 | 33 | Low |
| os 10 | 111 | Extreme |
| os 11 | 71 | Extreme |
| os 12 | 18 | Low |

Offshore Sensitivity Spring (April - May)

Environmental Description (Figure 8.9)

Offshore area 1 (os 1): *Resource use (R os 1):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. Hunting areas for Brünnich's guillemots near the coast mainly during autumn and winter. *Species occurrence:* Seabirds occur with alcids (**Al os 1**), mainly Brünnich's guillemots; with gulls (**Gu os 1**) which all are widespread in the area; with seaducks (**Se os 1**) mainly king and common eiders; and with northern fulmars (**Tu os 1**). Large stocks of deep sea shrimp (**De os 1**) occur in waters 100 to 600 m deep.

Offshore area 2 (os 2): *Resource use (R os 2):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur mainly with gulls (**Gu os 2**) and northern fulmars (**Tu os 2**), all widespread in the area. Large stocks of deep sea shrimp (**De os 2**) occur in waters 100 to 600 m deep.

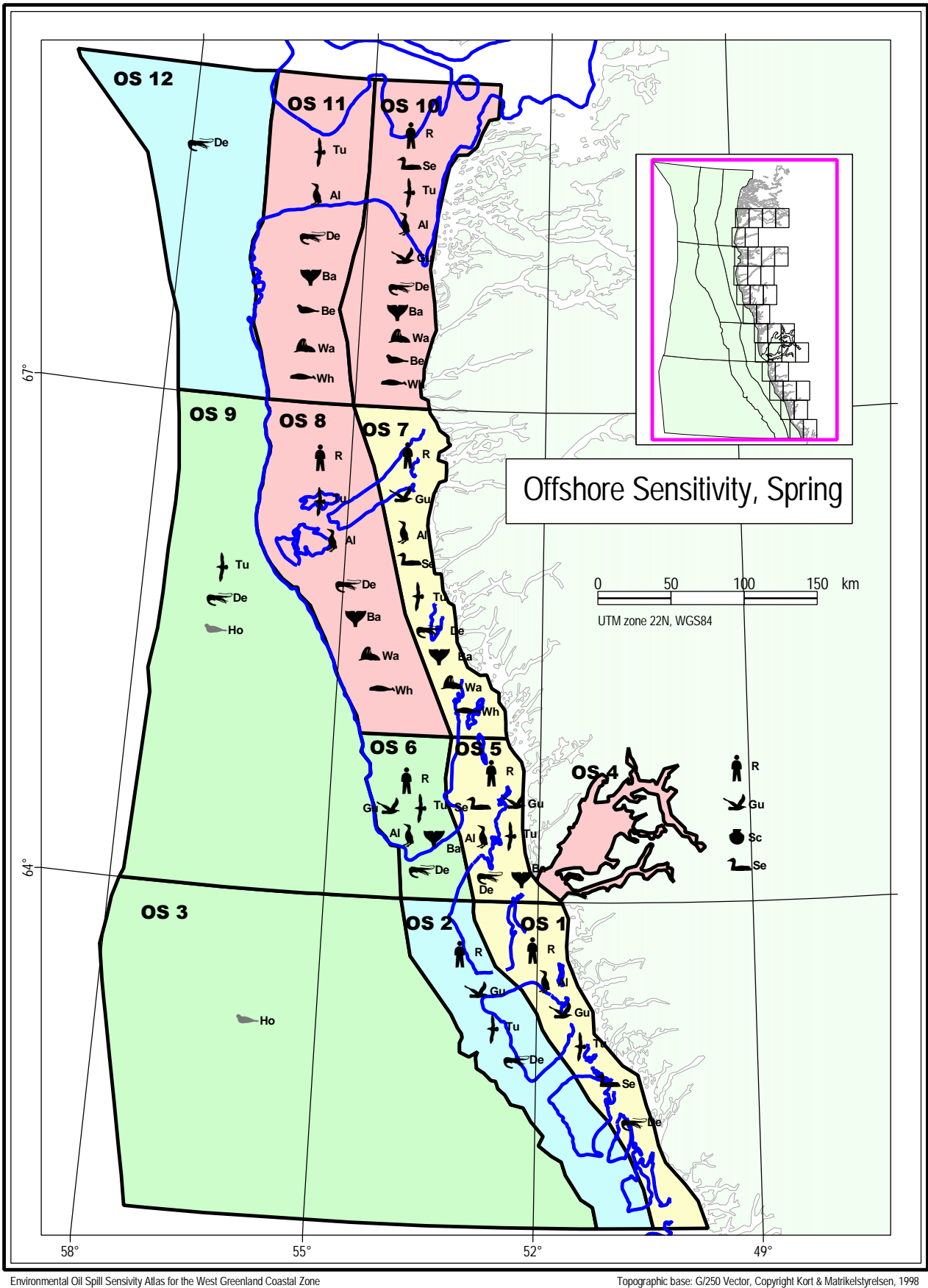
Offshore area 3 (os 3): *Resource use:* Not significant, why no icon on map. Longline and trawl fishery for Greenland halibut at depth between 1000 and 1500 m takes place in the northern part. Moderate fishery for deep sea shrimp takes place along the eastern border of the area. *Species occurrence:* Among the marine mammals hooded seals (**Ho os 3**) assemble in a whelping area in the driftice in March and April in the northwestern part of the area; the position of this area is highly dynamic and follows the movements of the ice, and may occur as far south as 61° 45' N.

Offshore area 4 (os 4): *Resource use (R os 4):* Important fishery for scallop takes place between the islands southwest of Nuuk, most extensively January to May and September to December; fishery for halibut and redfish takes place at several sites in the fjord system; important hunting areas for both seals and seabirds (Brünnich's guillemots and eiders) are located in mouth of Godthåb Fjord and at several sites in the fjord system. *Species occurrence:* Seabirds occur with gulls (**Gu os 4**) which are widespread in the area; and with seaducks (**Se os 4**) mainly common eiders and long-tailed ducks. Large scallop banks which are utilised (**Sc os 4**) are found among the islands south of Nuuk.

Offshore area 5 (os 5): *Resource use (R os 5):* Important deep sea shrimp fishery takes place in the area, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 5**) mainly Brünnich's guillemots; with gulls (**Gu os 5**) and northern fulmars (**Tu os 5**) which all are widespread in the area; and with seaducks (**Se os 5**) mainly king eiders in areas with water depth less than 50 m. Among the marine mammals baleen whales (**Ba os 5**) occur mainly with minke whales. Large stocks of deep sea shrimp (**De os 5**) occur in waters 100 to 600 m deep.

Offshore area 6 (os 6): *Resource use (R os 6):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 6**) mainly Brünnich's guillemots and little auks; with gulls (**Gu os 6**) and northern fulmars (**Tu os 6**) which all are widespread in the area. Among the marine mammals baleen whales (**Ba os 6**) occur mainly with minke whales. Large stocks of deep sea shrimp (**De os 6**) occur in waters 100 to 600 m deep.

Offshore area 7 (os 7): *Resource use (R os 7):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 7**) mainly Brünnich's guillemots; with gulls (**Gu os 7**) and northern fulmars (**Tu os 7**) which all are widespread in the area; and with seaducks (**Se os 7**) mainly king eiders in areas with water depth less than 50 m. Among the marine mammals baleen whales (**Ba os 7**) such as bowhead whales occur in the northwestern part in May and minke whales occur from May; white whales (**Wh os 7**) occur with important concentrations in the central and northern part of the area; and walrus (**Wa os 7**) have an important winter habitat in the northwestern part until May. Large stocks of deep sea shrimp (**De os 7**) occur in waters 100 to 600 m deep.



Environmental Oil Spill Sensitivity Atlas for the West Greenland Coastal Zone

Topographic base: G/250 Vector, Copyright Kort & Matrikelstyrelsen, 1998

Figure 8.9. Offshore sensitivity in spring. Legend to map on page 8-17.

Offshore area 8 (os 8): *Resource use (R os 8):* Deep sea shrimp fishery takes place along the edges of the shallow banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 8**) mainly Brünnich's guillemots and with northern fulmars (**Tu os 8**). Among the marine mammals baleen whales (**Ba os 8**) occur with bowhead whales in the northwestern part in May and minke whales from May; white whales (**Wh os 8**) may occur with important concentrations in the central eastern and northeastern part of the area; and walrus (**Wa os 8**) have an important winter habitat in the northeastern part. Stocks of deep sea shrimp (**De os 8**) occur in waters 100 to 600 m deep.

Offshore area 9 (os 9): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Seabirds occur with northern fulmar (**Tu os 9**) which are wide spread. Among the marine mammals hooded seals (**Ho os 9**) have a whelping area in the driftice in March and April in the southeastern part of the area. The position of this area is highly dynamic and follows the movements of the ice, and may reach as far north as 64°45' N. Stocks of deep sea shrimp (**De os 9**) occur in waters 100 to 600 m deep.

Offshore area 10 (os 10): *Resource use (R os 10):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 10**) mainly Brünnich's guillemots; with gulls (**Gu os 10**) and northern fulmars (**Tu os 10**) all widespread in open water areas; and with king eiders (**Se os 10**) mainly in waters less than 50 m deep. Among the marine mammals baleen whales (**Ba os 10**) occur with bowhead whales in the northern part and from May also minke whales throughout the area; white whales (**Wh os 10**) may occur in important concentrations; bearded seals (**Be os 10**) occur in important concentrations the central part of the area; and walrus (**Wa os 10**) have an important winter habitat in the central and southern part of the area until May. Large stocks of deep sea shrimp (**De os 10**) occur in waters 100 to 600 m deep.

Offshore area 11 (os 11): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Seabirds occur with alcids (**Al os 11**) mainly Brünnich's guillemots and black guillemots; and with northern fulmars (**Tu os 11**). Among the marine mammals baleen whales (**Ba os 11**) occur with bowhead whales in the northern part and from May also minke whales throughout the area; white whales (**Wh os 11**) may occur in important concentrations mainly in the central, eastern and southeastern parts of the area; bearded seals (**Be os 11**) occur in important concentrations the central part of the area; and walrus (**Wa os 11**) have an important winter habitat in the central and southern part of the area from February through May. Stocks of deep sea shrimp (**De os 11**) occur in waters 100 to 600 m deep.

Offshore area 12 (os 12): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Stocks of deep sea shrimp (**De os 12**) occur in waters 100 to 600 m deep.

Offshore Sensitivity Summary, Spring

| Area | Sensitivity value | Ranking |
|-------|-------------------|----------|
| os 1 | 55 | High |
| os 2 | 33 | Low |
| os 3 | 39 | Moderate |
| os 4 | 88 | Extreme |
| os 5 | 54 | High |
| os 6 | 38 | Moderate |
| os 7 | 61 | High |
| os 8 | 77 | Extreme |
| os 9 | 40 | Moderate |
| os 10 | 120 | Extreme |
| os 11 | 90 | Extreme |
| os 12 | 25 | Low |

Offshore Sensitivity Summer (June - August)

Environmental Description (Figure 8.10)

Offshore area 1 (os 1): *Resource use (R os 1):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. Salmon fishery takes place in the eastern parts during late summer. *Species occurrence:* Seabirds occur with alcids (**Al os 1**), mainly Brünnich's guillemots, puffins and razorbills from breeding colonies on the coast; with gulls (**Gu os 1**), mainly Iceland gulls and kittiwakes, also skuas in small numbers; and with tubenoses (**Tu os 1**) of which the most important are non-breeding great shearwaters occurring in large numbers in July and August. Among the marine mammals, baleen whales (**Ba os 1**) occur with humpback, fin and minke whales. Large stocks of deep sea shrimp (**De os 1**) occur in waters 100 to 600 m deep.

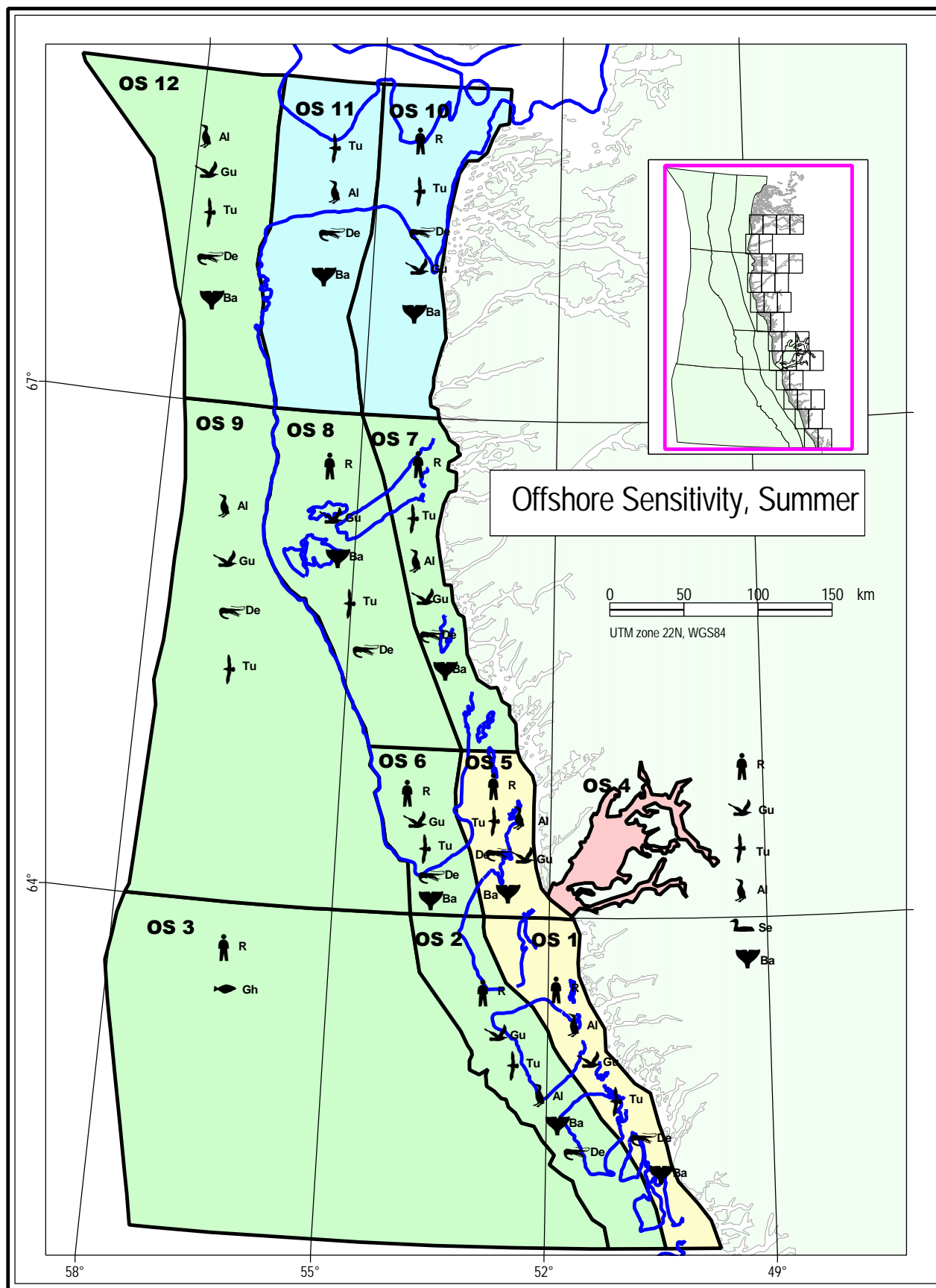
Offshore area 2 (os 2): *Resource use (R os 2):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 2**), mainly Brünnich's guillemots, puffins and razorbills from breeding colonies on the coast; with gulls (**Gu os 2**), mainly Iceland gulls and kittiwakes and also skuas in small numbers; and with tubenoses (**Tu os 2**) of which the most important are non-breeding great shearwaters occurring in large numbers in July and August. Among the marine mammals, baleen whales (**Ba os 2**) occur with humpback, fin and minke whales. Large stocks of deep sea shrimp (**De os 2**) occur in waters 100 to 600 m deep.

Offshore area 3 (os 3): *Resource use (R os 3):* Greenland halibut fishery with longlines takes place mainly in the area between 63° N and 64° N and 54° W and 56° W and trawl fishery mainly west of 57° W and north of 63° 30' N. Small amounts of deep sea shrimp are taken in the area. *Species occurrence:* Greenland halibut (**Gh os 3**) occur in large numbers in waters 1000 to 1500 m deep.

Offshore area 4 (os 4): *Resource use (R os 4):* Important fishery for scallop takes place between the islands south of Nuuk, most extensively January to May and September to December; fishery for halibut and redfish takes place at several sites in the fjord system; and the mouth of Godthåb Fjord is an important hunting area for seals. *Species occurrence:* Seabirds occur with alcids (**Al os 4**), mainly black guillemots and razorbills from breeding sites along the coast; with all species of gulls (**Gu os 4**) including Arctic terns and Arctic skuas; with seaducks (**Se os 4**), mainly common eiders and both moulting birds and birds from breeding colonies on the coast; and with Tubenoses (**Tu os 4**), mainly non-breeding great shearwaters in July and August and mainly in the westernmost parts. Among the marine mammals baleen whales (**Ba os 4**) occur with humpback, fin and minke whales.

Offshore area 5 (os 5): *Resource use (R os 5):* Important deep sea shrimp fishery takes place in the area, most extensively during the summer months; salmon fishery takes place in the eastern part of the area; the waters east and south east of Toqqusaq Banke are important hunting grounds for fin whale mainly from June. *Species occurrence:* Seabirds occur with alcids (**Al os 5**) mainly Brünnich's guillemots and puffins; gulls (**Gu os 5**) occur mainly with kittiwakes; and tubenoses (**Tu os 5**) occur with large concentrations of non-breeding great shearwaters and fulmars. Among the Marine mammals, baleen whales (**Ba os 5**) occur mainly with humpback whales, minke whales, fin whales and occasional blue whales. Large stocks of deep sea shrimp (**De os 5**) occur in waters 100 to 600 m deep.

Offshore area 6 (os 6): *Resource use (R os 6):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with gulls (**Gu os 6**), mainly kittiwakes; and with tubenoses (**Tu os 6**) such as great shearwaters in July and August and northern fulmars throughout the summer. Marine mammals are represented with baleen whales (**Ba os 6**), mainly humpback whales, minke whales, fin whales and occasional blue whales. Large stocks of deep sea shrimp (**De os 6**) occur in waters 100 to 600 m deep.



Environmental Oil Spill Sensitivity Atlas for the West Greenland Coastal Zone

Topographic base: G1250 Vector, Copyright Kort & Matrikelstyrelsen, 1998

Figure 8.10. Offshore sensitivity in summer. Legend to map on page 8-17.

Offshore area 7 (os 7): *Resource use (R os 7):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months; salmon fishery takes place in the eastern part of the area in late summer. *Species occurrence:* Seabirds occur with alcids (**Al os 7**), mainly Brünnich's guillemots; with gulls (**Gu os 7**), all species inclusive Arctic terns and Arctic skuas; and with tubenoses (**Tu os 7**) both great shearwaters in July and August and northern fulmars. Marine mammals are represented with baleen whales (**Ba os 7**) of which humpback whales, fin whales and minke whales are widespread. Large stocks of deep sea shrimp (**De os 7**) occur in waters 100 to 600 m deep.

Offshore area 8 (os 8): *Resource use (R os 8):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with gulls (**Gu os 8**) mainly kittiwakes, and with tubenoses (**Tu os 8**) mainly great shearwaters in August and northern fulmars throughout the summer. Marine mammals occur with baleen whales (**Ba os 8**) such as humpback whale, fin whale and minke whale. Stocks of deep sea shrimp (**De os 8**) occur in waters 100 to 600 m deep.

Offshore area 9 (os 9): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Seabirds occur with alcids (**Al os 9**) mainly Brünnich's guillemots; with gulls (**Gu os 9**), mainly kittiwakes; and with tubenoses (**Tu os 9**), mainly northern fulmars. Stocks of deep sea shrimp (**De os 9**) occur in waters 100 to 600 m deep.

Offshore area 10 (os 10): *Resource use (R os 10):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months; salmon fishery takes place in the eastern part in late summer. *Species occurrence:* Seabirds occur with gulls (**Gu os 10**), all species incl. Arctic terns and Arctic skuas; and with tubenoses (**Tu os 10**) mainly northern fulmars. Marine mammals occur with baleen whales (**Ba os 10**) such as fin whale and minke whale. Large stocks of deep sea shrimp (**De os 10**) occur in waters 100 to 600 m deep.

Offshore area 11 (os 11): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Seabirds occur with alcids (**Al os 11**) mainly Brünnich's guillemots, and tubenoses (**Tu os 11**) mainly northern fulmars. Marine mammals occur with baleen whales (**Ba os 11**) as fin whale and minke whale. Stocks of deep sea shrimp (**De os 11**) occur in waters 100 to 600 m deep.

Offshore area 12 (os 12): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Seabirds occur with alcids (**Al os 12**) mainly Brünnich's guillemots; and with gulls (**Gu os 12**) mainly kittiwakes; and tubenoses (**Tu os 12**) mainly fulmars. Marine mammals occur with baleen whales (**Ba os 12**) such as fin whale and minke whale. Stocks of deep sea shrimp (**De os 12**) occur in waters 100 to 600 m deep.

Offshore Sensitivity Summary, Summer

| Area | Sensitivity value | Ranking |
|-------|-------------------|----------|
| os 1 | 55 | High |
| os 2 | 42 | Moderate |
| os 3 | 46 | Moderate |
| os 4 | 96 | Extreme |
| os 5 | 54 | High |
| os 6 | 37 | Moderate |
| os 7 | 39 | Moderate |
| os 8 | 35 | Moderate |
| os 9 | 40 | Moderate |
| os 10 | 32 | Low |
| os 11 | 30 | Low |
| os 12 | 40 | Moderate |

Offshore Sensitivity Autumn (September - December)

Environmental Description (Figure 8.11)

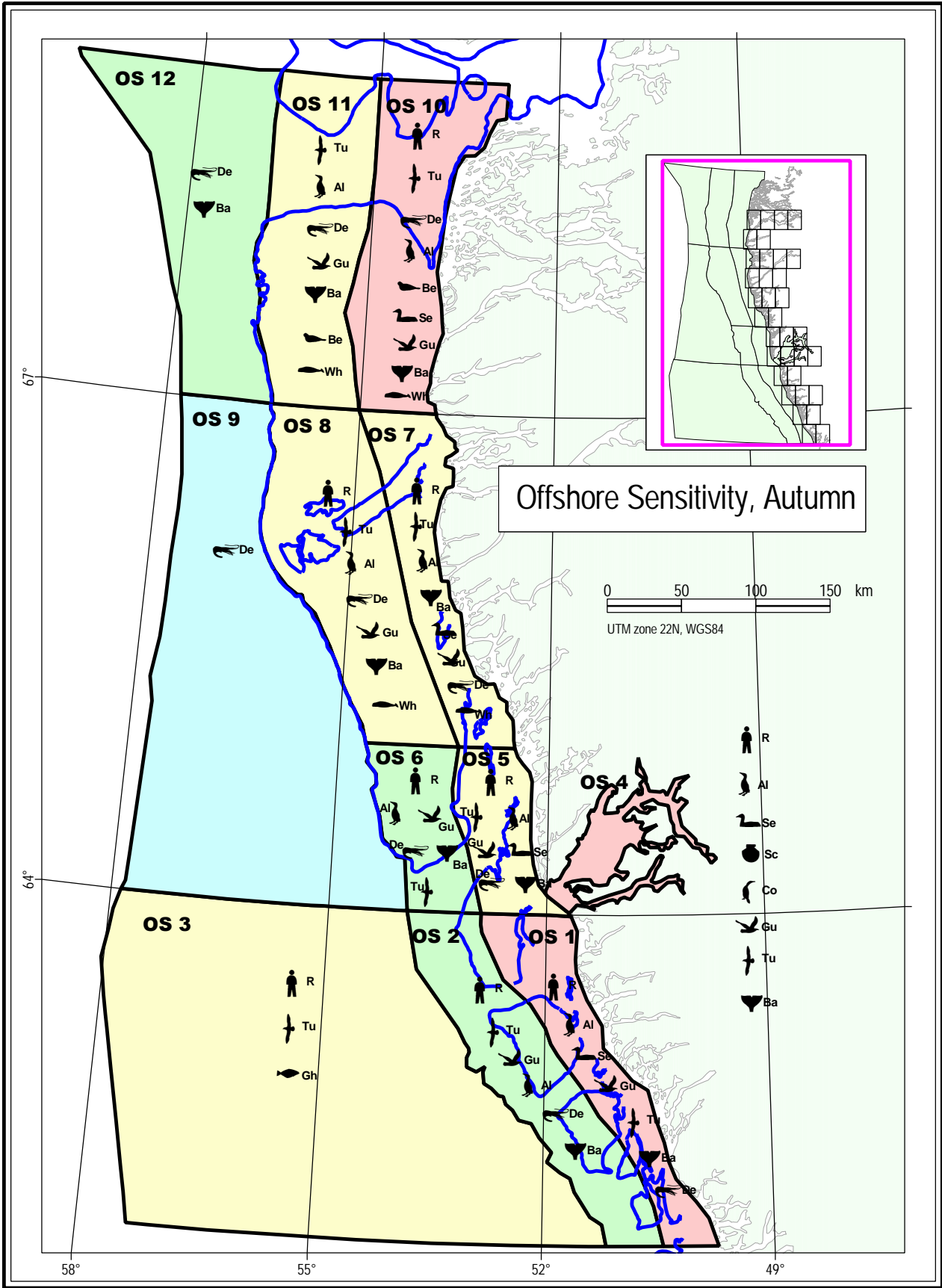
Offshore area 1 (os 1): Resource use (R os 1): Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. Salmon fishery takes place near the coast in early autumn. Hunting areas for Brünnich's guillemots are located near the coast from October. *Species occurrence:* Seabirds occur with alcids (**Al os 1**) mainly Brünnich's guillemots, but significant numbers of little auks and puffins may occur; with gulls (**Gu os 1**) mainly kittiwakes in decreasing numbers November and December; with king eiders (**Se os 1**) in December; and with tubenoses (**Tu os 1**) including northern fulmars throughout the season, great shearwaters in September and a few Leach's storm petrels October and November. Among the marine mammals baleen whales (**Ba os 1**) as humpback whales, minke whales and fin whales occur through October/November. Large stocks of deep sea shrimp (**De os 1**) occur in waters 100 to 600 m deep.

Offshore area 2 (os 2): Resource use (R os 2): Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 2**) mainly Brünnich's guillemots and little auks; with gulls (**Gu os 2**) mainly kittiwakes in decreasing numbers November and December; and with tubenoses (**Tu os 2**) as northern fulmars throughout the period, great shearwaters in September and a few Leach's storm petrels October and November. Among the marine mammals baleen whales (**Ba os 2**) occur with humpback whales, minke whales and fin whales through October/November. Large stocks of deep sea shrimp (**De os 2**) occur in waters 100 to 600 m deep.

Offshore area 3 (os 3): Resource use (R os 3): Greenland halibut fishery with longlines takes place mainly in the area between 63° N and 64° N and 54° W and 56° W and trawl fishery mainly west of 57° W and north of 63° 30' N. Some fishery for deep sea shrimp takes place along the eastern border of the area. *Species occurrence:* Seabirds occur with northern fulmars (**Tu os 3**) throughout the area. Greenland halibut (**Gh os 3**) occur in large numbers in waters 1000 to 1500 m deep.

Offshore area 4 (os 4): Resource use (R os 4): Extensive fishery for scallop takes place between the islands southwest of Nuuk, most extensively January to May and September to December; fishery for halibut and redfish takes place at several sites in the fjord system; important hunting areas for both seals and seabirds (Brünnich's guillemots and eiders) are located in the mouth of Godthåb Fjord. *Species occurrence:* Seabirds occur with alcids (**Al os 4**) mainly Brünnich's guillemots usually in the westernmost part of the area; with great cormorants (**co os 4**) mainly in the western part; with all species of gulls (**Gu os 4**); with common eiders (**Se os 4**) mainly in December; and with tubenoses (**Tu os 4**) mainly great shearwaters in September and northern fulmars. Marine mammals occur with baleen whales (**Ba os 4**) such as humpback whales, minke whales and fin whales usually until October/November. Large scallop occurrences are utilised (**Sc os 4**) in the mouth of Godthåb Fjord.

Offshore area 5 (os 5): Resource use (R os 5): Important deep sea shrimp fishery takes place in the area, most extensively during the summer months; salmon fishery takes place in the eastern part in early autumn; an important fin whale hunting ground are located east and south east of Toqqusaq Banke, hunting peaking in September; hunting for Brünnich's guillemots takes place near the coast during autumn and winter. *Species occurrence:* Seabirds occur with alcids (**Al os 5**) mainly Brünnich's guillemots and little auks; with gulls (**Gu os 5**) mainly kittiwakes in decreasing numbers through November and December; with seaducks (**Se os 5**) mainly king eiders from December; and with tubenoses (**Tu os 5**) as great shearwaters in September and northern fulmars. Among marine mammals baleen whales (**Ba os 5**) such as humpback whales, minke whales, fin whales and occasional blue whales until October/November. Large stocks of deep sea shrimp (**De os 5**) occur in waters 100 to 600 m deep.



Environmental Oil Spill Sensitivity Atlas for the West Greenland Coastal Zone

Topographic base: G/250 Vector, Copyright Kort & Matrikelstyrelsen, 1998

Figure 8.11. Offshore sensitivity in autumn. Legend to map on page 8-17.

Offshore area 6 (os 6): *Resource use (R os 6):* Important deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 6**) mainly Brünnich's guillemots and little auks; with gulls (**Gu os 6**) mainly kittiwakes in decreasing numbers through November and December; and with tubenoses (**Tu os 6**) mainly great shearwaters in September and northern fulmars. Among marine mammals baleen whales (**Ba os 6**) such as humpback whales, minke whales, fin whales and occasional blue whales until October/November. Large stocks of deep sea shrimp (**De os 6**) occur in waters 100 to 600 m deep.

Offshore area 7 (os 7): *Resource use (R os 7):* Deep sea shrimp fishery takes place along the edges of the banks in waters 100 to 600 m deep, most extensively during the summer months; salmon fishery in the eastern part in late summer and early autumn; hunting for Brünnich's guillemots takes place near the coast during autumn and winter. *Species occurrence:* Seabirds occur with alcids (**Al os 7**) mainly Brünnich's guillemots; with gulls (**Gu os 7**) mainly kittiwakes; with seaducks (**Se os 7**) mainly king eiders in the northern part; and with tubenoses (**Tu os 7**) mainly northern fulmars. Among marine mammals occur baleen whales (**Ba os 7**) such as humpback whales, fin whales and minke whales widespread until October/November; and white whales (**Wh os 7**) occur in important concentrations in the central and northern part of the area from November. Large stocks of deep sea shrimp (**De os 7**) occur in waters 100 to 600 m deep.

Offshore area 8 (os 8): *Resource use (R os 8):* Deep sea shrimp fishery takes place along the edges of the banks, most extensively during the summer months. *Species occurrence:* Seabirds occur with alcids (**Al os 8**) mainly Brünnich's guillemots; with gulls (**Gu os 8**) mainly kittiwakes; and with tubenoses (**Tu os 8**) mainly northern fulmars. Among marine mammals are baleen whales (**Ba os 8**) such as humpback whales fin whales and minke whales widespread until October/November; and white whales (**Wh os 8**) may occur in important concentrations in the central eastern and northeastern part of the area from November. Stocks of deep sea shrimp (**De os 8**) occur in waters 100 to 600 m deep.

Offshore area 9 (os 9): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Stocks of deep sea shrimp (**De os 9**) occur in waters 100 to 600 m deep.

Offshore area 10 (os 10): *Resource use (R os 10):* Deep sea shrimp fishery takes place along the edges of the banks in waters 100 to 600 m deep, most extensively during the summer months. Salmon fishery takes place in the eastern part in early autumn. *Species occurrence:* Seabirds occur with alcids (**Al os 10**) mainly Brünnich's guillemots; with gulls (**Gu os 10**) mainly kittiwakes; with seaducks (**Se os 10**) mainly king eiders in waters less than 50 m deep; and with tubenoses (**Tu os 10**) mainly northern fulmars. Among marine mammals are baleen whales (**Ba os 10**) such as minke and fin whales widespread until October and bowhead whale occur from December; white whales (**Wh os 10**) may occur in important concentrations throughout the area from November; and bearded seals (**Be os 10**) occur in important concentrations in the central part of the area from November. Large stocks of deep sea shrimp (**De os 10**) occur in waters 100 to 600 m deep.

Offshore area 11 (os 11): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Seabirds occur with alcids (**Al os 11**) mainly Brünnich's guillemots; with gulls (**Gu os 11**) mainly kittiwakes; and with tubenoses (**Tu os 11**) mainly northern fulmars. Among marine mammals occur baleen whales (**Ba os 11**) such as minke and fin whales until October and bowhead whales from December; white whales (**Wh os 11**) may occur in important concentrations mainly in the central eastern and southeastern part of the area from November; and bearded seals (**Be os 11**) occur in important concentrations in the central part of the area from November. Stocks of deep sea shrimp (**De os 11**) occur in waters 100 to 600 m deep.

Offshore area 12 (os 12): *Resource use:* Not significant, why no icon on map. *Species occurrence:* Among marine mammals occur baleen whales (**Ba os 12**) such as minke and fin whales until October/November. Large stocks of deep sea shrimp (**De os 12**) occur in waters 100 to 600 m deep.

Offshore Sensitivity Summary, Autumn

| Area | Sensitivity value | Ranking |
|-------------|--------------------------|----------------|
| os 1 | 70 | Extreme |
| os 2 | 42 | Moderate |
| os 3 | 52 | High |
| os 4 | 115 | Extreme |
| os 5 | 60 | High |
| os 6 | 48 | Moderate |
| os 7 | 59 | High |
| os 8 | 56 | High |
| os 9 | 27 | Low |
| os 10 | 79 | Extreme |
| os 11 | 63 | High |
| os 12 | 39 | Moderate |

8.4 Offshore Ice Zones and Ice Edges in Davis Strait and Southwest Greenland Waters (60° N - 72° N)

8.4.1 Definitions and terminology

The following description of the sea ice environment contains a number of terms describing the sea ice thickness or stage of development, as defined by World Meteorological Organization.

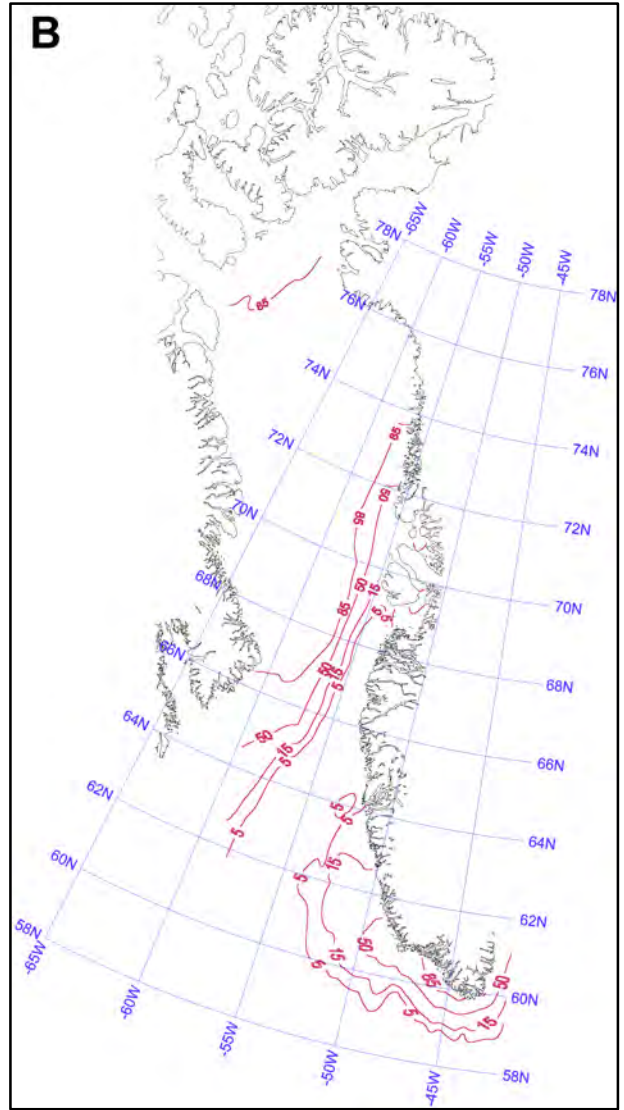
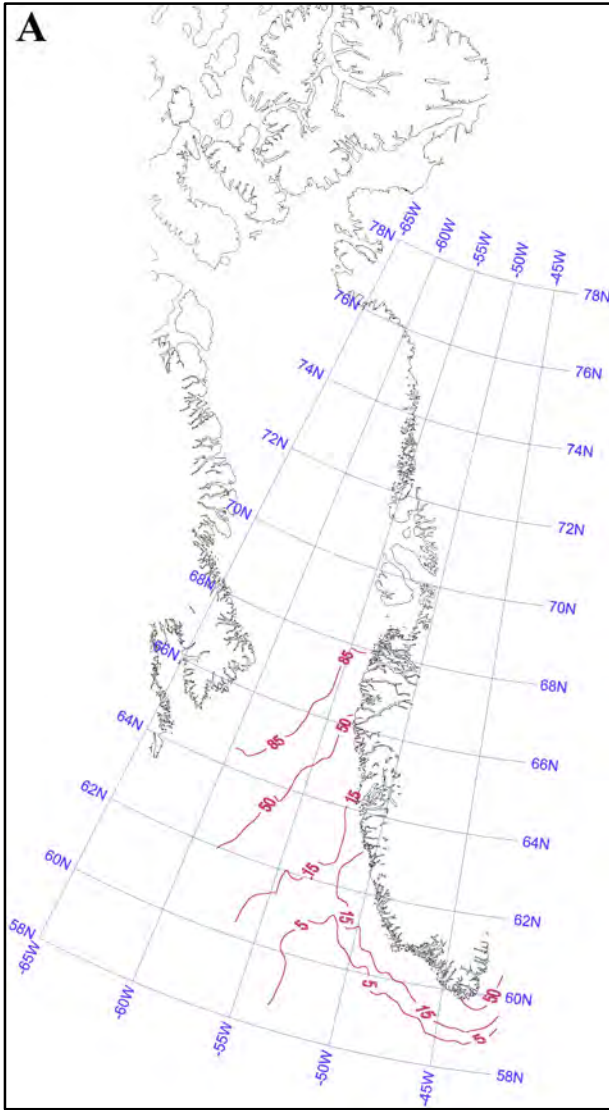
| Ice types:: | Thickness | WMO-code (Egg-code) |
|--------------------------------------|------------|---------------------|
| New ice-frazil, grease, slush, shuga | 0-10 cm | 1 |
| Nilas, ice rind | 0-10 cm | 1-2 |
| Young ice | 10-30 cm | 3 |
| Gray ice | 10-15 cm | 4 |
| Gray-white | 15-30 cm | 5 |
| First year ice | 30-200 cm | 6 |
| Thin first year ice | 30-70 cm | 7 |
| Medium first year ice | 70-120 cm | 1• |
| Thick first year ice | 120-200 cm | 4• |
| Multi-year ice | >2 m | 7• |

8.4.2 The 'West Ice'

The ice conditions between 60° N and 72° N are primarily determined by the relatively warm north or northwest flowing West Greenland Current (WGC) and the cold south flowing Baffin Current (BIC). The WGC delays the time of ice formation in eastern Davis Strait and results in an earlier break up than in the western parts of the Davis Strait (Figure 8.12). The BIC conveys large amounts of sea ice from Baffin Bay to the Davis Strait and the Labrador Sea for most of the year, especially during the winter and early spring months. During this period sea ice normally covers most of the Davis Strait north of 65° N, except areas close to the Greenland coast, where a flaw lead (open water or thin ice) of varying width often appears between the shore or the fast ice and the drift ice offshore as far north as latitude 67° N [\[link\]](#) [\[link\]](#) . South of 65-67° N, sea ice free areas dominate throughout the year. The sea ice edge (the boundary between drift ice and sea ice free water) is normally oriented to the southwest towards Hudson Strait or the Labrador Coast [\[link\]](#), [\[link\]](#) . In the beginning of the melt season a wide lead or polynya-like feature often forms west of Disko Island in front of Disko Bay. The eastern part of Davis Strait, south of Disko Island, is free of sea ice during this period (Figure 8.15) [\[link\]](#) , whereas drifting ice is dominating to the west and north. In Greenland this ice regime is recognized as the 'The West Ice' (Figure 8.13a & b).

The predominant sea ice type in the Davis Strait and the southern Baffin Bay is first-year ice. Small amounts of multi-year ice of Arctic Ocean origin drift to the western parts of the area 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 dominate in eastern parts (up to about 100 km from the Greenland coast). The western and central parts of Davis Strait and southern Baffin Bay are dominated by medium and thick first year ice categories mixed locally with small amounts (1-3 tenths) of multi-year ice.

The dominant size of ice floes range from large floes of about 1 kilometer wide to vast floes larger than 10 km. Near the ice edge in Davis Strait, the size of the common floes are reduced to less than 100 meters as a result of melting and break up by waves. These floes are often very consolidated.



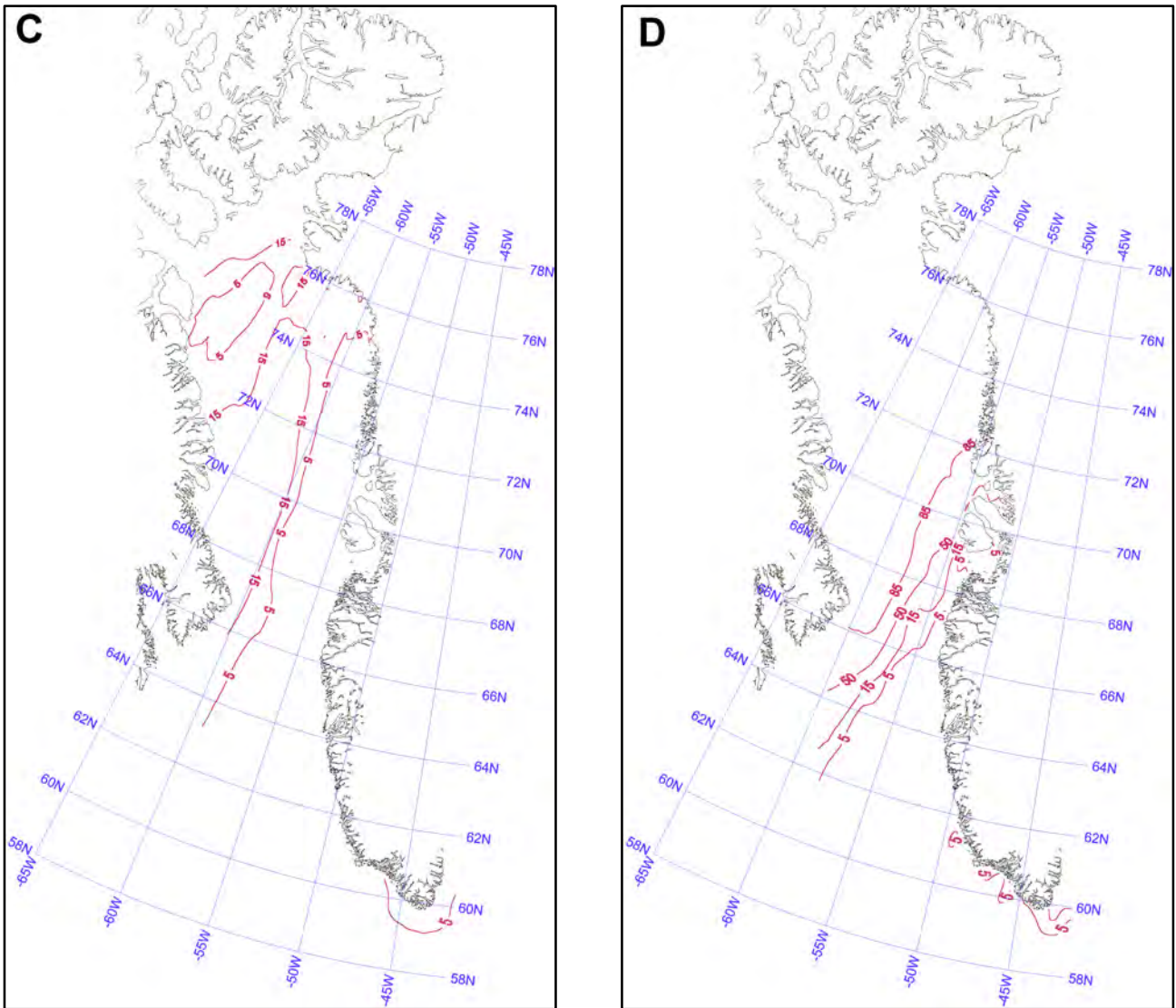


Figure 8.12. Probability of sea ice in West Greenland Waters based on data from the period 1960-96. (A) March the 1st, (B) June the 4th, (C) September the 3rd, (D) December the 3rd. (Data sources: Danish Meteorological Institute and Canadian Ice Service).

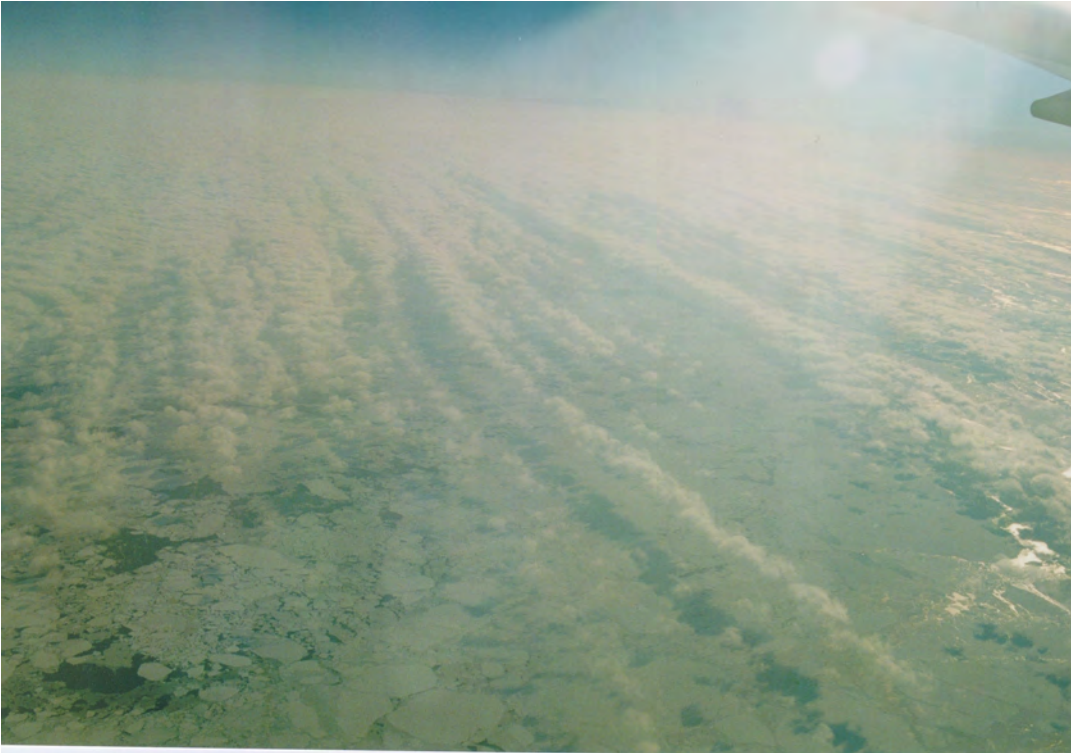


Figure 8.13a. Typical winter phenomenon in Eastern Davis Strait, February 26th, 1999 at a position near (66°N, 55°W). Convection clouds develop rapidly near the sea ice edge when cold air masses meet the warm sea surface. (Photo: Keld Q. Hansen).



Figure 8.13b. The 'West Ice', Eastern Davis Strait, February 26th, 1999 at a position near (66° N, 57° W), normally consists of large floes of a variety of ice types ranging from young (gray) ice to thin/medium first-year ice. Cracks and leads indicate that the ice is drifting. (Photo: Keld Q.Hansen).

8.4.3 Multi-year sea ice ('Storis' from the Greenland East coast)

A wide belt of multi-year sea ice originating from the Arctic Ocean is normally present most of the year covering the entire east coast of Greenland. Under normal conditions the multi-year ice reaches the Cape Farewell area in December/January, depending on the intensity of the East Greenland Current and the amount of ice in it. The track and intensity of low pressure systems in the North Atlantic Ocean also influence the distribution of sea ice near Cape Farewell (Figure. 8.14).

Due to long periods with strong north-westerly winds resulting from cold air out breaks from northern Canada during the winter, the ice often only passes Cape Farewell for short periods. The amount of multi-year ice in South Greenland Waters peaks in early summer. The intensity of the lows normally decrease in spring and summer, and may cause the multi-year ice to drift north-westwards along the Southwest Greenland coast in the West Greenland Current. The width, concentration, and position of this ice belt varies from year to year. Some years the ice never passes Nunarsuit, while other years it passes Nuuk and the Fyllas Banke area. The northernmost position of the multi-year ice on the west coast is normally situated around Paamiut (Frederikshåb) at 62° N [tables] . These waters are normally free of sea ice from early August. The diameter of the multi-year ice floes are always less than 100 m and normally about 5 to 20 meters. When multi-year ice occurs off Southwest Greenland, it is usually characterized by low or medium concentrations when averaged over large areas, however, long narrow belts of high concentrations are also common [photo], [photo], [satellite image], [satellite image] . In Greenland, this ice regime is known as the 'Storis' ('Great Ice'), mainly because of the thickness of the ice. However, the key word for the sea ice distribution in the South Greenland Waters is variability due to strong ocean currents and severe weather which characterize the area.

8.4.4 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 Current, however, the strength and direction of the surface winds also affect the local drift of sea ice, especially in the southern waters.

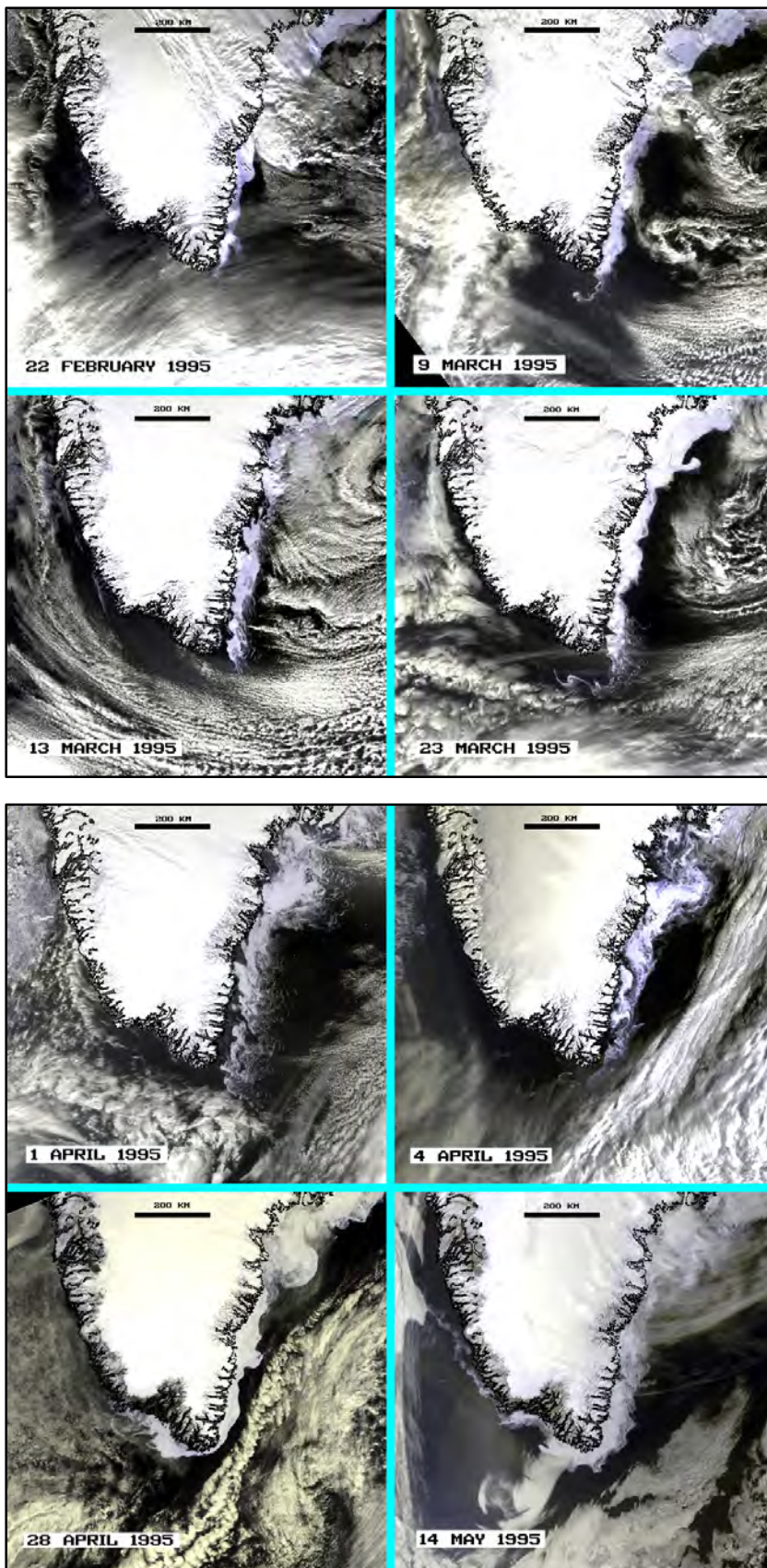
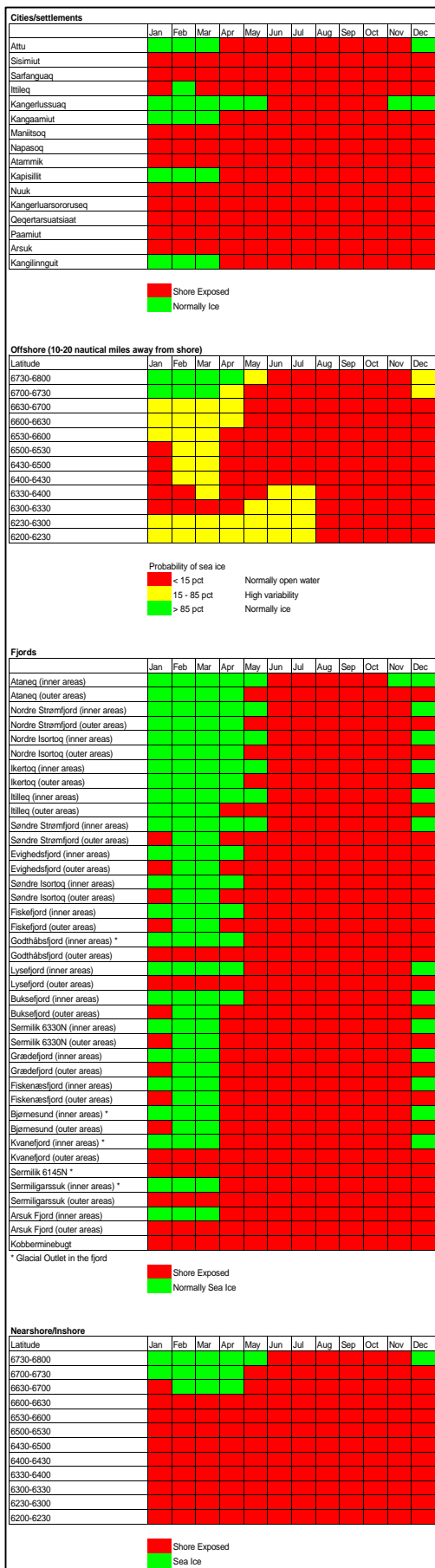


Figure 8.14. The end of the freeze-up season 1994/95. Some of the characteristic physical features:

- The 'West Ice' covers most of the Davis Strait including the 'Fyllas Banke' area, but open water areas occur north of Nuuk.
- Close to the south west Greenland coast, sea ice often forms locally but is very dependant on the air temperature and the salinity stratification in the sea. Due the changeable winds in the area this kind of ice cover normally only exists for short periods (less than one week).
- Large amounts of 'Storis' off the east coast of Greenland. Depending on the dominant wind direction the ice from time to time drifts far south of Cape Farewell. In March 1995, multi-year ice was reported south of 58° N, more than 200 km from the Greenland-coast, but only for a few days.

The maximum coverage of the 'West Ice' occurred in early April this year (1995). March 31st and April 1st a very violent meteorological event was observed. The pass of an atmospheric low southeast of Greenland caused 'Piteraqq' (very strong katabatic winds) on most of the east coast, and this event affected the sea ice dramatically as can be observed on the satellite image. After a few days the ice conditions were back to a normal state again. From late April the 'Storis' covered most of the Julianehåb Bay and drifted later to the Davis Strait area due to dominant weak or southeasterly winds .

8.5 Fjord and Coastal Ice Freeze-up and Break-up



Isolated from the offshore conditions, sea ice forms locally throughout the winter in many fjords on the west coast of Greenland. This is especially the case with the northern fjords, which are covered with fast ice for several months. Freeze-up begins at the inner parts of the fjords in November or December, but may be significantly affected or reduced by very strong winds in the fjords throughout the winter.

The presence of a sea ice cover can protect the West Greenland shores and fjords from offshore oil spills. Although large local differences are to be expected, the southern shorelines are generally free of sea ice from spring until mid-winter. Towards the north the ice free periods generally persist from early summer until early winter.

On the basis of data from the literature, historical ice charts, satellite data, and local experience, it is possible to evaluate which shores are likely to be susceptible to oil exposure over time. The result of this evaluation is shown in Figure 8.15 and Figure 8.16. It is important to note, however, that the estimates of potential exposure periods are only evaluated roughly due to the high number of fjords and islands on the West Greenland coast. Thus, the maps and tables in this section will not necessarily reflect the actual conditions of oil exposure, i.e. in a very mild winter or during exceptional oceanographically conditions. In addition strong winds frequently occur along the shorelines, resulting in a localized break up of fast ice.

Figure 8.15. The West Greenland shore was divided into four subgroups. A study of the potential oil exposure was conducted for each of these:

- cities/settlements,
- offshore areas 10-20 nautical miles from the coast,
- major fjords,
- the near shore environment.

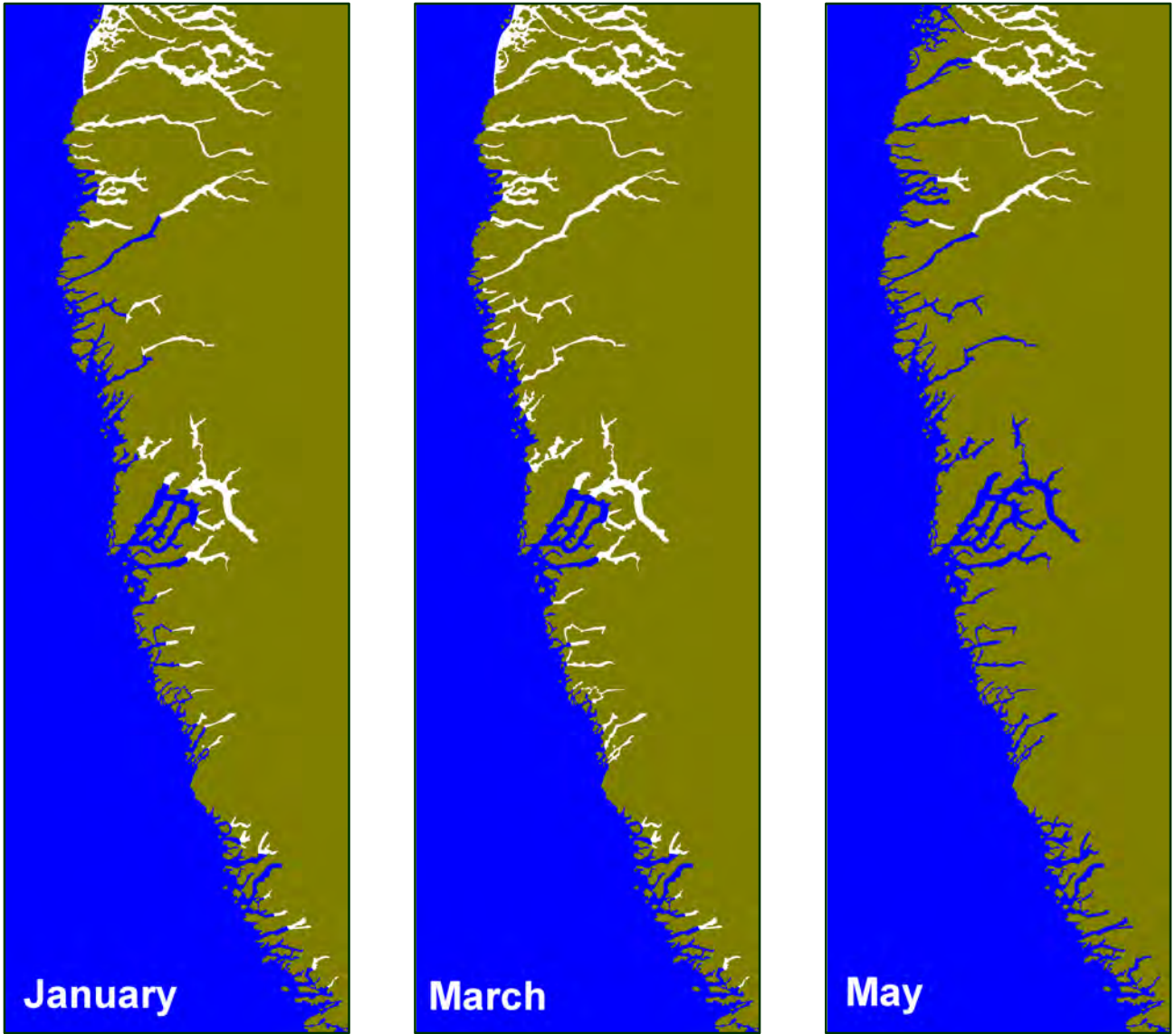


Figure 8.16. The exposed and sea ice covered shores for January, March and May.

8.6 Summary of Regional Observations of Sea Ice

8.6.1 Uummannaq Fjord

Most of Uummannaq Fjord is normally covered with fast ice from late December until late May/early June. The medium first-year ice category is reached in the areas northwest, north and east of Ubekendt Ejland at the end of the freeze-up season. Freeze-up begins in the small fjords in the area in early November.

8.6.2 Baffin Bay, west of Ubekendt Ejland

During winter and spring, the waters west of or near Ubekendt Ejland mark the shear zone between the fast ice in Uummannaq Fjord and the mobile drift ice in southeastern Baffin Bay. When sea ice is present, the area is characterized by large ice floes primarily in the thin first-year ice category. Sea ice normally is present from December until June. Wide leads or large sea ice free areas are also common, which is an indication of the complexity of the surface currents. During the freeze-up and break up season, sea ice drifts out of Uummannaq Fjord, driven by easterly winds.

8.6.3 Vaigat and Disko Bay

During winter, sea ice normally forms in early January and melts again during May or early June, depending on the severity of the previous winter. Fast ice is generally formed by midwinter in periods of cold and calm weather conditions. The occurrence of sea ice in Disko Bay can be summarized as follows:

Mild winters: freeze up early February, young ice and thin first-year ice, mostly large drift ice floes, free of sea ice early May. Normal winters: freeze up mid January, young ice and thin first-year ice, very large floes or fast ice, free of sea late May. Cold winters: freeze up late December, thin first-year ice, mostly fast ice except in the break-up season, free of sea late June. The latest report of sea ice in Disko Bay since 1958 is early July (1970).

Sea ice appears earlier and melts later close to the coast in south-eastern Disko Bay than in the rest of the Disko Bay area. The melt and break-up of the fast ice or consolidated ice in Disko Bay is often a 'pincers process', starting from the waters around Kronprinsens Ejland and from the waters east of Disko Island. This process is mainly controlled by the anticlockwise surface currents in Disko Bay.

8.6.4 Davis Strait, west of Disko Island

The waters west of Disko Island and around Hareøen are normally free of sea-ice from mid-June to mid-November, however, belts of sea ice occasionally drift from the central parts of southern Baffin Bay to the area during the summer. An 'ice bridge' often occurs northwest of Disko Island due to onshore currents west of Nuussuaq, even when large open water areas are present west of Uummannaq Fjord and Svartenhuk. When sea ice is present, the area is characterized by large floes of thin first year ice, however the ice cover is very variable, and large open water areas or large areas with young ice only occur from time to time.

8.6.5 Davis Strait, west of Aasiaat and Disko Bay

Kronprinsens Ejland south of Disko Island marks a north-south boundary between the ice regime of Disko Bay and the ice regime southwest of Disko Island. Here the sea ice is characterized by the young and thin first-year ice categories. The ice concentrations vary depending on the local meteorological conditions. Sea ice normally occurs from mid-December until early May. In normal winters, a second west-east oriented 'ice bridge' consisting of high concentrations of slowly moving drift ice forms west of Aasiaat at 68° N, primarily due to the onshore component of the surface current. During the summer, belts of remaining sea ice in the central parts of Davis Strait occasionally drift close to the Greenland coast.

8.6.6 Davis Strait between 65°N and 68°N

Even in severe winters, navigation normally is possible in the eastern part of Davis Strait as far north as Sisimiut due to the existence of the relatively warm north going current. Furthermore, the sea ice drift has a significant offshore component (the West Ice), and for this reason sea ice only covers the Davis Strait in the last half of very cold winters. If sea ice is present close to the Greenland coast, it is very sensitive to easterly winds, and break-up occurs quickly. When sea ice covers the entire strait, a narrow lead (may be covered with thin ice) normally forms close to the Greenland coast, just off the fast ice edge. The normal ice type in the area is young ice or thin first-year ice in varying floe sizes. Wide belts of small floes normally occur near the ice edge. Multi-year ice ('Storis') from the Greenland east coast almost never drifts north of 65° 30' N. This has only been observed a few times in 20th century and not in the period 1958-99.

8.6.7 Fyllas Banke

Fyllas Banke probably is the offshore area at Greenland which is least affected by the occurrence of sea ice. Sometimes the 'West Ice' drifts eastward in late winter into the Fyllas Banke area for periods ranging from only a few days to several weeks. Other times, also in late winter, sea ice forms locally during very cold periods. Locally formed sea ice in the Fyllas Banke area is normally characterized by the young and thin first-year ice categories, and is very sensitive to southeasterly (warm) winds. The ice cover may disappear within a few days, however it normally takes one or two weeks to clear the Fyllas Banke. Under normal conditions, the northwestern part of the area is free of sea ice ('West Ice') from early May until early January and the southeastern part from mid April until late January.

Multi-year ice from the Arctic Ocean drifts southward along the east coast of Greenland to the Cape Farewell area. Melt and break-up processes significantly reduce the sizes of these floes. When the floes drift into the Cape Farewell area they are always less than 100 meters in diameter, however, the thickness of the floes is still about 2-3 meters. The atmospheric pressure lows in spring and summer are weaker and less frequent than during winter. During winter, the lows move into the Davis Strait and cause south-easterly winds. Under these physical conditions, the belts of multi-year ice or 'Storis' in the Cape Farewell area normally drift westwards into northeastern Labrador Sea or northwestward along the West Greenland coast. The 'Storis' drifts north of 63° N (into the Fyllas Banke area) every second year on average. In some years, the multi-year ice is only present as a few narrow ice belts for a couple of days, while other years the 'Storis' may cover large areas and persist for several weeks. Since 1958, the Fyllas Banke has always been reported as being completely free of sea ice from mid-August until mid-December. In January 1982, multi-year ice drifted north of 63° N due to extreme wind conditions in the last months of 1981. With the exception of 1982, 'Storis' has not been observed north of 63° N earlier than late February during the period 1958-99.

8.6.8 Northeastern Labrador Sea between Nunarsuit and 63° N

This area is normally free of sea ice from late summer until mid-winter. In the late winter the 'West Ice' occasionally affects the area. In very cold periods sea ice forms locally within 50-60 kilometers of the Greenland coast. Varying amounts of 'Storis' occur almost every year from late winter/early spring until mid-summer. Due to the offshore component of the West Greenland Current, the multi-year ice is sometimes present only far from the shoreline.

8.6.9 Julianehåb Bay and Cape Farewell waters

The 'West Ice' almost never affects the area. The occurrence of 'Storis' varies from nothing to huge amounts from early-or mid-winter depending on the storm tracks and low pressure intensity. In the spring and summer months, wide belts of close packed multi-year ice are normally present close to the Greenland coast.

8.7 The West Greenland Iceberg Environment

To shipping the most dangerous aspect of ice in the sea is the occurrence of icebergs. They differ from sea ice in many ways:

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

The process of calving from the front of a glacier produces an infinite variety of icebergs, bergy bits and growlers with calving occurring throughout the year. Icebergs are described by their size according to the following classification:

| <u>Type</u> | <u>Height (above sea level)</u> | <u>Length</u> |
|--------------------|---------------------------------|---------------|
| growler | less than 1 m | up to 5 m |
| bergy bit | 1 to 5 m | 5 to 15 m |
| small iceberg | 5 to 15 m | 15 to 60 m |
| medium iceberg | 16 to 45 m | 61 to 120 m |
| large iceberg | 46 to 75 m | 121 to 200 m |
| very large iceberg | over 75 m | over 200 m |

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.

8.7.1 Iceberg sources

Glaciers are numerous in West Greenland, however, the productive glaciers are concentrated between Nares Strait and Disko Bay. Although icebergs occur throughout the West Greenland waters between 60° N and 72° N, they are rare in some areas, e.g. off Sisimiut. In other areas, e.g. in Disko Bay, hundreds of icebergs are always present (Figure 8.17 and 8.18).

Eastern Baffin Bay north of Upernavik is a major source of icebergs. Over 10,000 icebergs are

calved from 19 major glaciers every year (Figure 8.19). Some of these are capable of producing icebergs of about 1 kilometer in diameter. Several active glaciers in Uummannaq Fjord and Disko Bay produce 10-15,000 icebergs per year, and they are very important for the iceberg input to the northern Davis Strait and Baffin Bay. The most active glacier is located near Ilulissat moving at the rate of 20 m/day. This glacier produces over 20 km³ of ice per year. The total annual production of icebergs calved in the Baffin Bay and the northern Davis Strait is estimated to be about 25-30,000, estimates however vary up to as high as 40,000. Surveys conducted by USCG International Ice Patrol decades ago indicate that the total number of icebergs in Baffin Bay and the northern Davis Strait are of the same order of magnitude. Almost no icebergs are produced south of Disko Bay. Here the fjords are longer, narrower, and shallower than in the northern areas of the Greenland west coast, and the calving is in the form of growlers and bergy bits rather than icebergs. Growlers and bergy bits nearly always melt before reaching the open sea. However, from time to time the glacier in Narsalik Fjord produces ice which affects offshore areas for a couple of days.

[satellite image]

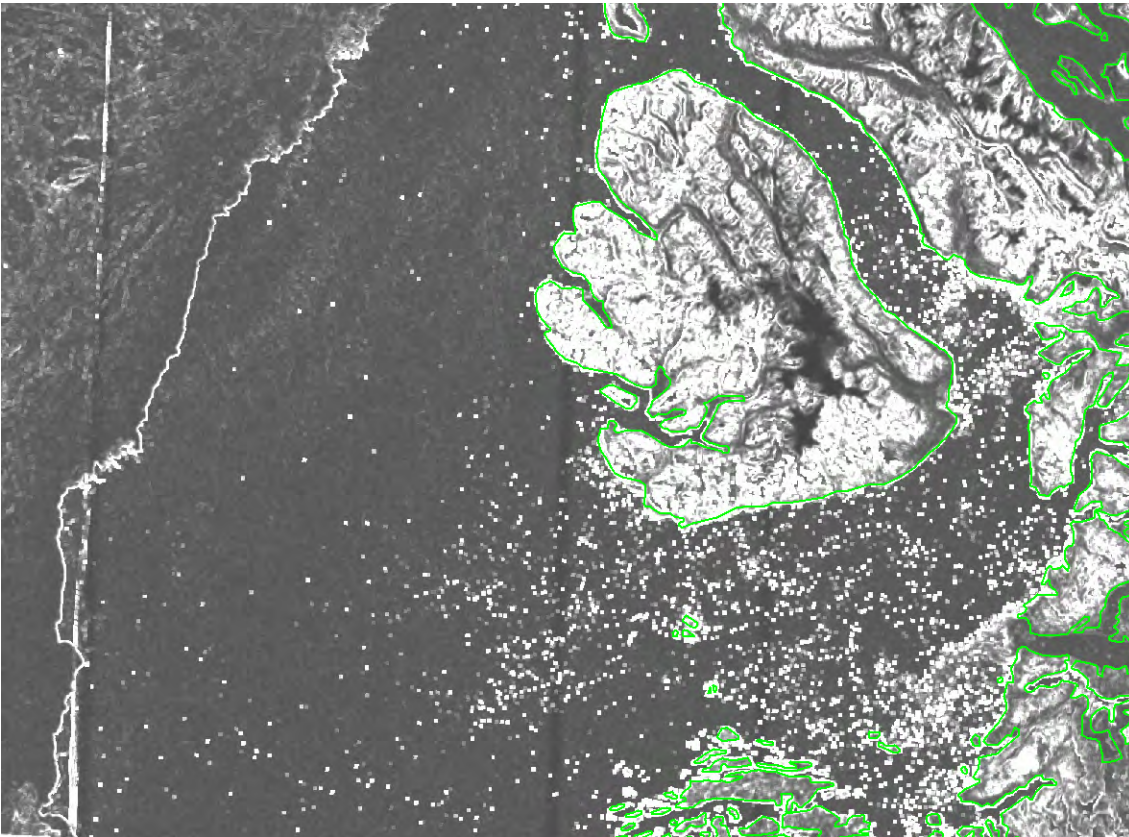


Figure 8.17. Radarsat PMR-filter image from June 14th 1999 20 UTC of the Disko Bay area showing the distribution of targets (icebergs). The 'West Ice' - edge is found in the western part of the image. (source: Radarsat).

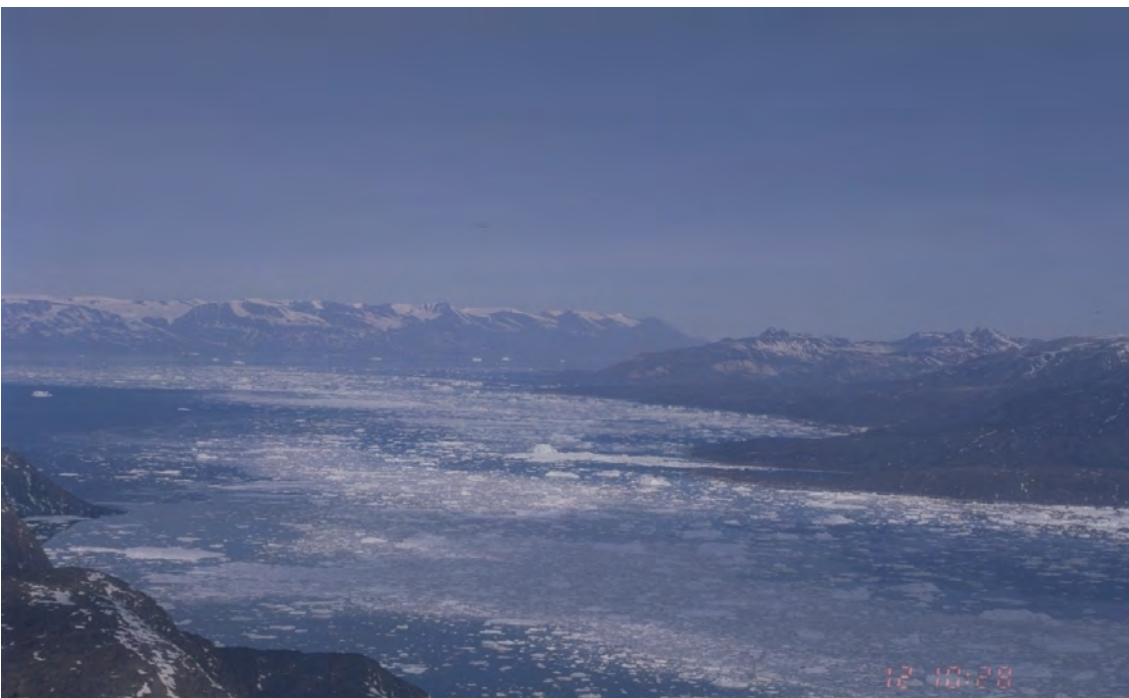


Figure 8.18. June 12th 1997. Glacial Ice, primarily small icebergs and bergy bits from one of the major sources in Northeastern Disko Bay, Torssukatak, which produces about 16 km³ ice/year. (Photo: Keld Q. Hansen).

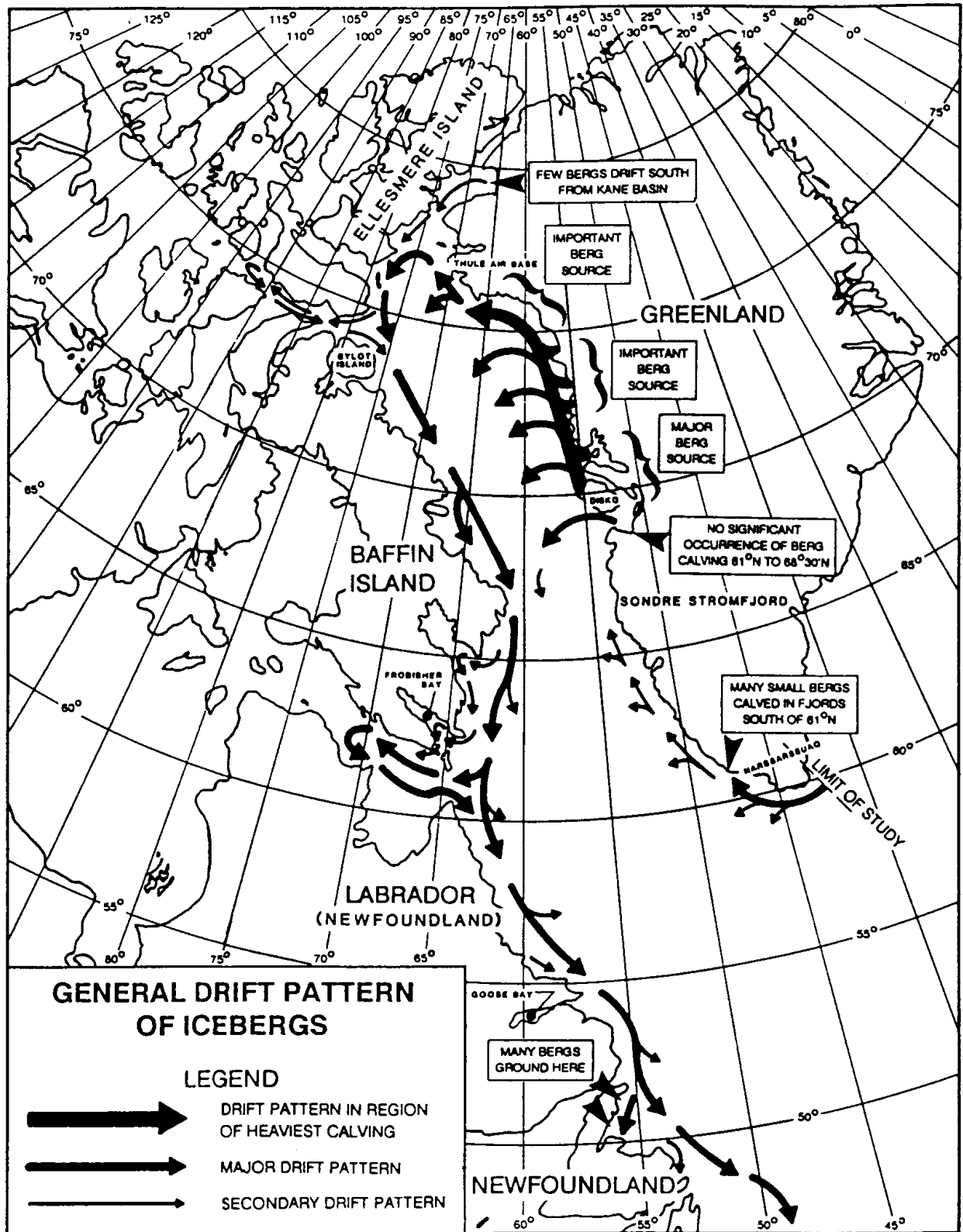


Figure 8.19. Major iceberg sources and general drift pattern in the West Greenland Waters. (US National Ice Center, Washington DC).

8.7.2 Iceberg drift and distribution

On a large scale the basic water currents and drift of icebergs in Baffin Bay and northern Davis Strait are fairly simple. 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 cause 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 Cape York 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 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. Many icebergs produced in the Disko Bay enter Davis Strait, partly through Vaigat and partly along the southern coast of Disko Island. Some icebergs manage to drift towards or into southern Disko Bay from the Davis Strait due to onshore component of the currents west of Aasiaat. Icebergs south of Sisimiut are of East Greenland origin. Occasionally many small icebergs and bergy bits calved in Southwest Greenland fjords are observed close to the coast in this area, however, these ice masses normally melt quickly and only rarely affect ocean areas farther offshore.

In a study in the late 1970s, DHI/GTO found the lowest iceberg densities in West Greenland at the northern part of Lille Hellefiskebanke and at the southern part of Store Hellefiskebanke between 65° N and 66° N. Iceberg densities increased both towards north and south. The density of icebergs in Disko Bay was significantly higher than outside the bay, with maximum concentrations of icebergs occurring in the northeastern part of Disko Bay. The iceberg density generally was highest in early summer, except in the area near Disko Bay where the highest density was seen in late summer, probably due to higher calving activity of the glaciers during the summer months. A similar distribution can be derived from data from USCG International Ice Patrol and the Canadian Ice Service and can also be observed by shipping companies operating in the area.

Icebergs only occasionally are seen in eastern Davis Strait between Nuuk and 67° N as a result of the pattern of dominant currents, the bathymetry, and the distance to calving glaciers. Growlers, bergy bits and a few icebergs usually do not drift out of Godthåb Fjord and could hardly ever affect the Fyllas Banke. The seasonal maximum density of icebergs in this area is normally closely related to the actual distribution of 'Storis'. Thus, under normal conditions, the seasonal maximum occurs from late April until late July. Off the ice edge of the 'Storis', the deterioration of icebergs increases significantly and therefore the seasonal minimum of glacial ice in the Fyllas Banke area normally occurs during the fall months of September to November. Due to the observed westward branching of the West Greenland Current and the bathymetry south of Fyllas Banke, the largest icebergs will probably be observed on the western side of the Fyllas Banke area, but some of these may manage to drift northeast into the deeper waters between Fyllas Banke and Toqqussaq Banke. **[satellite images]**

8.7.3 Icebergs from East Greenland glaciers

Thousands of large icebergs are calved every year from several glacier outlets on the east coast of Greenland. When the icebergs reach open sea they drift southwards in the East Greenland Current, which also contains large amounts of sea ice from the Arctic Ocean most of the year. Even in winter, most of the sea ice from high latitudes melts when it drifts southward off the southeast coast of Greenland. Many icebergs drift off the sea ice edge and melt quickly due to a higher water temperature here and to the wave/swell action. Within the sea ice edge in the cold East Greenland Current, the deterioration of the icebergs is limited. The actual positions of icebergs off Southwest Greenland is to a certain extent controlled by the occurrence and the distribution of multi-year ice 1-2 months earlier. Under normal conditions, sea ice occurs in the Cape Farewell area from early winter until late summer. During spring and early summer, the sea ice sometimes drifts into the

Fyllas Banke area. Therefore, the maximum iceberg density off Southwest Greenland is expected to occur in early and mid-summer. This pattern was indirectly observed in the DHI/GTO study in the late 1970ies (Mangor and Zorn 1983). 'Storis' was observed off the southwest coast of Greenland for several weeks during each of both years' study, however, the sea ice distribution and length of the sea ice season were close to normal conditions.

Large variations in the number and size of icebergs rounding Cape Farewell are to be expected because of the variability of the currents, the amounts of sea ice, and weather conditions. An important factor controlling the iceberg environment off Southwest Greenland is the input of icebergs to the East Greenland Current at high latitudes during summer. It is well known that sea ice is present off the east coast most of the year, although there are large seasonal and inter annual variations, especially during summer. In many cases the occurrence and drift of sea ice controls the movements of icebergs. If the fast ice in fjords with major iceberg sources, e.g. Scoresbysund or Kong Oscar Fjord, does not melt during summer, or if the East Greenland sea ice does not drift off the coast, this will probably reduce the input of icebergs to the East Greenland Current and cause a decrease in the number of icebergs at lower latitudes. However, this phenomenon has not been systematically investigated.

8.7.4 Iceberg dimensions

The characteristics of iceberg masses and dimensions off the Southwest coast of Greenland are poorly investigated, and the following is mainly based on the DHI/GTO study in the late 1970s.

In Eastern Davis Strait the largest icebergs were most frequently found south of 64° N and north of 66° N. South of 64° N, the average mass of an iceberg near the 200 m depth contour varied between 1.4 and 4.1 million tons, with a maximum mass of 8.0 million tons. Average draft was 60-80 m and maximum draft was 138 m. Between 64° N and 66° N, average masses were between 0.3 and 0.7 million tons. The maximum mass was 2.8 million tons. Average draft was 50-70 m and maximum draft is estimated to be 125 m.

The largest icebergs north of 66° N were found north and west of Store Hellefiskebanke. The average iceberg mass was about 2 million tons with a maximum mass of 15 million tons. In Disko Bay, the average masses of icebergs were in the range 5-11 million tons with a maximum recorded mass of 32 million tons. 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, e.g. at Fyllas Banke where the water depth in large areas is only about 100 meters. Thus, large icebergs will ground before they drift into many offshore areas in Greenland.

Maximum draft can be evaluated by studying factors which limit the dimension: glacier thickness, topographic factors which cause icebergs to be calved in small pieces, and thresholds in the mouths of the fjords with glaciers. The measurements of iceberg drafts north of 62° N indicate that an upper limit for a draft of 230 m will only be exceeded very rarely, however, no systematic maximum draft measurements exist and the extremes remain unknown. Several submarine cable crushes or breaks have occurred at water depths of about 150-200 meters; the maximum depth recorded was 208 meters, southwest of Cape Farewell. These observations agree with the DHI/GTO conclusions, however, larger drafts of icebergs of East Greenland origin cannot be excluded because observations are sparse. The large icebergs originating in Baffin Bay are expected to have a maximum draft of about 250-300 meters.

A field program, Berg Watch 97, carried out by the Danish Meteorological Institute, Danish Hydraulic Institute and ASIAQ/Greenland Field Investigations documented the presence of very large icebergs in eastern Baffin Bay characterized by a draft of more than 260 meters, or a mass of

up to 90,000,000 tons, or a diameter of more than 1400 meters. Due to the predominant currents in Baffin Bay and Davis Strait, these icebergs will not reach the West Greenland shores south of 68° N. Surveys conducted by the USCG International Ice Patrol and other field studies of icebergs in the East Canadian Waters have improved the knowledge on the iceberg environment in the western Davis Strait and the Labrador Sea. However, the amount of iceberg data relevant for the Eastern Davis Strait are very sparse.