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A review of biological resources in West Greenland sensitive to oil spills during winter

With an appendix:
Potential impacts of oil spill on marine fish and invertebrates

NERI Technical Report, No 246

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Data sheet

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Abstract:	The biological conditions during winter in marine West Greenland (60°-71°N) is reviewed in relation to oil spills from offshore oil exploration. Datagaps are identified and studies to fill these gaps are proposed.
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Preface

The present report describes the biological environment in West Greenland during winter (November - April). It is a supplement to previous reports describing the West Greenland biological environment in spring, summer and autumn (May - October). These reports were prepared for the Mineral Resources Administration for Greenland by the Department of Arctic Environment, National Environmental Research Institute, Denmark (before 1996, Greenland Environmental Research Institute).

The primary aim of these reports is to describe the biological conditions, based on current knowledge, and to identify data gaps which are considered to be of importance for oil spill sensitivity mapping.

This report was partly financed by the Danish Environmental Protection Agency under The Arctic Environmental Program through grants from the Danish Environmental Support Fund. Information about the program is available in *Danish EPA News Report*.

Summary

This report describes the biological conditions in West Greenland (60° - 71° N) during winter (November - April) in an oil spill context. The report focuses on higher trophic level species and on species important to the Greenland fishery and subsistence hunting.

The information was derived from published sources and from our own ongoing surveys.

Many fish and invertebrates species are found in the study region. Greenland halibut and deep sea shrimp are among the most important to the Greenland fishery. In relation to oil spills the spawning and post-spawning period with high concentrations of eggs and larvae is crucial. Winter and early spawners include Atlantic cod, Greenland cod, Atlantic halibut and Greenland halibut.

The study area is an internationally important winter habitat for large seabird populations. These are found both in coastal and offshore waters of the Open Water Region and in drift ice over shallow parts of Store Hellefiskebanke. A significant segment of local seabird populations winter in the study area: mallard, harlequin duck, red-breasted merganser and great cormorant. Large populations of international seabird population winter in the area: common eider, king eider, thick-billed murre, little auk and great black-backed gull.

The drift ice covered part of the northern study region is important to wintering marine mammals, particularly for populations of white whale, narwhal, bowhead whale and walrus.

Hooded seals assemble in the drift ice in central Davis Strait west of Nuuk, where they whelp during March. Only two other whelping areas are known for this species.

The most important biological resources vulnerable to oil spills during winter are the large seabird concentrations in the Open Water Region and in the drift ice in Store Hellefiskebanke and the whelping population of hooded seals in the driftice areas west of Nuuk.

The most important data gaps in relation to oil spill sensitivity mapping identified are:

- the distribution (temporal and spatial) and abundance of the different flyway populations of thick-billed murre, little auk and king eider in offshore areas,

- the distribution (temporal and spatial) and abundance of the same populations and including common eider in coastal areas.

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1 Introduction

Earlier reports issued by the Greenland Environmental Research Institute and its successor, the National Environmental Research Institute, Department of Arctic Environment (Boertmann 1994, Boertmann et al. 1992, 1994, Mosbech et al. 1996, 1998) described the physical and biological conditions in West Greenland during the "summer" (May - October) in an oil spill sensitivity mapping context. Important data gaps were identified, and studies to fill these gaps were proposed. The reports were prepared at a time when oil exploration was anticipated and before any licences were issued. Exploration was supposed to take place only during the summer months when weather and light conditions are favourable.

Now the situation is different. An exploratory drilling was carried out on land at Nuussuaq (71° N) in 1996, and exploration and exploitation licenses have recently been issued for two areas offshore Southwest Greenland. An initial assessment of the potential environmental impacts of oil exploration in the Fylla Area has been conducted (Mosbech et al. 1996), and an inventory of the biological resources and the human use of these resources has been compiled (Mosbech et al. 1998) for the Southwest Greenland area (62°-68° N). If oil is located and is subsequently exploited, activities will probably be conducted during the winter as well as summer.

The present report describes the biological conditions during the winter (November - April) in an area from Kap Farvel (60° N) in the south, to the Nuussuaq peninsula (71° N) in the north (Fig. 1). The data presented is based on the available literature and information obtained by our own studies. Major data gaps in relation to oil spill sensitivity mapping are identified.

Compared to the summer period, the physical and biological information in the study area is much more limited for the winter period. This is the case for the offshore region in particular, which is to a large extent inaccessible during winter due to severe ice conditions, short daylight and harsh weather.

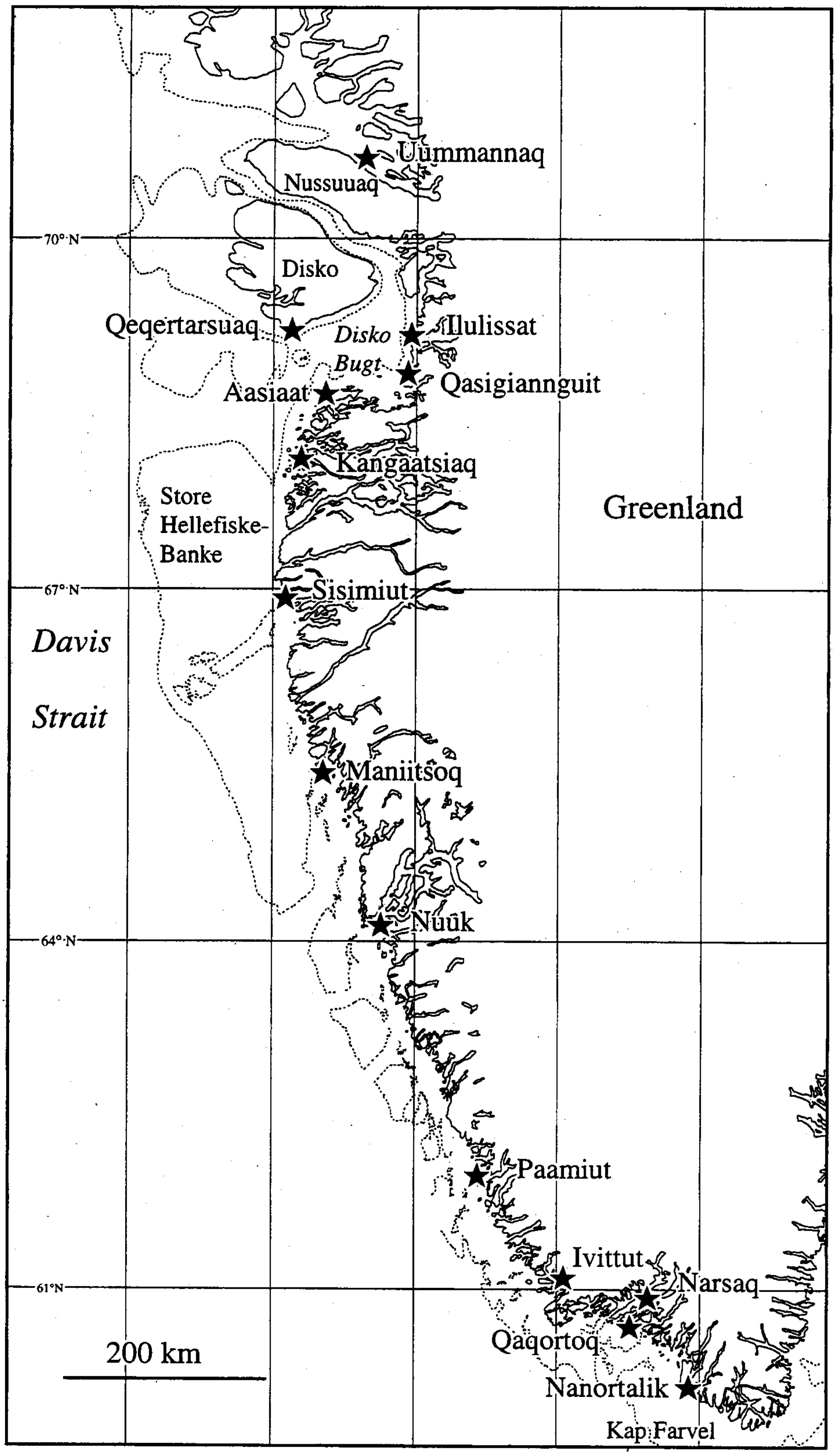

Fig. 1. Map showing the study area. The shelf and fishing banks are indicated by the 200 m depth curve (dotted line). Cities are indicated by an asterisk.

2 Physical conditions

Only a brief description of the ice and light conditions is provided in this section. Both are very significant physical factors during winter – at least from a biological point of view. Other physical conditions have been described in earlier reports (Boertmann et al. 1992, 1994, Mosbech et al. 1996, 1998). Moreover, comprehensive reviews covering northeastern Labrador Sea, eastern Davis Strait and Baffin Bay have been issued recently by the Danish Meteorological Institute (Valeur et al. 1996a, b, 1997).

2.1 Ice

The following review is based on Valeur et al. (1997). A biologically important feature during winter is the presence of an open water area, which are usually found in the eastern Davis Strait between 62° and 66° throughout the winter. Here the relatively warm Atlantic water from the Irminger Current keeps the sea off the outer coasts free of ice. This particular part of the West Greenland coast is therefore named the "Open Water Area". Further north, first year driftice from the Baffin Bay may cover the offshore waters from late November (northern part), or until May (in the southern part), although the temporal and spatial variation between years is considerable. North of the Open Water Area, recurrent open water is found in several fjord mouths and in straits with strong tidal currents. A rather large open water area is often present west of Disko in late winter and spring. During spring open water forms from the Open Water Area and northwards along the outer coast. South of 63° N, multi-year drift ice from the East Greenland Current often covers the waters in spring and early summer. The fjords and bays are usually covered by fast ice during winter, although mainly the inner parts in the Open Water Area. Disko Bugt is in most years ice covered from mid-January. See Fig. 2.

2.2 Light

The annual variation in daylength is considerable throughout the study area. The Arctic circle at 66°30′ N represents the border between areas were midnight sun (summer) and polar darkness (winter) occur. At Nuuk, c. 64° N the daylength (sun above the horizon) in mid-winter is about 4 hours and about 21 hours in mid-summer.

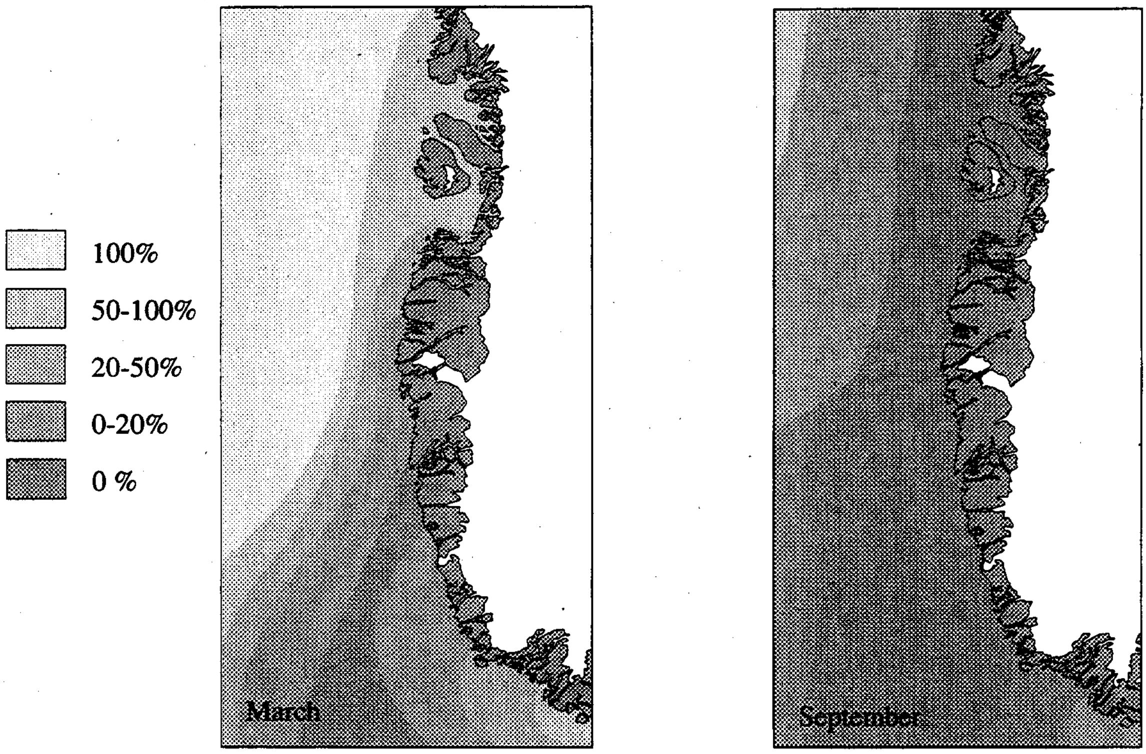

Fig. 2. The probability of ice cover in March (the month with the most extensive ice cover) and September (the month with least ice).

3 Biological resources

This chapter gives an account of selected species occurring in the region during the winter period. Focus is put on species from higher trophic levels, i.e. birds and marine mammals, and on species important to the Greenland fisheries.

3.1 Fish and shellfish

Some of the important fish species in Greenland spawn during the winter or early spring (Table 1). Only these species will be described in more detail below. However, many more fish and invertebrates occur in the study region, and some of these are described in previous reports (Boertmann et al. 1992, 1994, Mosbech et al. 1996, 1998).

Table 1. Important fish and large invertebrate species occurring in the area (60°N - 71°N), and which spawn in winter or early spring.

Species	Main habitat	Spawning area	Spawning period	Exploitation
Deep sea shrimp *Pandalus borealis*	offshore and in certain fjords, 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 *Chionoecetes opilio*	coastal waters and fjords, 180-400 m depth		larvae released April-May	c
Atlantic cod *Gadus morhua*		pelagic eggs and larvae in upper water column		See text
offshore stock	on banks north to 64°N	western slope of banks	March-April,	
inshore stock	fjords	inner fjords	April-May	
Greenland cod *Gadus ogac*	inshore/fjords	inshore/fjords, demersal eggs	February-March	c & s
Atlantic halibut *Hippoglossus hippoglossus*	offshore and inshore	? western slope of banks south of 66°N, pelagic eggs and larvae	winter	c & s
Greenland halibut *Reinhardtius hippoglossoides*	offshore and in certain fjords, deep water	offshore south of 66°N, deep water, pelagic eggs and larvae	spring	important c & s

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

3.1.1 Atlantic cod (*Gadus morhua*)

Distribution, habitat and ecology

West Greenland cod is divided into four separate stocks with different spawning areas, as shown in Fig. 3 (Hovgaard 1991):

Icelandic cod are recruited from spawning grounds off Southwest Iceland, and are carried to Southeast and Southwest Greenland by the Irminger Current. East Greenland cod spawn off East Greenland, and the eggs and larvae subsequently drift to the Davis Strait. West Greenland offshore cod are recruited from spawning grounds on the banks off Southwest Greenland. West Greenland inshore cod spawn within the fjords, and are generally stationary (Hovgaard & Christensen 1990). The offshore cod regularly migrate to and from spawning areas.

The West Greenland offshore cod spawns in March and April at depths ranging from 120 - 1,000 m; mainly on the western slopes of the banks (Hovgaard 1991). The eggs and larvae are usually found in the upper 25 m of the water column. They drift towards the north and probably also to the west. Young fish move to the bottom around October/November.

The West Greenland offshore stock has decreased drastically since about 1968, corresponding with a decrease in recruitment from Iceland. As a result, cod are virtually absent from the banks today. This is most likely due to a combination of excessive fishing pressure in connection with a decrease in water temperature (Anon. 1997).

Capelin (*Mallotus villosus*) and sand eel (*Ammodytes spp.*) are important prey species to cod in Greenland waters.

Fisheries

Historically, Atlantic cod was the most important species to the Greenland fishery (see Fig. 4), and the majority of the catch was taken on the banks off West Greenland. In the 1950s and 1960s, the annual catches of cod in offshore areas off West and East Greenland were in the order of 300,000 to 500,000 tons. In recent years, the majority of the catches have been taken inshore in the fjord areas. There has been no cod fishery in the offshore area since 1992.

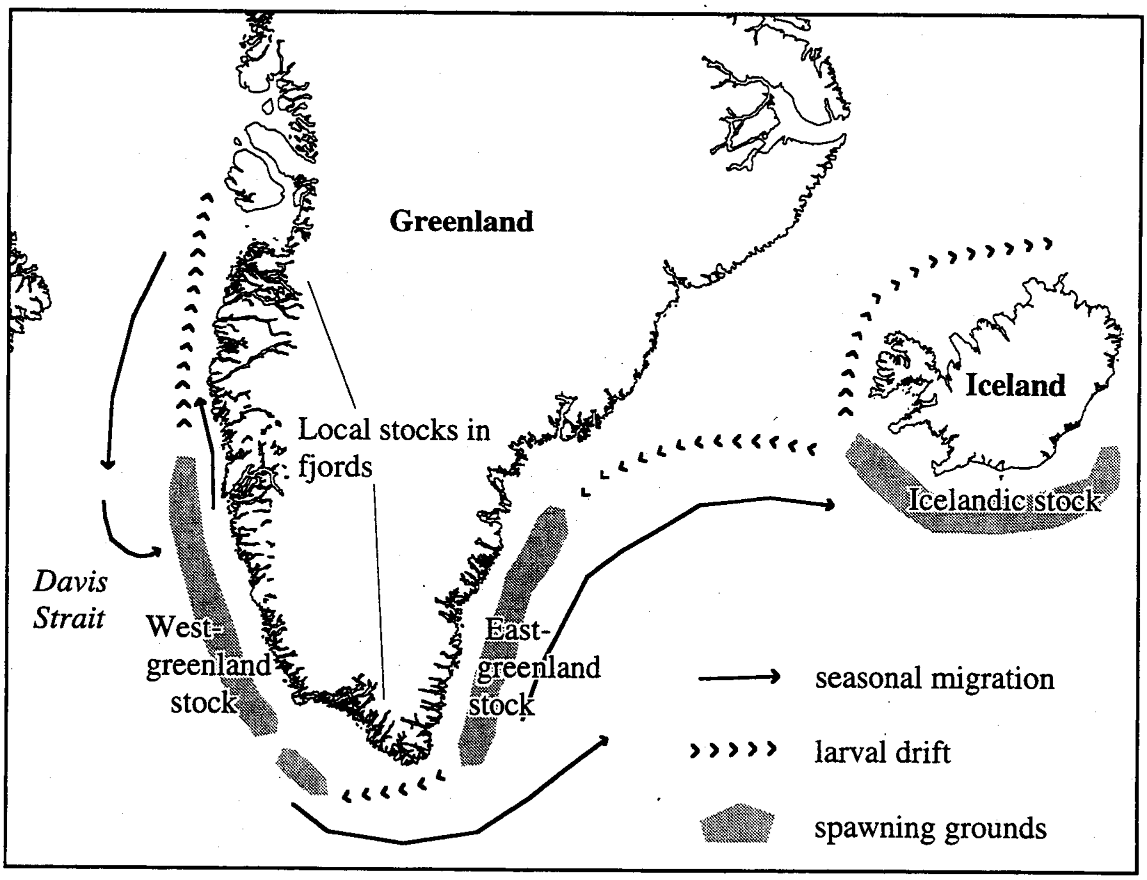

Fig. 3. Main spawning grounds, migration routes of mature fish, and larval drift routes of the cod stocks occurring off West Greenland.

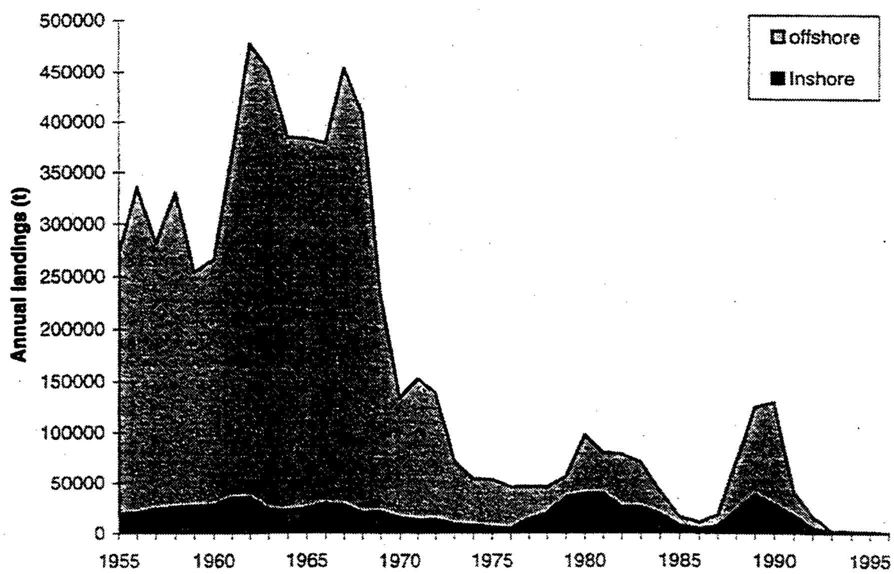

Fig. 4. Catches of cod off Greenland (Anon. 1997).

3.1.2 Greenland cod *(Gadus ogac)*

Distribution, habitat and ecology

Greenland cod is a more or less stationary inshore species, which occurs almost everywhere along the coasts of the study region down to depths of c. 300 m (Nielsen 1992).

Spawning usually takes place in February and March. Since the eggs are demersal, they do not disperse to the same extent as the eggs of the Atlantic cod, and the eggs generally remain inshore. Although spawning has been reported close to the shoreline (Hansen 1961), it is generally supposed that Greenland cod spawn at greater depths (Horsted pers. comm.). Spawning concentrations have not been reported.

Fisheries

Total annual catches of Greenland cod have been around 2,000 tons in recent years. The catches take place in the inshore areas along West Greenland, from Upernavik in the north to Kap Farvel in the south. With the decline and virtual absence of the Atlantic cod, the Greenland cod has become an increasingly important resource. According to Grønlands Statistik (1997), the distribution of catches of Greenland cod among municipalities in West Greenland in 1996 was:

District	Nan	Qaq	Nuu	Man	Sis	Kan	Aas	Qeq	Uum	Upe
	30%	13%	12%	6%	<1%	31%	3%	<1%	<1%	4%

(Nan=Nanortalik, Qaq=Qaqortoq, Nuu=Nuuk, Man=Maniitsoq, Sis=Sisimiut, Kan=Kangaatsiaq, Aas=Aasiaat, Qeq=Qeqertarsuaq, Uum=Uummannak, Upe=Upernavik).

3.1.3 Greenland halibut (*Reinhardtius hippoglossoides*)

Distribution, habitat and ecology

Greenland halibut in the North West Atlantic are considered to belong to a single spawning complex (Jensen 1935, Smidt 1969, Templeman 1973). Greenland halibut is a common deep water fish in certain fjords and in offshore waters throughout the study area and further north. Spawning takes place during spring. The spawning areas are presumed to be located in deep water (2,000-3,000 m) south of the ridge between Greenland and Baffin Island (Smidt 1969). However, tagging experiments have indicated that some fjord stocks in southwestern Greenland may be recruited from spawning areas off Iceland (Riget & Boje 1989, Boje 1994). The eggs and early larval stages are bathypelagic, remaining at considerable depths in the water column. Later, the larvae rise in the water column where they exist pelagically (Jensen 1935). They are subsequently dispersed to the north and west by currents. The larvae settle on the banks and immature Greenland halibut slowly migrate towards the deep fjords (Riget & Boje 1989) or the deep parts of Davis Strait (Jørgensen 1997). The main prey of the adult offshore Greenland halibut are shrimp and redfish, supplemented with other small fish and benthic invertebrates (Pedersen and Riget 1993).

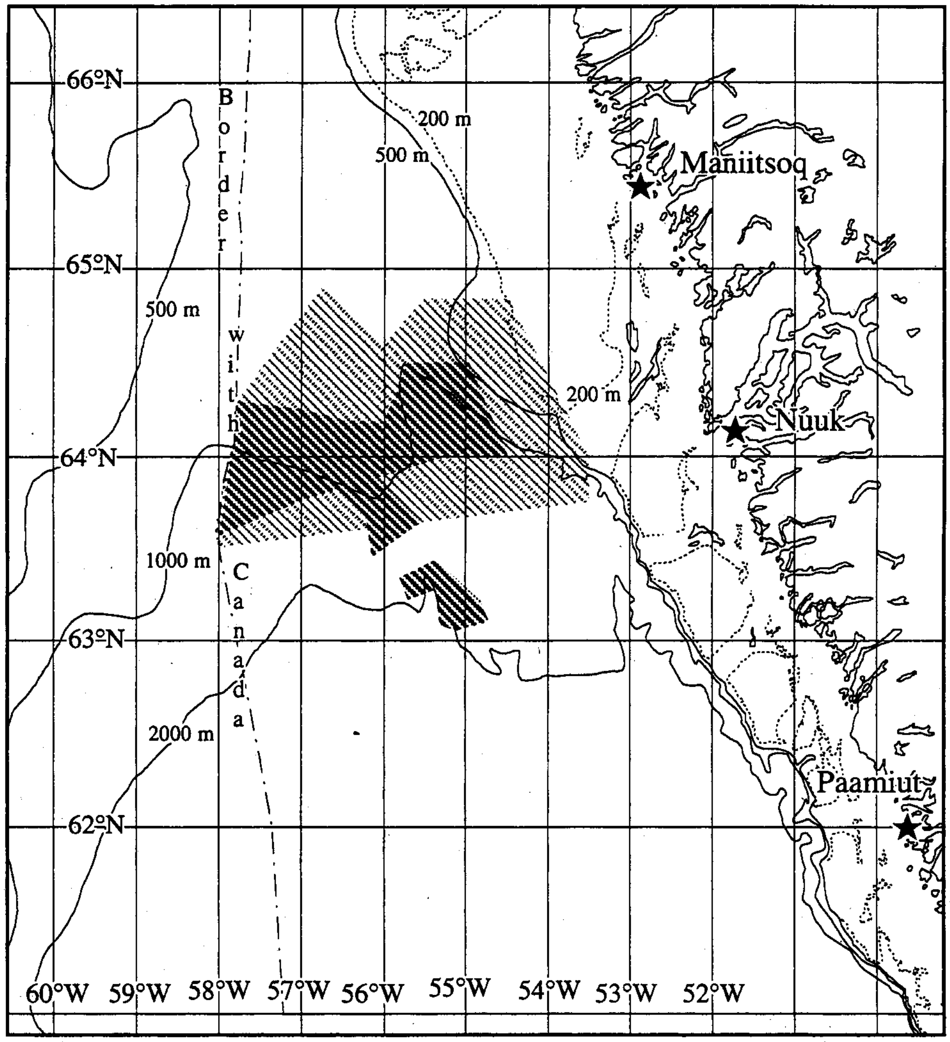

Fig. 5. Distribution of offshore Greenland halibut fishing grounds. Heavy shading indicate extensive fishing, light shading less extensive fishing . (Based on data from Anon. 1995, Boje pers. comm. and Jørgensen pers. comm.).

Fisheries

The annual Greenland halibut catch in the area between 60'45°N to 68'50°N is around 5,000 tons. Nearly all catches take place offshore in the area west off Nuuk (Fig. 5). The majority of this catch (81% in 1996) is taken by trawlers; the remaining by longliners. Almost all the fishery takes place in the second half of the year. Further north the Greenland halibut fishery is also carried out in deep fjords (Ilulissat, Uummannaq and Upernavik municipalities), where the catches have increased in recent years to 17,000 tons in 1996.

The biomass of offshore Greenland halibut in waters off Southwest Greenland has been estimated annually since 1987 on the basis of bottom trawl surveys. Although biomass has fluctuated during this period, overall the biomass has shown a decreasing trend (Jørgensen 1997).

3.1.4 Atlantic halibut (*Hippoglossus hippoglossus*)

Distribution, habitat and ecology

Atlantic halibut occur throughout the study region. The West Greenland stock is probably recruited from spawning areas off Iceland. There are, however, indications that Atlantic halibut also spawn on the western slope of the West Greenland banks (Hansen & Hermann 1953).

Spawning probably takes place during winter at depths of 300 - 1,000 m (Riget unpubl.). Eggs and small larvae are pelagic and are found in the middle of the water column - at considerable depths (e.g. 700 m). Small immature halibut assemble in nursery areas where they remain for 4-6 years (Godø & Haug 1987). They are usually stationary, but some may perform long range multidirectional migrations (Godø & Haug 1987). Mature halibut are found on the banks and also in some of the fjords during summer (Hansen & Hermann 1953).

Fisheries

In recent years, the total annual catches of Atlantic halibut in Greenland have been around 35 tons. Historically, the catches peaked in 1920's and 1930's with annual catches of about 7,000 tons. Since then catches have decreased dramatically, probably as a result of overfishing. Today, Atlantic halibut is mainly taken as by-catch in trawl fisheries.

3.1.5 Deep sea shrimp / northern deep water shrimp (*Pandalus borealis*)

Distribution, habitat and ecology

Shrimp occur both offshore and in the deep fjords throughout the study region at depths of 100-600 m. They are found in waters with temperatures ranging from 0° to 4°C (Horsted & Smidt 1956,

Carlsson & Smidt 1978). The northwestern part of Store Hellefiskebanke is probably an important nursery area for juvenile shrimp (Carlsson & Kanneworff 1987). Relatively high numbers of shrimp larvae have also been found in the Disko Bay area (Pedersen & Smidt 1995).

Shrimp spawn from July to September. Females carry eggs until March/May at which time the shrimps move to somewhat shallower waters to release the larvae. The larval phase lasts for a period of four months, and the larvae are pelagic during an unknown period (Carlsson & Smidt 1978, Horsted et al. 1978, Klimenkov et al. 1978). Both adult and larvae are found near the sea floor during daylight, while at night they move upwards in the water column (Horsted & Smidt 1956, Klimenkov et al. 1978).

Fisheries

The shrimp fishery is the most important fishery in Greenland today. It is one of the worlds greatest cold water shrimp fisheries, with a total annual catch of about 70,000 to 85,000 tons in the Greenland part of Davis Strait in recent years (Fig. 6). Nearly all of the catches

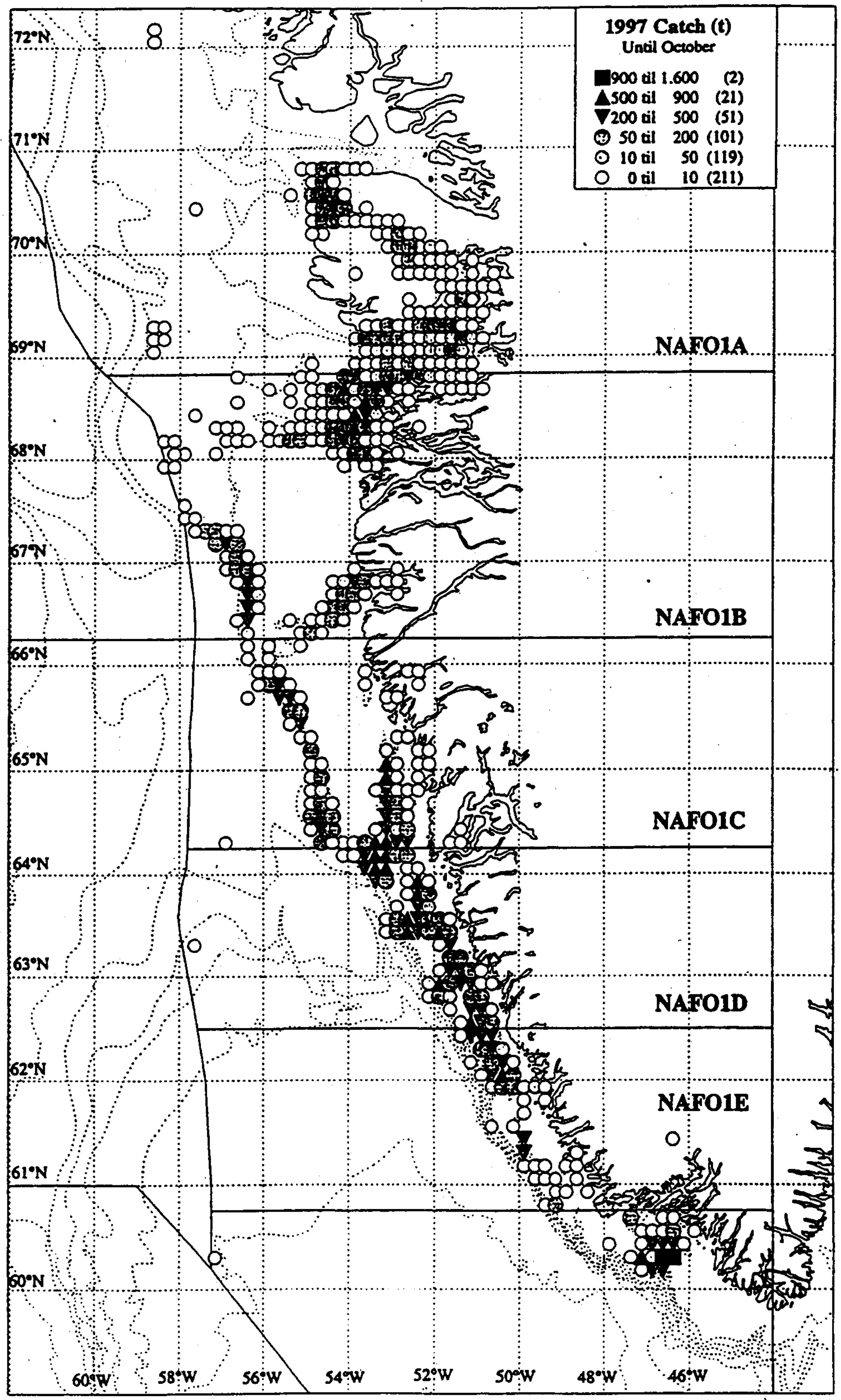

Fig. 6. The geographical distribution of the Greenland deep sea shrimp catches in 1997 by vessels larger than 50 GRT (Hvingel et al. 1997). in the area were taken offshore between 60°45'N and 68°50'N. The main inshore shrimp grounds are located further north in Disko Bay.

Shrimp are mainly trawled on the slopes of the banks, at depths between 300 and 600 m. In recent years the fishery has gradually moved southward (Siegstad 1996). While the main effort of the fleet was directed at the area between 66°N to 69°N in the late 1980's, a large part of the effort is now carried out between 62°N and 66°N (Hvingel 1996).

Shrimp are caught all year round, with the highest fishing intensity occurring from April to June, and lowest in December and January. The decrease in fishing intensity during winter is to some extent caused by ice cover.

Catch statistics are generally not very useful in assessing the state of a fishery resource. The Greenland Institute of Natural Resources (GINR) has therefore conducted bottom trawl surveys annually in the Davis Strait since 1988 in order to estimate the trawlable shrimp biomass. Although some fluctuation in the shrimp biomass in the Davis Strait area have been recorded, the surveys indicate a rather stable biomass during the period.

3.1.6 Snow crab (*Chionoecetes opilio*)

Distribution, habitat and ecology

Several crab species occur in the West Greenland waters. However, only the snow crab reaches an exploitable size. Snow crab occurs from Kap Farvel to Upernavik at depths from 20-400 m, most frequently in soft bottom area below 180 m. The biology of the snow crab in Greenland is almost unknown, and there is no detailed knowledge on it's distribution and population densities. However, during a survey of the fishery in 1991 the crabs were mainly found in the fjords (Andersen 1993).

Fisheries

A commercial fishery for crabs was initiated at Qeqertarsuaq in 1992, and in recent years fishing has also taken place at Aasiaat, Sisimiut and Nuuk. The fishery is mainly carried out, during autumn. Fig. 7 shows the most important fishing grounds in West Greenland.

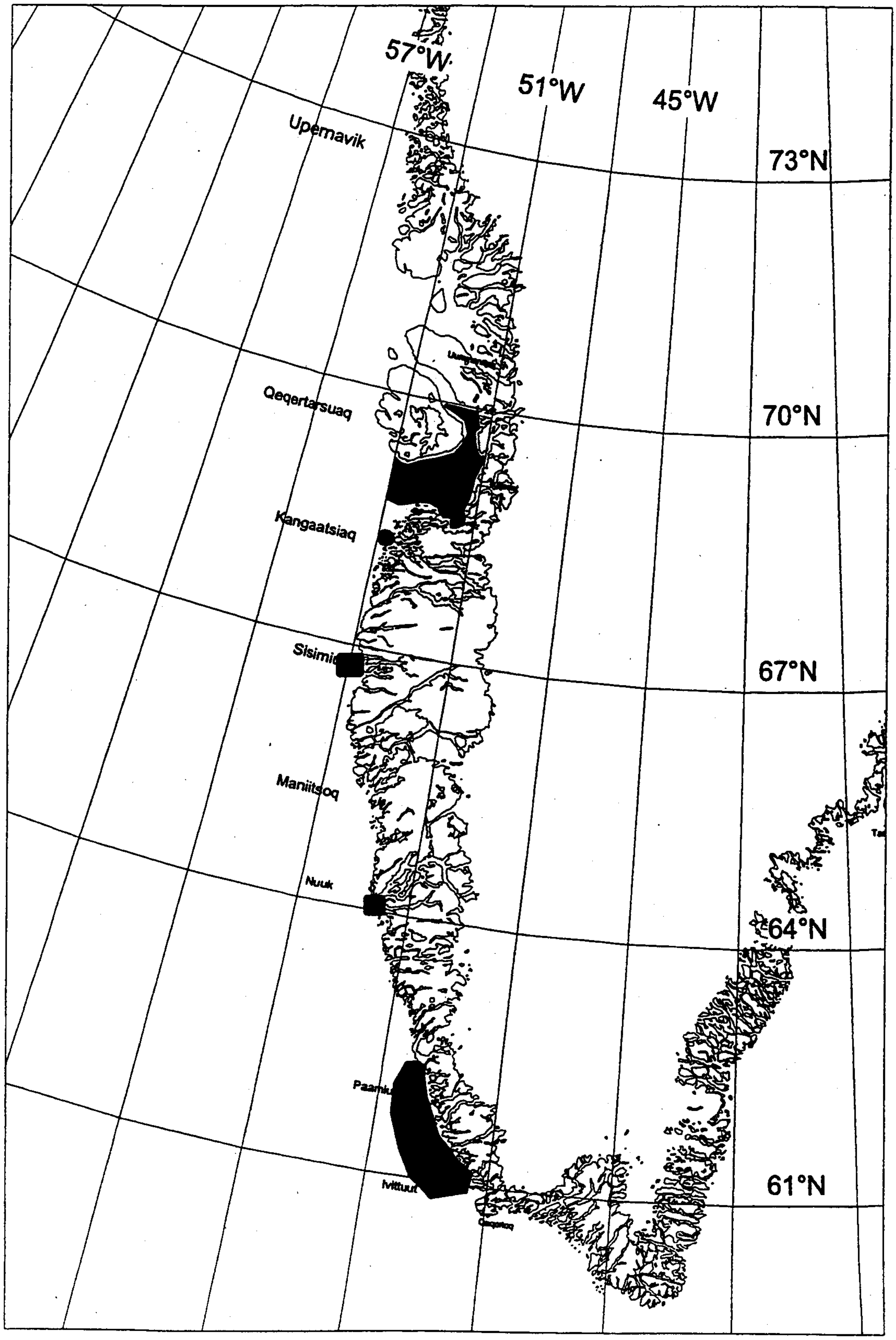

Fig. 7. Areas with commercial exploitation of snow crab.

3.2 Birds

Information on bird distribution and abundance during winter is sparse. The historical information is anecdotal, however, a few systematic surveys have been carried out (Brown 1986, Durinck & Falk 1996, Mosbech & Johnson in prep.).

General information on the occurrence and biology of the bird species presented here have mainly been derived from Salomonsen (1950, 1967, 1990), Cramp and Simmons (1977, 1979), Cramp (1985) and Boertmann (1994).

	Region within study area				
Species	Central and Western Davis Strait	Shelf north of the Southwest Greenland Open Water Area	Coastal lead north of the Southwest Greenland Open Water Area	Northern part of Southwest Greenland Open Water Area (63°-67°N)	Relationship to Ice Conditions
Northern Fulmar	-	-	-	Dispersed offshore	Apparently avoids more than 5/10 ice
King eider	-	Large concentrations on shallow banks	Some dispersed	Some on shallow banks and coastal	Main concentrations show only weak responsive movements to ice conditions
Common eider	-	Some on shallow banks	Dispersed	Mainly coastal, both concentrations and dispered	Depends on local coastal open water
Murre spp.	-	Some large concentrations	Dispersed	Dispersed	Apparently avoids closed ice (8-10/10) on the continental shelf
Black guillemot	Dispersed	Dispersed	Dispersed	Few	Aparently avoids open water and closed (9-10/10) ice
Glaucous/Iceland gull	-	-	Concentrations near communities	Dispersed	Few in closed ice; distribution appears related to fishery, towns and scavenging possibilities
Great black-backed gull	-	-	Few	Dispersed	Few in closed ice
Ivory gull	Dispersed offshore in southwestern Davis Strait	-	-	-	Stays in outher marginal ice zone off Labrador
Black-legged kittiwake	-	-	-	Dispersed offshore	Apparently avoids more than 5/10 ice

Table 2. Late winter bird habitats recorded in Davis Strait (63°-70° N) during aerial surveys for marine mammals in March 1981, 1982, 1991, 1993 and April 1990 (Mosbech & Johnson in prep.).

3.2.1 Northern Fulmar (*Fulmarus glacialis*)

Distribution and movements

Fulmars are widespread and numerous in Baffin Bay and Davis Strait during autumn (Brown et al. 1975, Brown 1986). While numbers apparently decline in winter, high densities were recorded in February and March in areas without ice (Durinck & Falk 1996, Mosbech & Johnson in prep.), indicating that fulmars are present in ice free areas throughout the winter. Recoveries of chicks ringed in West Greenland indicate that fulmars leave Greenland waters soon after fledging (Salomonsen 1967), which in turn may indicate that the birds present during winter represent other populations, e.g. from high Arctic Canada and Avanersuaq. The relatively high proportion of dark morph birds recorded by Durinck & Falk (1996) supports this hypothesis.

Habitat and ecology

The fulmar is strictly associated with the open sea, only coming to land in the breeding season. Fulmars arrive to their breeding colonies as early as April.

Fulmars are omnivorous, feeding on fish, plankton, squid etc. (Petersen 1996). They are also scavengers, and are often attracted to working trawlers in great numbers.

Human exploitation

The hunting season is from 16 August to 31 May. However, fulmars are only hunted locally and only on a very small scale.

3.2.2 Great cormorant (*Phalacrocorax carbo*)

Distribution and movements

The total Greenland population are found within open water areas of the study region during winter.

Cormorant arrive at the breeding colonies during April and depart again during September.

Population size and trends

The total breeding population is estimated to include about 2,000-3,000 pairs (Boertmann & Mosbech 1997). The population is probably increasing, as many new colonies have been established in recent decades (Boertmann & Mosbech 1997).

Habitat and ecology

Great cormorants are fish-eating birds, feeding in shallow waters (Debout et al. 1995) by diving from the surface. Cormorants usually stay close to the coast, as they are dependant on terrestrial resting sites; even during the non-breeding season. Age of first breeding is two or three, and the clutch is 3-4 eggs, indicating a moderate population turnover.

Human exploitation

The hunting season from 1 October to 31 March. Cormorants are hunted on an opportunistic basis and the species have no significance to households in West Greenland. The hunting pressure seems to have decreased in recent decades (Boertmann & Mosbech 1997).

3.2.3 Mallard (*Anas platyrhynchos*)

Distribution and movements

Mallards spend the winter along ice free coast, and almost all mallards from the Greenland population winter in the study area mainly in Paamiut and Qaqortoq municipalities (Salomonsen 1967).

Population status and trends

The Greenland mallards constitute a discrete population which are referred to an endemic subspecies, characterised by their large size and adaptations to the marine environment. The population size has never been estimated, however, it is probably low and fluctuates in relation to the severity of the winters (Salomonsen 1967).

Habitat and ecology

Mallards have a relatively high fecundity, breeding at one year of age and laying 6-10 eggs. This indicates a fast population turnover rate. Mallards feed in shallow waters and in the tidal zone where they can reach the bottom and the submerged vegetation from the surface by "up-ending".

Human exploitation

The hunting season is from 16 August to 31 May. Hunting is opportunistic, and only very few hunters have specialised in mallard shooting. Although the number of bagged mallards has never been estimated, it is probably low.

3.2.4 Common eider (*Somateria mollissima*)

Distribution and movements

Common eiders occur along coasts with open water throughout the study area, where large numbers, from both Greenland and Canada, winter (Fig. 8) (Salomonsen 1967, Abraham & Finney 1986, Mosbech & Johnson in prep.). Nevertheless, compared to the numbers of king eiders, comparatively few common eiders were observed and estimated off Nuuk in February/March 1989 (Durinck & Falk 1996).

Population size and trends

There is no doubt that the wintering population in the study area is very large, as it probably sustains an annual harvest of about 100,000 birds. This population is likely to be decreasing, however, evidence of this is anecdotal.

Habitat and ecology

The common eider is a coastal seaduck, which feed on benthic fauna such as molluscs and polychaetes by diving. Moulting birds in Greenland (Frimer 1995) and wintering birds in Norway (Bustnes & Lønne 1997) prefer hard bottom areas at depths of less than 10 - 15 m.

The common eider is highly gregarious, often occurring in large flocks on the wintering grounds.

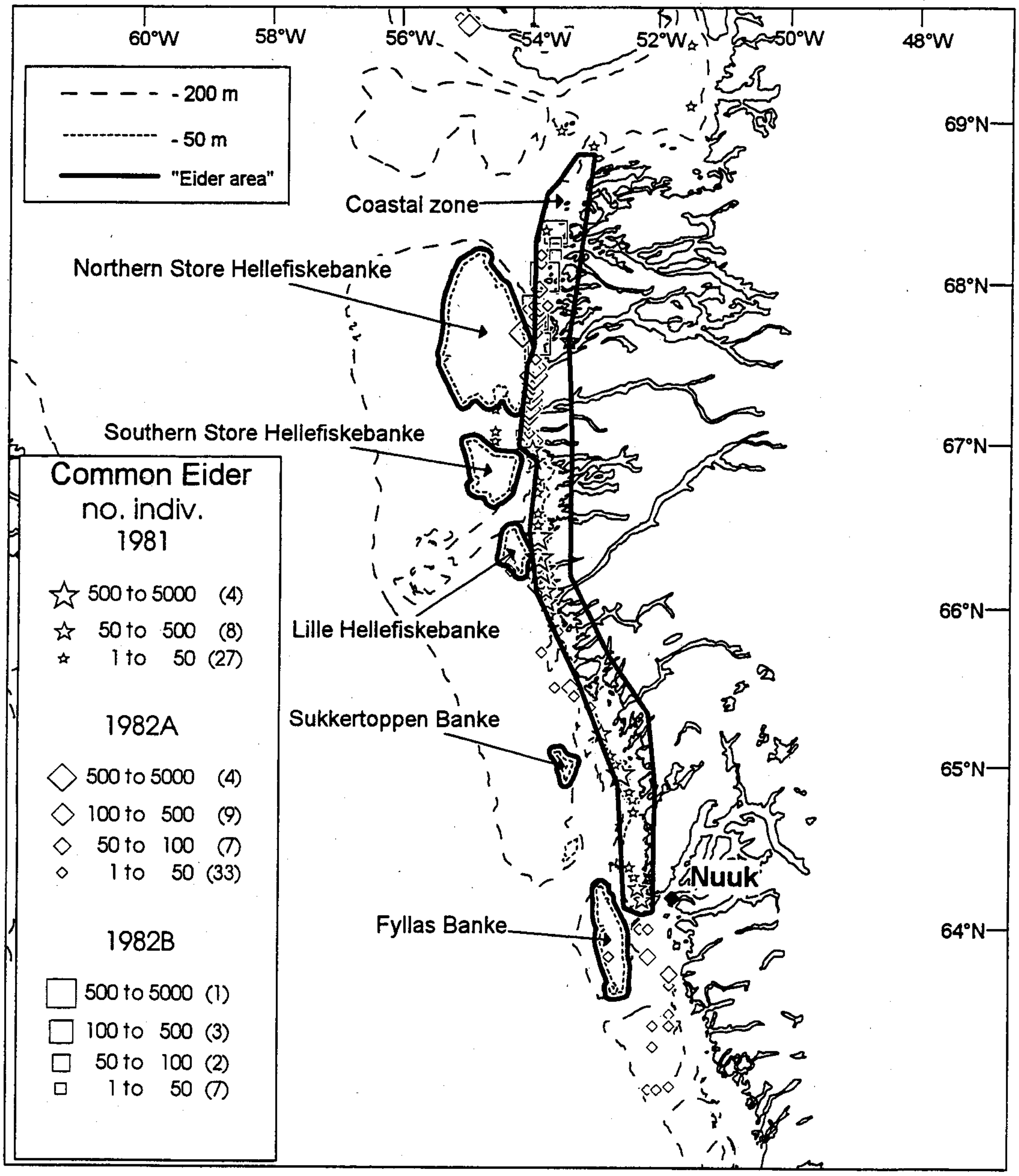

Fig. 8. Observations of common eider in the eastern Davis Strait during aerial marine mammal surveys in March 1981 and March 1982 (from Mosbech & Johnson in prep.).

Human exploitation

The hunting season from Kangaatsiaq and southwards is 1 October to 31 May. North of Kangaatsiaq it is 16 August to 31 May. The common eider is the secondmost important bird to the Greenland subsistence hunters. The newly introduced bag record system (Namminersornerullutik Oqartussat 1997) recorded an annual harvest of 72,000-87,000 eiders from 1993 to 1995 (common and king eider pooled). These numbers include all of Greenland, but by far the majority are shot south of Disko Bugt. These numbers are probably an underestimate of the actual catch. A previous catch estimate was 144,000 (common and king eider pooled, entire Greenland) shot annually in 1948-1951 (Kapel & Petersen 1982).

3.2.5 King eider (*Somateria spectabilis*)

Distribution and movements

King eiders winter in the study area in large numbers (Fig. 9) (Salomonsen 1967, Abraham & Finney 1986, Reed & Erskine 1986, Durinck & Falk 1996, Mosbech & Johnson in prep., Mosbech & Boertmann in prep.). Large recurrent concentrations (> 100,000) have been recorded on Store Hellefiskebanke in March (Mosbech & Johnson in prep.). Large concentrations, estimated at 280,000 birds, were recorded off Nuuk in February/March 1989 (Durinck & Falk 1996). However, king eiders occur throughout the coasts of the region south of Disko Bugt during the winter. In South Greenland (Qaqortoq and Nanortalik) mainly juvenile birds occur, and in fluctuating numbers between years (Zobbe 1973, Pihl 1976).

Population status and trends

King eiders have a circumpolar breeding distribution. The population occurring in the study area (the eastern North American population) breeds in Arctic Canada, east of 110 W, and in north-western Greenland. There are no reliable estimates of the size of the breeding population size, and there are only few data available on trends in this population (Elliot 1997). Regional declines in the breeding population have been reported in the Melville and Boothia Peninsulas. The winter population in the study region is estimated at 200,000-500,000 birds (Mosbech & Johnson in prep.).

Habitat and ecology

The winter habitat of king eiders is the relatively shallow (<50 m) parts of the banks, which are often far form the coast. Large and dense flocks, up to 25,000 individuals have been observed in heavy drift ice, with very restricted open water (Mosbech & Johnson in prep.). King eiders feed mainly on molluscs, crustaceans and echinoderms (Frimer 1997). Feeding often takes place further from shore and at greater depths than the feeding areas of common eider. King eiders feed by surface diving. Diving depths of more than 50 m have been reported (Cramp & Simmons 1977, Bustnes & Lønne 1997).

Human exploitation

The hunting season is from 16 August to 31 May. Harvest data is not presented here, because many hunters do not discriminate between the two eider species.

3.2.6 Harlequin duck (*Histrionicus histrionicus*)

Distribution and movements

The Greenland harlequin ducks spent the winter along exposed rocky coasts of the southern part of the study region. Satellite tracking has recently shown that Canadian harlequin ducks migrate to Greenland in late summer to moult and possibly to winter (M. Robert in litt., Canadian Wildlife Service).

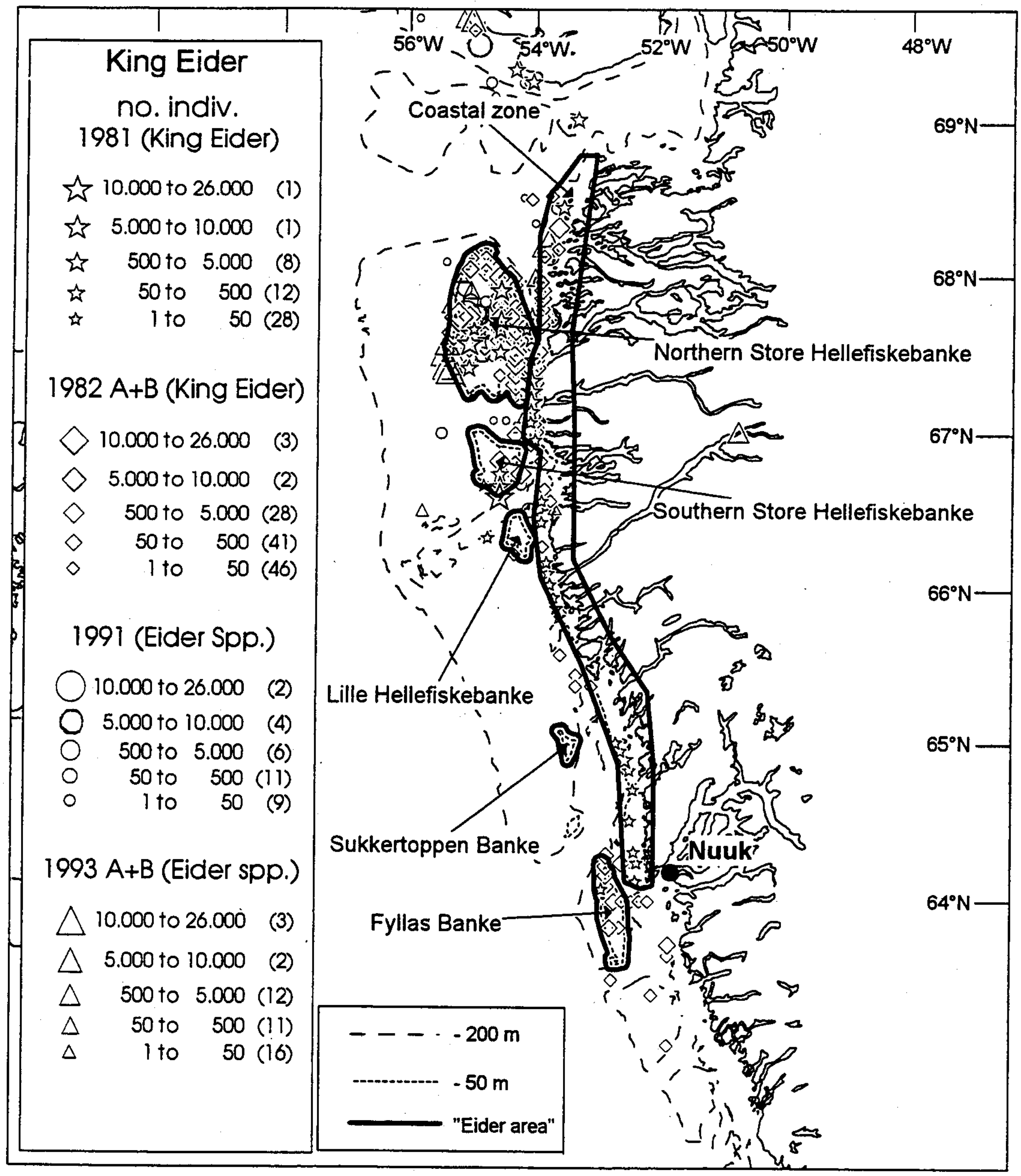

Fig. 9. King eider observations in the eastern Davis Strait during marine mammal surveys in March 1981, 1982, 1991 and 1993 (from Mosbech & Johnson in prep.).

Population size and trends

We "guesstimate" the Greenland population at 200-500 breeding pairs, and at 1,000-2,000 individuals during winter. However, with the Canadian contingency the winter population may be somewhat larger. The eastern Canadian population, which is estimated at less than 2,000 birds, is listed as endangered by Canadian authorities (Elliot 1997). There is no information on population trends, however, no immediate threats are apparent, and the Greenland population is believed to be stable.

Habitat and ecology

The habitat of the harlequin ducks outside the breeding habitats is the exposed rocky coasts of the outermost islands and peninsulas, where wave action is strong.

Age of first breeding is 2-3 years, and the clutch is 3-8 eggs, indicating a rather fast population turnover. During winter, harlequin ducks occur in small flocks. They feed by diving in waters usually not deeper than 3 to 4 m.

Human exploitation

Harlequin ducks are protected throughout the year.

3.2.7 Long-tailed duck (*Clangula hyemalis*)

Distribution and movements

The open water areas of the study region are important wintering grounds for long-tailed ducks. Birds from the Greenland breeding population winter in these areas. Ring recoveries show that Icelandic birds are present as well (Salomonsen 1967). A single recovery of a bird ringed in Greenland and recovered in Canada (abmigration) indicates that North American birds also winter in West Greenland (Salomonsen 1967). In February/March 1989, Durinck & Falk (1996) only recorded small concentrations, and only close to the coast off Nuuk. There is no other information on winter concentrations available. However, many long-tailed ducks were recorded in coastal areas and along the coastal fast ice edge between Nuuk and Disko Bugt during aerial surveys in April and May 1995-1997, (Mosbech et al. in prep).

Population size and trends

The size of the wintering population in Greenland is unknown. However an Icelandic/Greenlandic population has been "guesstimated" at 150,000 birds (Scott & Rose 1996).

Habitat and ecology

Long-tailed ducks have been observed in coastal areas and along fast ice edges during winter. Long-tailed ducks feed on benthic invertebrates which they catch by diving.

Human exploitation

The hunting season is from 16 August - 31 May. While the harvest is unknown, it is likely to be small, and not at all comparable to the harvest of the two eider species.

3.2.8 Red-breasted merganser (*Mergus serrator*)

Distribution and movements

According to Salomonsen (1950, 1967) red-breasted mergansers winter along the coast in the Open Water Region, most frequently in the area between Maniitsoq and Paamiut, and as far north as Kangaatsiaq. Very few birds were recorded during aerial surveys from Sisimiut and northwards in May, 1995 to 1997 (Mosbech et. al. in prep.), indicating that the majority occur further south. However, none were observed during offshore surveys between Nuuk and Paamiut in February/March 1989 (Durinck & Falk 1996). Thus, red-breasted mergansers probably occur close to the coast. The West Greenland population is probably discrete, as the birds deviate slightly in some morphological traits. Some authors regard the population as a separate subspecies.

Population size and trends

Although the size of the West Greenland population is unknown, it is probably small, as mergansers are rather rare. There is no available information on population trends.

Habitat and ecology

First age of breeding is at least 2 years, and the clutch is about 9 eggs, indicating a rather rapid population turnover. Outside the breeding season, the red-breasted mergansers are generally gregarious, occurring in small flocks. Red-breasted mergansers feed on fish and invertebrates which they catch by pursuit diving.

Human exploitation

The hunting season is from 16 August to 31 May. While the harvest is unknown, it is likely to be small, and mergansers are insignificant to households in Greenland.

3.2.9 White-tailed eagle (*Haliaeetus albicilla*)

Distribution and movements

White tailed eagles breed dispersed from Kap Farvel northwards to about 68° N (Kampp & Wille 1990). White-tailed eagles are mainly resident, although juvenile and immature birds make some seasonal movements within Greenland.

Population status and trends

The total breeding population in Greenland is very low, estimated at 150-170 pairs. The population is isolated and is recognised by some authors as an endemic subspecies (Salomonsen 1950). The population size appears to have been rather stable during recent decades (Kampp & Wille 1990).

The white-tailed eagle population in Greenland is listed as near threatened by IUCN (1996).

Habitat and ecology

During winter, white-tailed eagles stay in the vicinity of open water coasts. Congregations of mainly juvenile and immature birds may occur at sites where food is abundant, such as fishing ports. White-tailed eagles feed mainly on fish, such as char and Greenland cod, and birds such as gulls, eiders and murres. White-tailed eagles plunge at their prey at or near the water surface, and occasionally swim with prey that are too heavy to lift (Kampp & Wille 1997). White-tailed eagles also scavenge all kinds of carcasses.

White-tailed eagles have a slow population turnover rate. They are five to eight years old before they start breeding, and they only lay one or two eggs. Moreover, many established pairs often abandon breeding in years with delayed spring.

Human exploitation

White-tailed eagles are protected throughout the year.

3.2.10 Purple sandpiper (*Calidris maritima*)

Distribution and movements

Purple sandpipers are common at ice free coasts in the Open Water Area during winter (Salomonsen 1950, 1967, Pihl 1976).

Population status and trends

No information.

Habitat and ecology

Purple sandpipers feed on small invertebrates at rocky shores in the littoral zone during winter.

Human exploitation

Sandpipers are not exploited and are protected throughout the year.

3.2.11 Iceland gull (*Larus glaucoides*)

Distribution and movements

A large proportion of the Iceland gulls breeding in Greenland winter in the Open Water Area. Large numbers were recorded off Nuuk in March 1989 (Durinck & Falk 1996).

Population size and trends

The entire Greenland breeding population has been estimated at 20,000-100,000 pairs (Boertmann et al. 1996). No serious population trends have been recorded.

Habitat and ecology

During the non-breeding season, Iceland gulls usually stay in coastal waters. However, large numbers have been observed seawards in moderately ice covered waters in March (Durinck & Falk 1996).

Iceland gulls first breed at an age of 4 years, and clutch size is usually three eggs, indicating a moderate population turnover.

Human exploitation

The hunting season is from 16 August to 31 May. The harvest is unknown, but is apparently rather small.

3.2.12 Glaucous gull (*Larus hyperboreus*)

Distribution and movements

During winter, glaucous gulls are numerous in the Open Water Area and in open waters further to the north. Ring recoveries indicate that gulls both from Greenland and Svalbard are present in Southwest Greenland during winter (Salomonsen 1967, Norderhaug 1989). Gulls from the Canadian Arctic probably also winter in this area. Mosbech and Johnson (in prep.) report large numbers of gulls (Iceland gull and glaucous gull pooled), mainly in the Open Water Region and in the coastal lead system further to the north. Many glaucous gulls were recorded off Nuuk in February/March 1989, mainly in moderate ice cover (Durinck & Falk 1996).

Population size and trends

It is not possible to give any figures of the winter population within the region, nor is there any data available on population trends.

Habitat and ecology

Glaucous gulls usually venture further from the coast than Iceland gulls during winter (Durinck & Falk 1996). Like other gulls, glaucous gulls feed mainly on the sea surface, along the shoreline and on the ice. The clutch size is usually three eggs, and age of first breeding is four years, indicating a moderate population turnover.

Human exploitation

The hunting season is from 16 August to 31 May. The harvest is unknown, but is probably rather small.

3.2.13 Great black-backed gull (*Larus marinus*)

Distribution and movements

The Greenland population of great black-backed gulls winters in the Open Water Area and also further north where there are open waters. The winter population is supplemented by birds from other north Atlantic (Iceland, Europe) populations (Salomonsen 1990, Boertmann 1994a). Durinck & Falk (1996) found great black-backed gulls omnipresent and in large numbers off Nuuk in February/March 1989; a year with extremely severe ice conditions. During aerial surveys in March (1981 and 1982), great black-backed gulls were recorded in low numbers dispersed throughout the Open Water Area and along the West Greenland coastal lead (Mosbech & Johnson in prep.).

Population size and trends

The breeding range of the great black-backed gull has expanded considerably towards the north in recent decades, indicating an increase in the size of the breeding population (Boertmann et al. 1996).

Habitat and ecology

The great black-backed gulls is omnivorous, and feeds mainly at the sea surface and in the tidal zone.

Durinck & Falk (1996) reported the largest numbers of great black-backed gulls from areas with moderate to high icecover in February/March 1989.

Breeding first takes place when the birds reach 4 or 5 years of age. Great black-backed gulls lay 2 to 3 eggs, indicating a moderate population turnover.

Human exploitation

The hunting season is from 16 August to 31 May. Although the harvest is unknown, it is probably rather small.

3.2.14 Black-legged kittiwake (*Rissa tridactyla*)

Distribution and movements

During winter kittiwakes occur in low numbers in the Open Water Area in areas without ice cover (Durinck & Falk 1996, Mosbech & Johnson in prep.).

Habitat and ecology

Mosbech & Johnson (in prep.) report observations from only one out of two season, and only from almost ice free waters.

Human exploitation

The kittiwake is a popular game bird in western Greenland. An annual harvest of about 60,000 kittiwakes was reported throughout Greenland during the first three years of the bag record system (Namminersornerullutik Oqartussat 1997).

3.2.15 Ivory gull (*Pagophila eburnea*)

Distribution and movements

The ivory gull is a winter visitor to the study area. Ivory gulls were seen in low numbers (14) offshore in the study area during aerial surveys in March 1982, - a year of heavy ice conditions. None were seen in March 1981, - a year with light ice conditions (Mosbech & Johnson in prep.). During an aerial survey off Labrador in March 1981, 100 ivory gulls were observed (0,02 birds/km; Mosbech & Johnson in prep.). MacLaren Marex (1979) also recorded ivory gulls quite abundantly in the ice edge zone west of 56°W. (A total of 328 birds were observed, 0.32 birds/km^2), suggesting that the marginal ice zone off Labrador is the main wintering area for ivory gulls (Hjort 1976, Reneaud & McLaren 1982).

Population size and trends

The global population is very small (probably less than 15,000 pairs) and breeding is restricted to Arctic Canada, Greenland, Svalbard and the Siberian archipelagoes eastwards to Severnaja Zemlja (Blomquist & Elander 1981).

Habitat and ecology

Ivory gulls are associated to the driftice of Baffin Bay and Davis Strait during winter.

Human exploitation

The ivory gull is fully protected in Greenland.

3.2.16 Thick-billed murre / Brünnich's guillemot (*Uria lomvia*)

Distribution and movements

The Open Water Area is an internationally important wintering area for thick-billed murre population. Recoveries of ringed birds indicate that the majority of the West Greenland population moves to winter quarters off Newfoundland, while the remaining birds mainly stay in the northern part of the Open Water Area (Kampp 1988). During autumn large numbers of thick-billed murres from Svalbard, Arctic Canada, and probably also from Russia, North and East Greenland migrate to the Open Water Area (Fig. 10), where at least one million murres spend the winter (Kampp 1988).

Large concentrations start to build up over the shelf in the eastern Davis Strait during September-October (Fig. 11) (Mosbech et al. 1998). In October and November, at least a part of the birds move closer to the coast and eventually into the fjords (Durinck and Falk 1996). The murres seem to disappear from the coastal areas during March.

Juvenile birds in particular are bagged in western Greenland (Falk & Durinck 1992, Kampp et al. 1994). Provided that adult birds and young birds are equally easy to shoot, this indicates that a large part of the winter population is young birds, or that the young birds occur more frequently close to the coast. Only very limited surveys have been conducted in the offshore areas during winter (November-April). Large concentrations have been seen outside Nuuk Fjord in 1989 during unusually severe ice conditions (Durinck & Falk 1996) and in the ice at Store Hellefiskebanke in April 1990 (Mosbech & Johnson in prep). These last mentioned birds could have been early migrants heading towards colonies in northern Baffin Bay and perhaps Reid Bay in Canada. The offshore distribution and densities during the winter period are virtually unknown for the large wintering population which sustains an annual hunting bag of more than 100,000 birds.

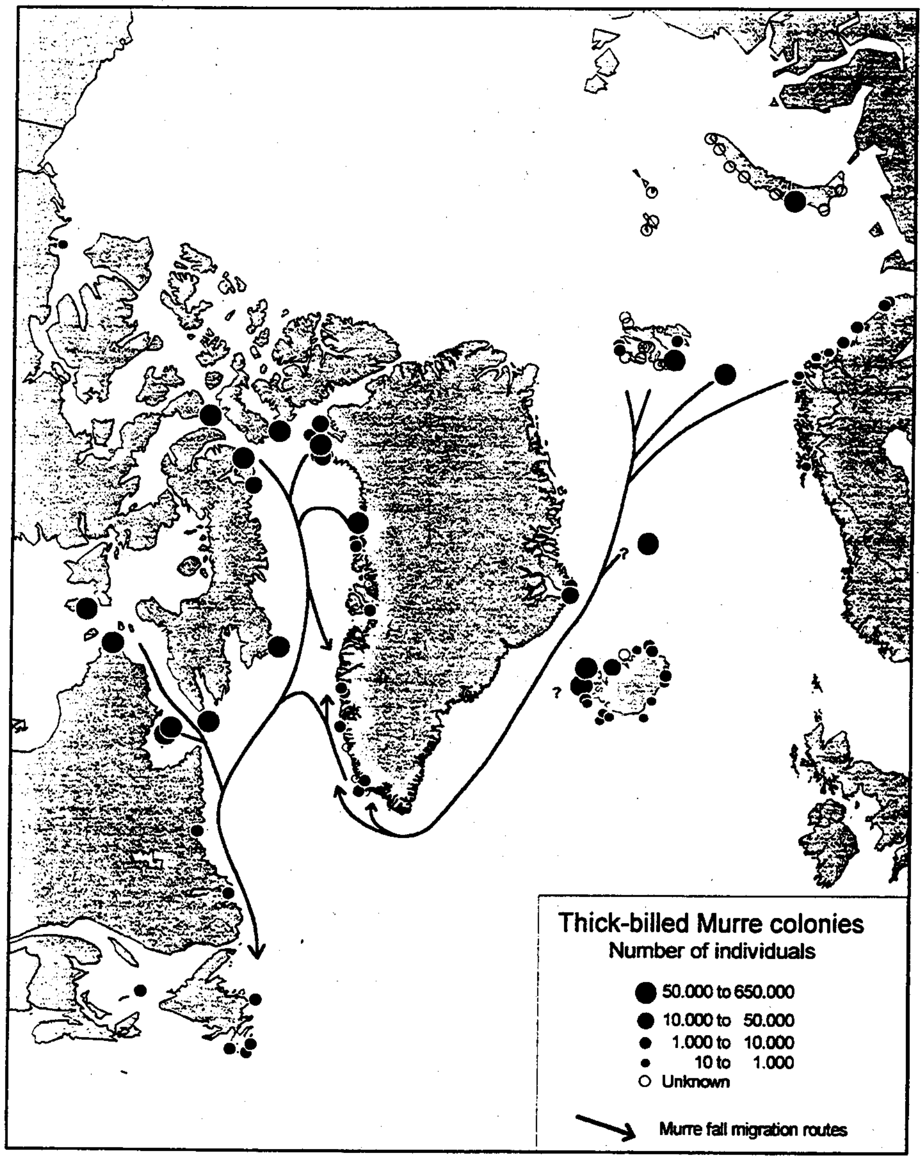

Fig. 10. Presumed migration routes of thick-billed murres wintering in West Greenland waters. Based on ring recoveries. Colonies indicated with black dots (from Falk & Kampp 1997).

Population size and trends

The West Greenland breeding population has decreased severely during recent decades (Kampp et al. 1994), while Canadian breeding populations have not showed signs of decline (Donaldson et al. 1997). No information on changes in the wintering populations of West Greenland is available.

Habitat and ecology

During winter, thick-billed murre feed on fish such as capelin, sand-eel and polar cod, and on large zooplankton such as euphausids and amphipods (e.g. Falk & Durinck 1993). Thick-billed murres dive from the surface to considerable depths, at least as deep as 75 m (Bradstreet & Brown 1985). However, a close relative, the common murre (*Uria aalge*), is able to dive to at least 180 m (Piatt & Nettleship 1985), and thick-billed murres are probably able to feed at similar depths.

The thick-billed murre is a typical example of a K-selected seabird: Murres are at least four or five years old before they breed, they have a high adult survival (long life expectancy) and they reproduce slowly (only one egg/pair annually). This means that the population turnover rate is slow, and that the populations are particularly vulnerable to increased adult mortality

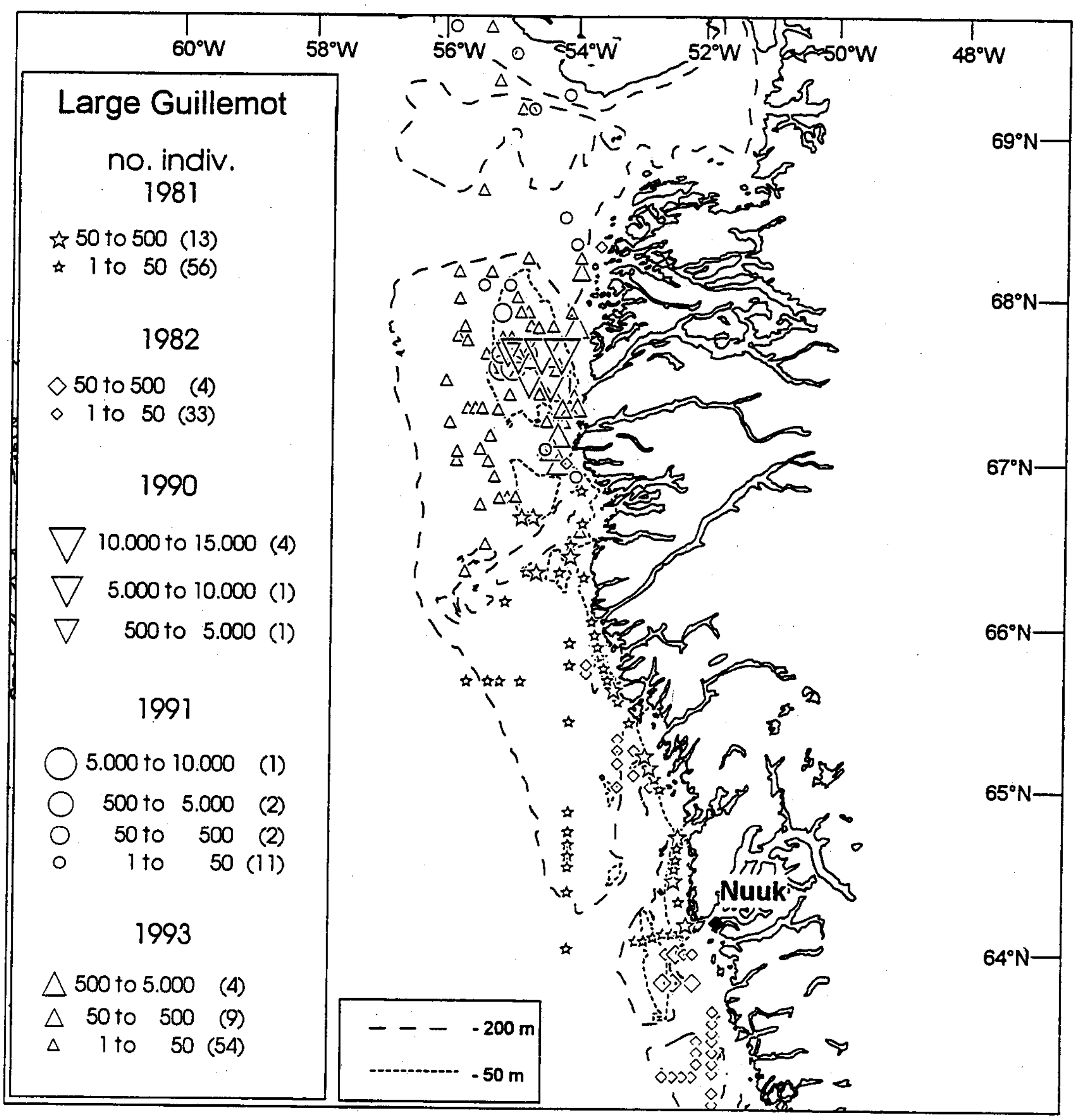

Fig. 11. Observations of thick-billed murres in eastern Davis Strait. (from Mosbech & Johnson in prep.).

Human exploitation

The hunting season from Kangaatsiaq municipality and southwards is from 16 October to 14 March. North of Kangaatsiaq municipality, the season opens on 1 August. The thick-billed murre and the two eider species are the most important birds to hunters in Greenland (Kapel & Petersen 1982). Kampp et al. (1994) give an thorough review of the development and impact of murre hunting in Greenland; - the summer hunt appears to be particular detrimental to the murre population. Falk & Durinck (1992) estimated the winter harvest in 1988/1989 in West Greenland at 300,000-400,000 murres, mostly of foreign origin. In 1993, 1994 and 1995, the annual harvest throughout Greenland was about 200,000 thick-billed murres as reported to the bag record system (Namminersornerullutik Oqartussat 1997).

3.2.17 Black guillemot (*Cepphus grylle*)

Distribution and movements

The black guillemot is a common breeder throughout the coasts of the study area. Birds breeding within the Open Water Area are mainly sedentary (Salomonsen 1967): they stay in the same area as they breed throughout the winter. Further north, the populations disperse mainly towards the south when the ice covers the water. However, black guillemots may be present in leads and cracks, and in other icefree areas all over the Baffin Bay area (Fig. 12). Durinck & Falk (1996) saw large concentrations in the partly ice covered sea just south of the ice edge off Nuuk in February/March 1989. In May 1995 and 1996, concentrations were recorded along the fastice edge off Kangaatsiaq and further north (Mosbech et al. in prep.). The Canadian aerial surveys in March 1981 and 1982 (Mosbech & Johnson in prep.) revealed that black guillemots were present almost everywhere in the Baffin Bay drift ice.

The black guillemots wintering in the Open Water Area are probably mainly of Greenland origin, however, substantial numbers of Canadian black guillemots may also be present. Ring recoveries show that black guillemots from Iceland also migrate to this area (Petersen 1977).

Population size and trends

The size and trends of the winter population in the study area are unknown.

Habitat and ecology

During winter black guillemots often are associated to ice such as drift ice and fast ice edges.

Black guillemots are not as extreme K-selected as the thick-billed murre: they start to breed at an age of two to four years, and the clutch is one or two eggs (Cramp 1985, Harris & Birkhead 1985, Hudson 1985). This indicates a somewhat faster population turnover rate, and they are probably less vulnerable to increased adult mortality.

Black guillemots are divers usually feeding on benthic fish and invertebrates in coastal waters. However, during winter they also stay in offshore areas and may feed on the eponthic fauna.

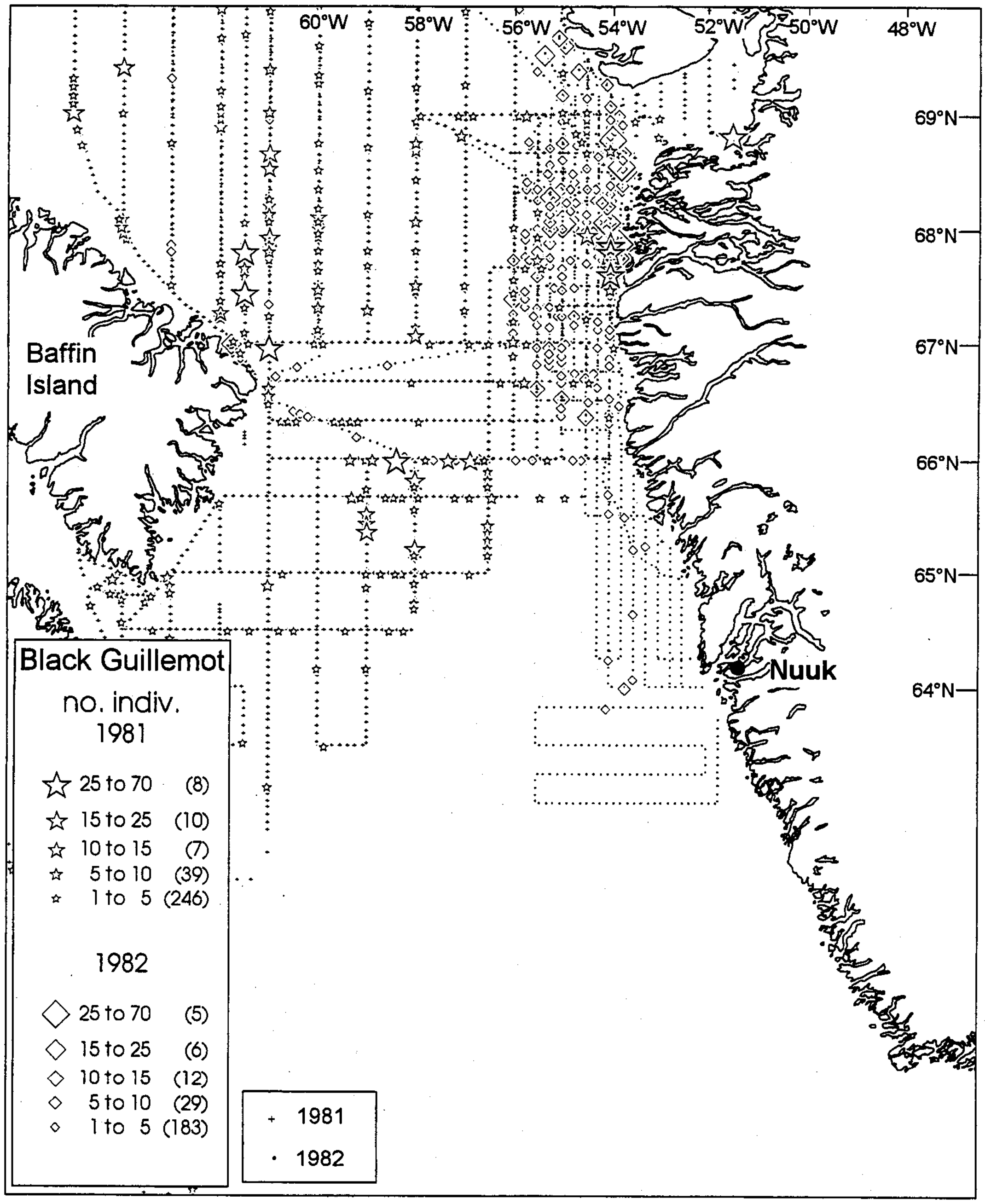

Fig. 12. Observations of black guillemots in Davis Strait. + indicates routes flown in 1981 and · routes flown in 1982. (from Mosbech & Johnson in prep.).

Human exploitation

The hunting season is from 16 August to 31 May. The black guillemot, juveniles in particular, are a popular quarry in some parts of Greenland. In 1994 and 1995 about 30,000 black guillemots were reported (entire Greenland) each year to the bag record system (Namminersornerullutik Oqartussat 1997).

3.2.18 Little auk / dovekie (*Alle alle*)

Distribution and movements

The little auk is a winter visitor to the study area. Ring recoveries show that little auks from Svalbard winter in the Open Water Area. Birds from the huge populations in Avanersuaq and East Greenland are probably also present, as indicated by the arrival pattern (Falk & Kampp 1992, Mosbech et al. 1998). Durinck & Falk (1996) estimated 6,000 little auks in a 6,000 km^2 area off Nuuk in Feb./March 1989, and much lower densities further south along the coast. Little auks have been recorded in high densities (10-50 birds/km^2)in the Fylla area in September - October (Mosbech et al. 1998). Salomonsen (1967) stated that the little auk is most numerous off South Greenland (Qaqortoq and Nanortalik municipalities) during winter. Kampp & Kristensen (1980) mentioned that little auks were numerous off Disko in the mild winter of 1978/79. The numbers of little auks and the distribution of the birds appear to show significant variations between years.

Population size and trends

No information is available regarding wintering birds in the Open Water Area.

Habitat and ecology

During winter, little auks occur both offshore on the banks and in coastal waters.

The population dynamics of the little auk are not well documented. Little auks are K-selected, although perhaps not to the same extent as the thick-billed murre. Little auks for example, only lay one egg per pair annually (Bedard 1985, Harris & Birkhead 1985).

Little auks feed primarily on zooplankton, which they catch during pursuit diving. Little is known of the winter diet of little auks (Bradstreet & Brown 1985).

Human exploitation

The hunting season in West Greenland is from 16 August to 31 May, however, few little auks are shot because they are usually considered to bee too small to hunt (Falk & Kampp 1992).Only a few thousand were reported to the bag record in 1993 in West Greenland (Namminersornerullutik Oqartussat 1995).

3.3 Mammals

Most of the information on the occurrence of marine mammals is derived from catch statistics and research programmes carried out mainly by the Greenland Institute of Natural Resources (formerly Greenland Fisheries Research Institute) and by the National Environmental Research Institute (formerly Greenland Environmental Research Institute).

Table 3. Global conservation status of some of the marine mammals mentioned in this report, as listed by the World Conservation Union (IUCN 1996) and the Washington Convention (Convention on International Trade in Endangered Species of Wild Flora and Fauna, CITES).

Species	IUCN	CITES appendix
Hooded seal	lower risk	-
Bearded seal	lower risk	-
Walrus	lower risk	III
Harbour porpoise	vulnerable	II
White whale	vulnerable	II
Narwhal	data deficient	II
Bowhead whale	vulnerable	I
Polar bear	lower risk	II

The category "lower risk" includes near threatened populations, conservation dependant populations or populations of least concern. CITES appendix I includes those species which are most threatened and which may not be exported or imported by member states (incl. Greenland). Included in CITES appendix II and III are threatened species which are subject to a limited and controlled export or import by the member states.

3.3.1 Harbour seal (*Phoca vitulina*)

Distribution, movements and population

The harbour seal is now rare in Greenland, occurring regularly in only a few places. Previously, the distribution included the coasts of West Greenland from Disko and southwards (Teilmann & Dietz 1994).

Broadly speaking, harbour seals are stationary, although they perform local movements between the outer coast and the fjords, as well as they avoid ice covered waters during the winter (Vibe 1990, Teilmann & Dietz 1994).

The Greenland harbour seal population belongs to the western Atlantic stock, often recognised as a separate subspecies *P.v. concolor* (Jong et. al. 1997a). This subspecies occurs from Greenland, southwards along the North American coast at least as far as northeastern USA (Bigg 1981).

The population size is unknown, however, the catch has declined steadily during this century within most of the range (Teilmann & Dietz 1994). Counts in one of the traditional haul-out sites indicates a similar trend (Teilmann & Dietz 1994).

Habitat and ecology

Harbour seals aggregate in common whelping and moulting grounds during spring and summer. The whelping grounds are usually offshore archipelagos or remote islets, while the moulting grounds are extensive sand banks, often located at the heads of the fjords (Vibe 1990, Teilmann & Dietz 1994). The harbour seal is the only seal in the study area which hauls out on land. There is no information on winter habitats available.

Harbour seals prey upon fish such as Arctic char (*Salvelinus alpinus*), Greenland cod (*Gadus ogac*), polar cod (*Boreogadus saida*), redfish (*Sebastes marinus*) as well as crustaceans and benthic molluscs (Teilmann & Dietz 1994).

Human exploitation and conservation status

The present Greenland population is small and is declining, probably as a result of overharvesting (Teilmann & Dietz 1994). The population should be considered as vulnerable.

Adult seals and pups are legally protected on breeding and moulting grounds from May 1 to September 30.

3.3.2 Ringed seal (*Phoca hispida*)

Distribution, movements and population

The ringed seal is the most common and widespread seal in Greenland. The highest densities of seals are found north of 69°N, where the occurrence of winter ice is regular. The ringed seals is common, but generally not numerous south of 69° N.

The ringed seal is usually regarded as stationary, but tagging has shown that immature seals at least are able to undertake considerable movements (Heide-Jørgensen et al. 1992, Kapel et al. in press).

No information on the population size and distribution in the study region is available. In the Baffin Bay area, the population was estimated at 370,000-787,000 individuals in the drift ice, and at c. 200,000 individuals on the fast ice from Uummannaq and northwards (Miller et al. 1982).

Habitat and ecology

Ringed seals are usually associated with coastal areas, where they whelp on stable ice in fjords. However, large offshore populations also occur in the drift ice of Baffin Bay (Finley et al. 1983). Unlike harp seals, ringed seals do not form herds, and usually occur as solitary individuals.

The whelping period is in March and April, and pups are born on the ice in snow covered lairs.

Siegstad & Neve (in press) analysed the diet of ringed seals in Greenland, and found a wide variation between seasons and locations. Polar cod (*Boreogadus saida*), Arctic cod (*Arctogadus glacialis*), capelin (*Mallotus villosus*), squid and amphipods were identified as important prey.

Human exploitation and conservation status

The Greenland ringed seal population is large and not threatened. As hunting is not regulated, the seals are hunted throughout the year. The ringed seals is generally the most important marine mammal to

Greenland's subsistence hunting (Kapel & Petersen 1982). Siegstad (1988) estimated that about 20% of the Greenland population was either directly or indirectly dependent on the ringed seal catch. The catch record of 1994, reported c. 25,700 seals in the region covered by this report; about 18,000 (68%) were taken during the period November to April (Kapel & Rosing-Asvid 1996).

3.3.3 Harp seal (*Pagophilus groenlandicus*)

Distribution, movements and population

The harp seals whelp in common whelping areas outside the Greenland waters in early spring, and are mainly summer visitors to the area covered by this report. However, many seals spend the winter in the Open Water Area off West Greenland (see catch statistics below), and do not return to the moulting areas until April (Sergeant 1965, Kapel 1995).

The north-west Atlantic stock has increased in recent years due to the ban on seal pup hunting off Newfoundland. The most recent (1994) population estimate was between 4.5-4.8 million individuals (Jong et al. 1997b).

Habitat and ecology

Harp seals are most numerous offshore, where large herds occur on the fishing banks. They also venture far into the fjords and along the coast in pursuit of spawning capelin.

The food of harp seals in Greenland waters has been reviewed by Kapel (1995). Although there is considerable annual variation in the diet, small fish such as capelin (*Mallotus villosus*) and sand eel (*Ammodytes spp.*), and large zooplankton species such as amphipods and euphausids are predominant prey items.

Human exploitation and conservation status

There are no regulations in relation to harp seal hunting in Greenland, and harp seals are caught throughout the year. The catch record of 1994 reports that c. 40.000 harp seals were caught in the region covered by this report (Kapel & Rosing-Asvid 1996). Of these, about 13,000 (33 %) were taken in the period November to April. The population is not threatened.

3.3.4 Hooded seal (*Cystophora cristata*)

Distribution, movements and population

The hooded seal is a migrating seal moving between whelping areas, moulting areas and feeding areas. Hooded seals occurring in Davis Strait and Baffin Bay have their whelping grounds on the ice off Newfoundland and on the pack ice edge in the Davis Strait (Sergeant 1974, 1977, Hay et al. 1985, Bowen et al. 1987, Stenson & Sjare 1996, Kapel 1982, 1996). After the breeding season in March, hooded seals arrive at the west coast of Greenland from late April. Also before the whelping period hooded seals appear to be common in Southwest

Greenland (Kapel & Rosing-Asvid 1996, Kapel 1997). The southward migration begins in September, but little is known about the migration routes.

The whelping ground in central Davis Strait was in 1974, 1977, 1978, 1984 and 1997 located on the drift ice between 62°N and 63° 30'N and between 56° and 62° W(Hay et al. 1985, Bowen et al. 1987, Kapel 1998). It is important to stress that the position of the whelping patches is highly dynamic, as they move with the drift ice (Fig. 13).

The total population, including the Greenland Sea whelping grounds, is estimated at 500,000-600,000 individuals (Jong et al. 1997c), and the number of pups present a single day on the ice in the Davis Strait was estimated at 18 590 on 24 March 1974 and at 9 820 on 25 march (Bowen et al. 1987). The difference is due to different survey methods and to the fact that the ice dispersed between the two surveys allowing pups to enter the water.

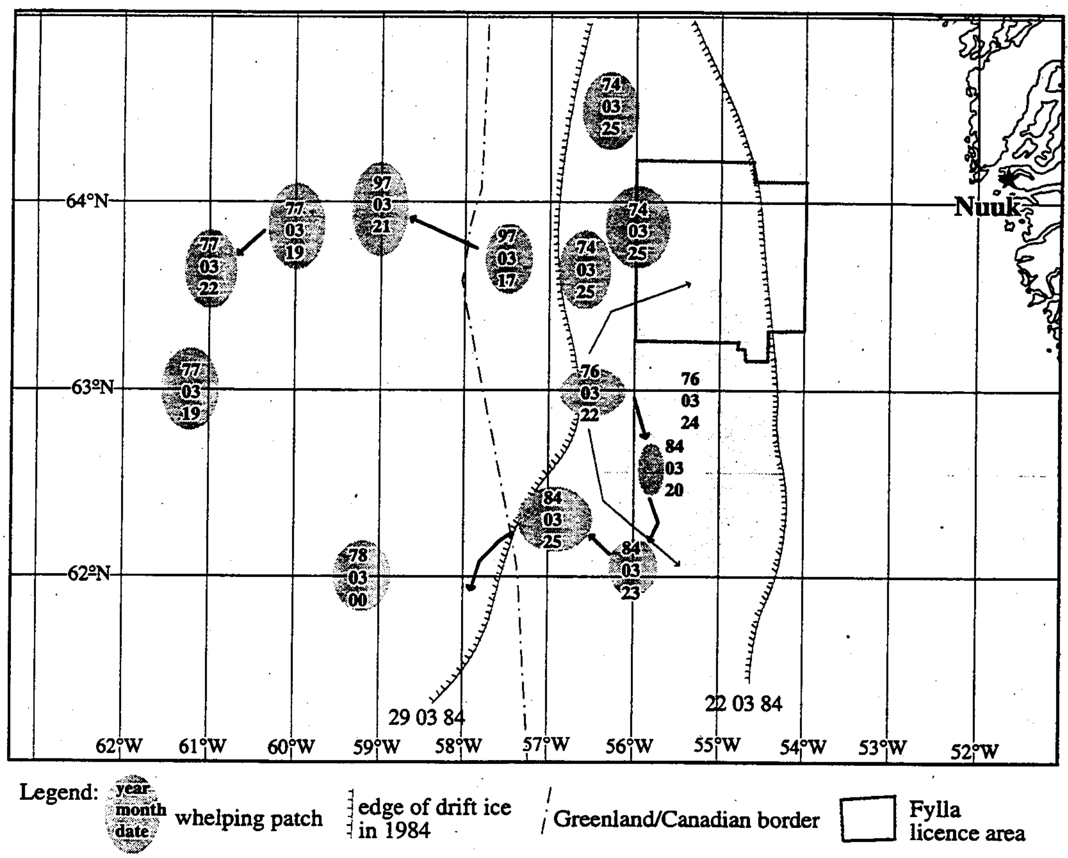

Fig. 13. Distribution and movements of hooded seal whelping patches 1974, 1976, 1977, 1978, 1984 and 1997. In 1976 the driftice broke up after 22 March and the whelping seals became more dispersed by 24 March. Solid arrows show movements of specific patches. The drift ice edge is shown for two different days in 1984. After Kapel (1998).

Habitat and ecology

Hooded seals are not gregarious except during the whelping season, and are usually found offshore and along the outer coast. They often dive to considerable depths; at least 1000 m (Folkow & Blix 1995). The food varies depending on the season and locality, however, fish such as Greenland halibut (*Reinhardtius hippoglossoides*), redfish (*Sebastes* sp.) and capelin (*Mallotus villosus*) are frequent prey, supplemented by squid and prawn (*Pandalus sp.*), see Kapel (1995).

Whelping takes place on thick drift ice from mid-March when the whelping patches are formed. The pups suckle for a very brief period (3-4 days) before they become independent of their mother, but stay in the ice for a longer period well into April. The whelping period is about three weeks during which time new females arrive to give labour and newborn pups are present on the ice; in the Davis Strait probably from second week of March to the end of the month (Kapel 1998).

Human exploitation and conservation status

The different hooded seals populations have declined in size as a result of heavy hunting in the past, and no recovery seems to have taken place (Jong et al. 1997c), although Bowen et al. (1987) suggest that the northwestern Atlantic population may have increased in recent years. The breeding grounds (as the Davis Strait ground) are considered as particularly important areas for the population (Jong et al. 1997c). See also Table 3.

There are no regulations in relation to hooded seal hunting in Greenland. The catch record for the region covered by this report reports c. 3,700 hooded seals caught in 1994, with 1200 (31%) taken in November to April (Kapel & Rosing-Asvid 1996). The population is not threatened.

3.3.5 Bearded seal (*Erignathus barbatus*)

Distribution, movements and population

The bearded seal is a winter visitor to the region covered by this report. Bearded seals are widely distributed in the Baffin Bay area, and usually occurring in low densities (see Koski 1980 for the Canadian part of Baffin Bay). Concentrations of bearded seals were located on the northern part of Store Hellefiskebanke during winter and spring surveys in 1980 -1981 and 1996-1997 (MacLaren & Davis 1983, Mosbech et al. in prep.).

Habitat and ecology

Bearded seals are not capable of maintaining breathing holes in ice thicker than 20-30 cm (Vibe 1950). They are therefore mainly found in loose pack ice or in areas where open water occurs regularly during winter. Bearded seals prefer rather shallow waters (< 50 m), but recent observations of wintering bearded seals at Store Hellefiskebanke indicate that they also occur in deeper waters (Mosbech et al. in prep.). They do not form herds and usually occur as solitary individuals. Bearded seals whelp on the ice during April and May (Vibe 1990). Whelping concentrations are not known for this species.

Bearded seals feed on benthic fish, crustaceans, echinoderms, polychaetes and molluscs (Vibe 1990, Kapel unpubl.). However, they may also feed on pelagic and eponthic fish (Vibe 1990), in waters deeper than 200 m, which is their maximum dive depth (Braham et al. 1977).

Human exploitation and conservation status

Nothing is known about population trends of bearded seals in Greenland. See also Table 3.

There are no regulations in relation to bearded seal hunting. Bearded seals are caught throughout the year. The catch record of 1993, reports c. 750 bearded seals caught in the region covered by this report (Namminersornerullutik Oqartussat 1995). The population is not threatened.

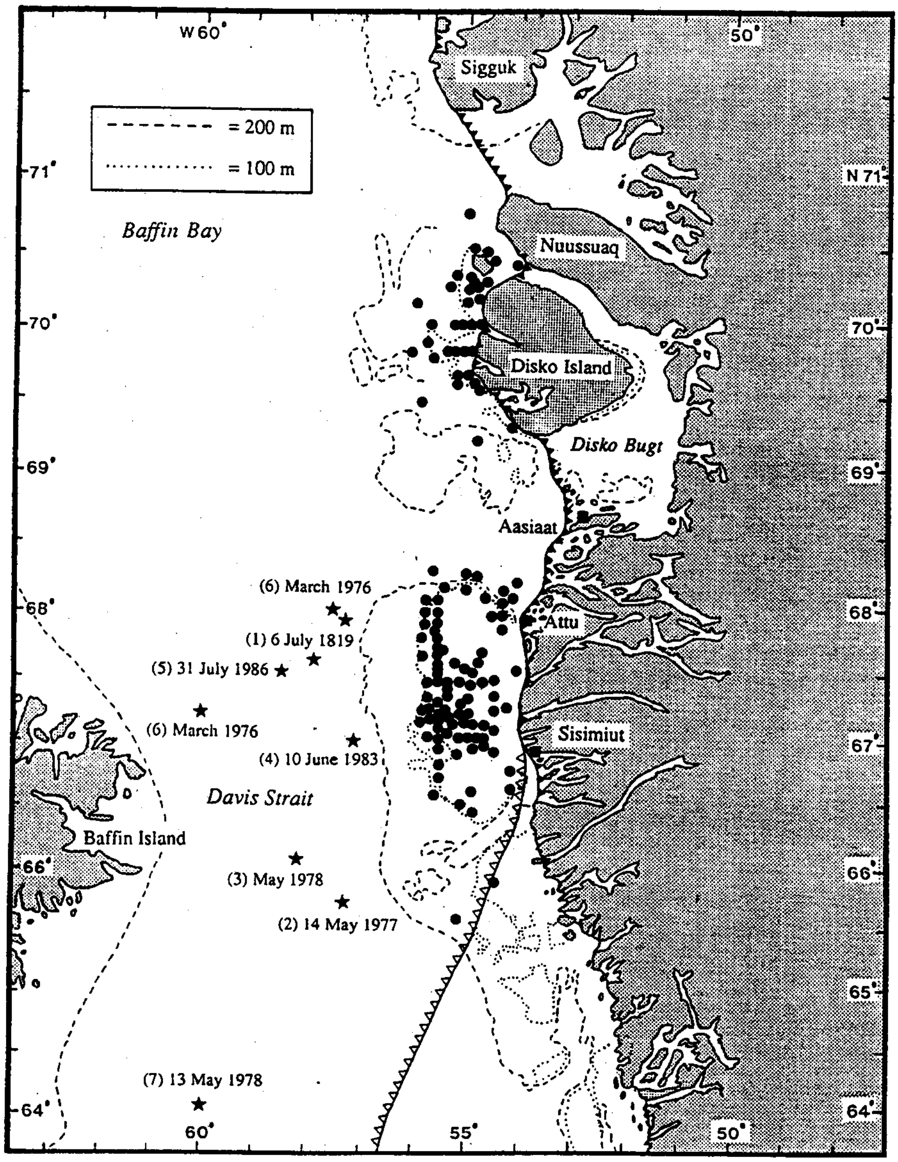

Fig. 14. Distribution of walrus observations reported by Born et al. (1994). Walrus observations are indicated with dots and stars. Dots refer to aircraft based sightings of groups in March/April; stars refer to ship based sightings of groups in March-July. The line with black triangles indicates the edge of the fast ice, the line with open triangles indicates average position of drift ice edge (From Born et al. 1994).

3.3.6 Walrus (*Odobenus rosmarus*)

Distribution, movements and population

The walrus is a winter visitor to the region covered by this report. Its main wintering grounds are located in the West ice on Store Hellefiskebanke between 66° and 68° 30′ N and west of Disko at about 70° N (Fig. 14) (Born et al. 1994). The walruses are present in these areas from February until late May (Born et al. 1994, 1995).

The population wintering in West Greenland is estimated to be at least 500 animals (Born et al. 1994). The stock relationships of the population remain unclear, however, the southern population may be connected with the Baffin Island/Foxe Bassin population, and the northern occurring off Disko with the North Water population (Born et al. 1994, 1995).

Habitat and ecology

Wintering walruses occur in areas with water depths less than 100 m and with dense drift ice on which they haul out (Born et al. 1994). In the West Greenland area, walruses occur as solitary individuals or in small groups (<10). Calves have not been observed in this area for many decades (Born et al. 1994).

Walruses in West Greenland feed on bivalves and occasionally sand eels (*Ammodytes spp.*) (Born et al. 1994).

Human exploitation and conservation status

The very small and declining walrus stock occurring in West Greenland is vulnerable and has been declining for decades (Born et al. 1994). This population previously used terrestrial haul-outs south of the settlement Attu in the period October to February. However, these sites have been abandoned since about 1940 (Born et al. 1994). See also Table 3.

The walrus hunting season is from January 1 to May 31 (for males) and January 1 to March 31 (for females). Walruses are fully protected south of 66°N. Only professional hunters are allowed to catch walrus. The reported catch for 1993 in the region covered by this report was 197 animals (Namminersornerullutik Oqartussat 1995).

3.3.7 Harbour porpoise (*Phocoena phocoena*)

Distribution, movements and population

The harbour porpoise occurs throughout the region covered by this report, with the main distribution between Paamiut and Sisimiut (Teilmann & Dietz 1998). Short seasonal movements probably takes place from inshore summer habitats to offshore winter habitats (Kinze 1990, Teilmann & Dietz 1998).

The population size is unknown (Teilmann & Dietz 1998), and no areas of particular importance are known.

Habitat and ecology

Harbour porpoises are found in coastal waters during summer. They give birth to their young in early July (Kinze et al. 1990, Teilmann & Dietz 1998).

Harbour porpoises are opportunistic feeders (Teilmann & Dietz 1998). The diet in Greenland waters consists of fish such as capelin (*Mallotus villosus*), Greenland halibut (*Reinhardtius hippoglossoides*), redfish (*Sebastes sp.*), cod (*Gadus sp.*), squid and crustaceans (Kinze 1989 a, b, c, 1990, Teilmann & Dietz 1998).

Human exploitation and conservation status

Harbour porpoises may be hunted throughout the year. In 1993 and 1994 about 1700 harbour porpoise were reported caught and in 1995 about 1400; almost all taken within the region covered by this report (Namminersornerullutik Oqartussat 1995, 1996, 1997). See also Table 3.

3.3.8 White whale (*Delphinapterus leucas*)

Distribution, movements and population

White whales are winter visitors to the northern part of the region covered by this report (Fig. 15). During aerial surveys in recent years, white whales have been recorded as far south as 65° 40'N (Heide-Jørgensen et al. 1993, Heide-Jørgensen & Reeves 1996). Early this century, white whales occurred much further south in West Greenland (Heide-Jørgensen 1994, Heide-Jørgensen & Reeves 1996). The whales arrive during November. By late May the majority of the whales have usually left the region, although this is somewhat dependent on the ice conditions.

Habitat and ecology

The white whale winter habitat is the open drift ice on shallow water (< 200 m) on the banks. The whales have not been recorded further than about 80 km from the coast (Heide-Jørgensen et al. 1993).

Human exploitation and conservation status

The population wintering in West Greenland was significantly reduced between the early 1980ies and the mid-1990ies, perhaps as much as 63% (Heide-Jørgensen et al. 1993, Heide-Jørgensen & Reeves 1996). This decline, or at least a part of it, can probably be attributed to overhunting (Heide-Jørgensen & Reeves 1996). The published catch record of 1993, reports that 304 white whales ere caught in the region covered by this report (Namminersornerullutik Oqartussat 1995). White whales may be caught all year round, however, the catch per boat is limited and hunting methods are restricted. See also Table 3.

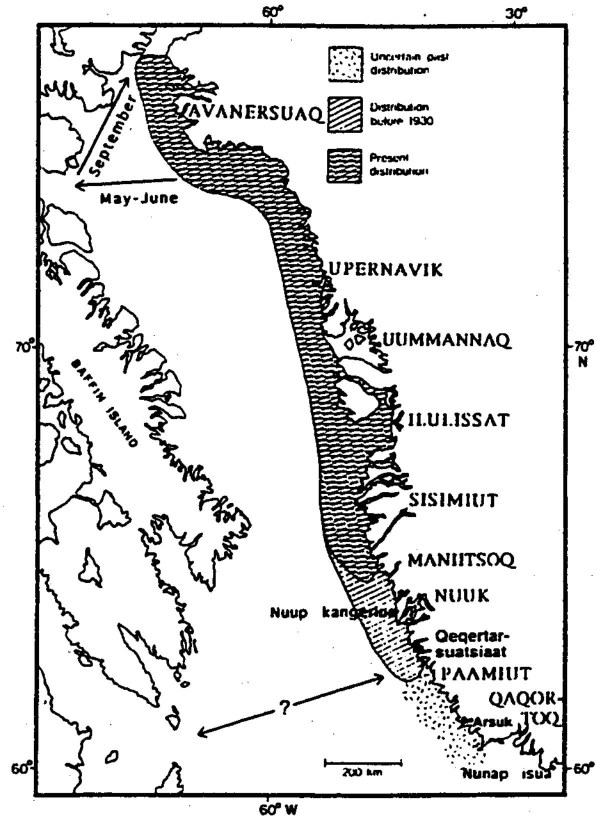

Fig. 15. Historic and present distribution of white whales in West Greenland, with likely routes of migrations indicated with arrows (from Heide-Jørgensen 1994).

3.3.9 Narwhal (*Monodon monoceros*)

Distribution, movements and population

Narwhals are winter visitors to the northern part of the region covered by this report. They winter throughout Baffin Bay and northern Davis Strait, and only in small numbers in the more open pack ice to the south of Disko as far south as 67° 30'N (Heide-Jørgensen et al. 1993, Koski & Davis 1994). Two narhwals equipped with satellite transmitters in 1993 and 1994 arrived at an area in central Baffin Bay (at about 70°N) in November, and stayed in this area until the transmitters ceased functioning in late November (Dietz & Heide-Jørgensen 1995). Koski & Davis (1994) observed a gradual movement into coastal and ice-edge areas on the Canadian side of Baffin Bay from early May until late July, however, whales were still widely dispersed in Baffin Bay pack ice during May and June.

Habitat and ecology

During winter, narwhals are strictly associated to the driftice staying mainly in deep waters (Heide-Jørgensen et al. 1993). The two narwhals equipped with satellite transmitters in 1993 and 1994 stayed in waters with depths between 500 and 1000 m (Dietz & Heide-Jørgensen 1995).

Human exploitation and conservation status

The narwhal population in Baffin Bay has been estimated at about 30,000 to 40,000 individuals (not corrected for submerged animals) based on spring surveys (Koski & Davis 1994). The population is harvested in both Canada and Greenland, and whether this harvest is sustainable remains an open question (Heide-Jørgensen 1994). The published catch record of 1993, reports a catch of 103 narwhals from the region covered by this report (Namminersornerullutik Oqartussat 1995). While narwhals may be hunted all year round, catch per boat is limited, hunting methods are restricted, and some summer grounds are closed for hunting. See also Table 3.

3.3.10 Bowhead whale (*Balaena mysticetus*)

Distribution, movements and population

Bowheads are winter and spring visitors to the northern part of region covered by this report (Fig. 16). These bowheads belong to the Baffin Bay/Davis Strait stock, which winters in the pack ice between Labrador and Greenland, and spends the summer in the arctic Canadian Archipelago (Moore & Reeves 1993). In the past, when the stock was much larger than it is today, the whales arrived at Sisimiut in December and moved slowly northwards between the pack ice and the coast during spring until mid-June (Reeves & Heide-Jørgensen 1996). Although this timing is probably still valid, the number of whales has been considerably reduced since then. Bowheads are regularly recorded in the waters south and southwest of Disko in the period March to May (Born & Heide-Jørgensen 1983, Reeves & Heide-Jørgensen 1996, Mosbech et al. in prep.).

The number of whales occurring in West Greenland waters are low, "a few tens of whales" according to Reeves & Heide-Jørgensen (1996). The total Baffin Bay/Davis Strait stock is limited to a few hundred whales (Finley 1990, Zeh et al. 1993).

Habitat and ecology

Bowheads prefer pack ice covered waters.

Bowheads in Alaska (the Bering Sea stock) feed mainly on copepods and euphausids (Lowry 1993).

Most calves in the Bering Sea stock are born in early April to late May (Koski et al. 1993). The same timing is indicated for the Greenland population (Vibe 1990). However, no calves were observed amongst 24 different bowheads seen during aerial surveys in May 1996 and 1997 (Mosbech et al. in prep.).

Human exploitation and conservation status

The Davis Strait/Baffin Bay stock has been totally protected since 1940, although a few individuals have been taken in Greenland since then (Reeves & Heide-Jørgensen 1996). See also Table 3.

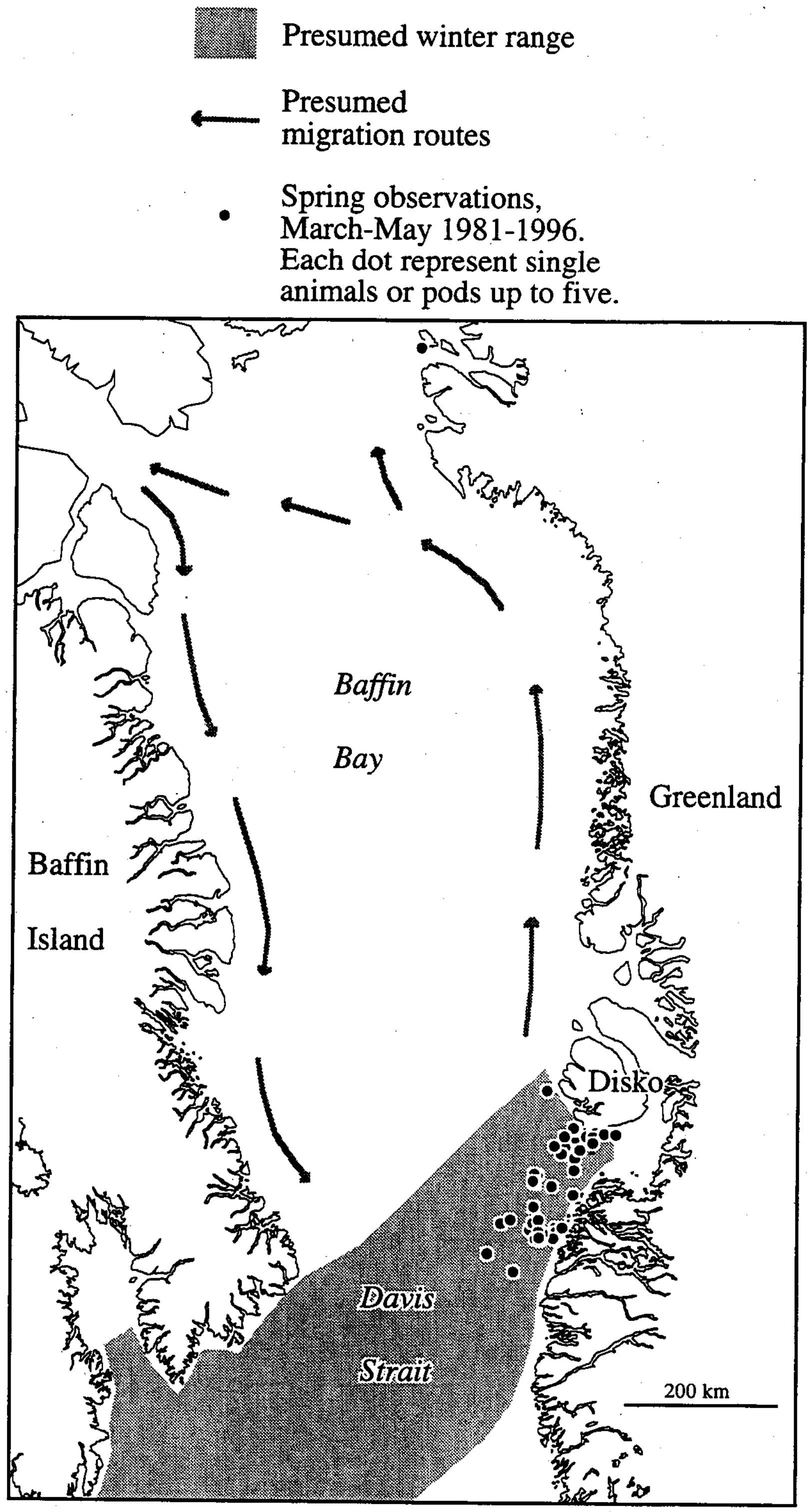

Fig. 16. Distribution of bowhead whale Davis Strait stock in the West Greenland area. Based on Born & Heide-Jørgensen 1983, Moore & Reeves 1993, Reeves & Heide-Jørgensen 1996 and NERI unpubl.

3.3.11 Polar bear (*Ursus maritimus*)

Distribution, movements and population

Polar bears are rare in the study region, occurring mainly during winter and spring (Born & Rosing-Asvid 1989, Born 1995). As polar bears are associated with the pack ice, their occurrence is dependent on the distribution of the pack ice (Born 1995). For example, bears have been observed in the hooded seal whelping grounds in the central Davis Strait and in the marginal zone of the pack ice and they often occur in the pack ice drifting around Kap Farvel (Hay et al. 1985, Born & Rosing-Asvid 1989, Born 1995). However, polar bears may occur everywhere in the region.

The bears occurring off central West Greenland have their denning areas on the Canadian side of Baffin Bay/Davis Strait, although bears in dens (probably not maternity dens) have occasionally been observed in the Disko Bugt area (Born & Rosing-Asvid 1989, Born 1995).

Habitat and ecology

Polar bears prefer drift ice areas with a high density of ringed seals (Born & Rosing-Asvid 1989). The denning areas are usually located on land, close to waters where food is easily accessible for the families when they leave the den (Born & Rosing-Asvid 1989).

Human exploitation and conservation status

The catch in the region covered by this report is limited and opportunistic. Only professional hunters are allowed to kill polar bears. The hunting season is from 1 September to 31 May, except for adult single males, which can be shot throughout the year. The catch record in the region covered by this report include 21, 10 and 35 bears shot in the years 1993, 1994, and 1995, respectively (Born 1997). See also Table 3.

4 Potential ecological impacts from oil spills in winter

Oil spills caused by accidents during off-shore exploration, production and transportation of oil may present serious hazards to the Arctic environment. Particularly if the oil spill coincides with the occurrence of concentrations of ecologically important and vulnerable species in the ice or at the coast.

The total volume of oil released to the Arctic marine environment from accidental spills is small compared to the inputs from river transport, atmospheric transport and sewage (Futsæter et al. 1991). Nevertheless, as accidental oil spills are localised and sometimes confined by physical barriers such as the coast or ice, high concentrations of hydrocarbons may build up in the water below the spill, even though the impacts will mainly be local or regional. Chronic pollution from many minor marine oil spills in heavily populated regions south of the Arctic can also represent a serious environmental threat (Mosbech 1990).

The natural degradation of oil in the Arctic will generally be slow due to low temperatures, and the possibilities of recovery and cleanup can be hampered by the harsh climatic conditions and lack of infra structure. Furthermore, if oil is spilled in broken ice, it will tend to pool in the open leads, and wind may keep it in the ice edge area (Futsæter et al. 1991). Such leads and ice edges are often utilised by high concentrations of birds and mammals during their northward migrations in spring.

4.1 Behaviour of oil in ice

This section is based on a review presented by Fingas (1992) who summarises the current knowledge based on field tests, laboratory work and modelling. Many questions are still unanswered, but research on this issue is expanding.

4.1.1 Oil under continuous ice (fast ice)

Spreading of oil under continuous ice is mainly dependent on the under-ice roughness. The under-ice surface is not smooth, and oil and gas will tend to accumulate in depressions close to the site where the oil reaches the surface. Currents may spread the oil, and strong currents may strip the oil from the under-ice depressions.

If the ice sheet is growing, oil and gas will be encapsulated in the ice. This oil and gas will be released when the ice deteriorates, either by rising vertically through brine channels or by ablation of the ice surface. Oil in first-year ice will be released the following spring. Small-scale field studies indicate that oil in multi-year ice will persist for at least two melt seasons, and possibly longer.

4.1.2 Broken and discontinuous ice (drift ice and leads)

Less is known about the behaviour of oil in broken ice and leads and observations are not conclusive. Laboratory testing indicates that relatively dense broken ice (5-8/10) effectively confines oil. Recent experiments in the Barents Sea drift ice (Singsaas et al. 1994) showed that the oil film on the water was thicker than in open water because the ice prevents spreading. A combination of low temperatures and increased thickness results in low evaporation. Furthermore, water uptake and viscosity increase is reduced due to low energy conditions (reduced wave action) within the ice. Wave action in the marginal ice zone is often stronger and oil weathering may, under certain conditions, resemble weathering in open waters.

Entrapped oil will follow the ice as it is moved by winds and currents.

4.2 Fish and invertebrates

It is not likely that pelagic and demersal adult fish and invertebrates will differ in exposure and vulnerability to oils spills in winter compared to summer, mainly because fish and invertebrates live in the water column and as such are not exposed to the oil on the surface. The conclusions drawn in our earlier works are also valid for the winter situation: Fish populations in offshore areas will not be particularly exposed or vulnerable to oil spills. In coastal habitats, where the oil can accumulate in bays, high concentrations of hydrocarbons can build up, thereby exposing organisms to toxic concentrations. Fish which spawn in dense schools may be vulnerable. During the spring (May), spawning capelin are at risk. Oil may accumulate along ice edges and may impact the ice associated fauna (mainly invertebrates). The primary production which can be high off the ice edge and under the ice in early spring may be affected as well. This may also be the case if oil entrapped below, or encapsulated in the ice is released during melting.

See also the appendix on p. 65: Potential oil spill impacts on fish and invertebrates.

4.3 Birds

Seabirds, particularly the diving species, are vulnerable to oil spills because they sit on the water for long periods. This is especially the case during winter when the birds do not seek to land to breed.

Oil destroys the feather structure. Even slight and restricted oiling reduces the waterproofing and insulating properties of the plumage allowing cold water to come into contact with the skin. This results in heat loss, often many times the normal rate. The heat loss is increased during winter due to the often very low ambient temperatures. Moreover, oiled birds are less efficient swimmers due to the soaked plumage, thereby reducing their ability to feed and compensate for the heat loss. The short daylight period in the Arctic winter also contributes to the reduced ability to compensate the heat loss. During preening, oiled birds will ingest oil, which can give rise to sublethal intoxication. This is also the case for birds that eat oil contaminated food. Finally, oil spills may impact feeding habitats for coastal birds such as waders.

Birds with a life strategy characterised as being K-selected (i.e. long expected lifespan, low annual reproduction, slow population turnover), are more susceptible to increased mortality than birds with a faster population turnover, particularly adult mortality. Where this K-selected strategy is combined with a behaviour which exposes large numbers of individuals to oil spills for prolonged periods, swimming birds which stays on the water surface in large flocks for example, the risk of effects on population level or subpopulation level (such as colonies) is high. However, healthy populations may have segments of non-breeding mature birds, which can replace the breeding adults, in the case of sudden die-off, and thereby moderate the effects on the population.

Species such as thick-billed murre, little auk, common eider and king eider all apply to the above mentioned characteristics. Moreover, the populations of thick-billed murre and both eider species are exposed to strong hunting pressure, which probably have removed a surplus of mature birds. These factors make the wintering populations of thick-billed murre, common eider, king eider and perhaps little auk, particularly vulnerable to oil spills. The winter populations of these species in West Greenland are international, coming from breeding populations in Greenland, Canada, Norway, Russia and perhaps Iceland.

Fulmars have an very slow population turnover (extremely K-selected). As such, populations are likely to be vulnerable to large oil spills, which have the potential to affect large numbers of adults. However, fulmars are most vulnerable during spring and summer when large concentrations occur at breeding colonies. During winter fulmar populations seem to be very dispersed over the sea, and recurrent concentrations have not been identified in the study area. Furthermore fulmars seem to be able to detect and avoid oil spills, and are perhaps rather robust to slight oiling (Lorentsen & Anker-Nilssen 1993). Fulmars are generally not hunted, and populations may include large segments of non-breeding mature birds, which can replace any sudden loss of breeding birds.

The Open Water Area is the main winter range for local and discrete populations of great cormorant, mallard, red-breasted merganser and great black-backed gull. These populations are rather small and probably do not exceed 10.000 pairs each. If large proportions of these populations are assembled in restricted areas, an oil spill hitting such areas may impact the population. However, the population dynamics of these species (faster population turnover rate) indicate a faster recovery rate from heavy adult mortality than in K-selected species such as the thick-billed murre.

The gulls occurring in West Greenland in winter, are less vulnerable than typical swimming birds such as auks and ducks. Gulls spend much time on land/ice, and a species such as the ivory gull rarely alight on the water. Moreover, gulls seem to be more robust to slight oiling than many other birds, and their population dynamics indicate a rather fast population turnover.

Even birds which do not sit on the water may be exposed to marine oil spills in winter. In West Greenland, the white tailed eagle and the purple sandpiper in particular may be affected. In Alaska, bald eagles (*Haliaeetus leucocephalus*), (a close relative to the white-tailed eagle and with a similar feeding biology) were killed by the Exxon Valdez oil spill in 1989 (Bowman et al. 1995, 1997). The Alaskan bald eagle population is very large and is increasing slightly (Bowman et al. 1997). It is probably much more resistant to perturbations than the small isolated Greenland white-tailed eagle population. Due to their scavenging habits, white-tailed eagles may ingest oil, if they eat oiled seabirds at the shoreline. Purple sandpipers may be exposed to oil spill during feeding in the intertidal zone.

In ice covered waters, open water is restricted. An oil spill coinciding with seabird concentrations in such areas pose a risk to many birds. The most vulnerable species in this context is the king eider, which occurs in huge, dense flocks in small openings in the drift ice. We have identified important wintering grounds for king eiders on shallow parts of Store Hellefiskebanke and Fyllas Banke (Mosbech & Johnson in prep.).

4.4 Mammals

Whales and adult seals do not seem not to be particularly vulnerable to oiling (St. Aubin 1990a, Geraci 1990), mainly because they do not rely on their fur, but on a well developed blubber layer for insulation. Moreover, marine mammals may be able to avoid oil on the surface of icefree waters. However, the presence of ice restrict the open water areas on which the marine mammals rely. If an oil spill is caught in leads and cracks in the ice, seals and whales may be forced to breathe air with toxic petroleum vapours. However, it is not known whether the vapours can be sufficiently concentrated to represent a threat (St. Aubin 1990a). White whales, narwhals, bowhead whales, ringed seals, walrus and bearded seals in particular are at risk as their primary habitat is ice covered waters.

According to Born et al. (1995) walruses are more vulnerable to oil spills than other seals, due to their high level of gregariousness, their pronounced thigmotactic behaviour (physical contact), their affinity to pack ice, and their benthic feeding habits; benthic invertebrates are known to accumulate petroleum hydrocarbons from the sediments and the water.

Like walrus, bearded seals often feed on benthic fauna and may also be vulnerable for similar reasons.

It is well known that seal pups are more sensitive to oiling of their skin than adults. The oil is usually conveyed to the pups by the oiled mother seals while nursing. Since ringed and bearded seals are dispersed during whelping, only relatively few pups are likely to be oiled, even during large spills. Why an oil spill is not likely to cause any population concerns. Hooded seals, on the other hand, whelp in common grounds on the driftice of central Davis Strait, where many pups can be exposed to an oil spill. Even though the pups become rapidly independent, they stay in the whelping area, and evidence indicate that they are in a rather bad condition for a prolonged period due to insufficient feeding abilities (Kapel 1998). This whelping area is vulnerable to oil spills.

In contrast to the other marine mammals, individual polar bears are very sensitive to oil spills (St. Aubin 1990b). They rely on their fur for insulation, and may ingest oil from the fur when grooming (Stirling 1990). This has resulted in lethal poisonings in an experimental study (Øritsland et al. 1981, Hurst & Øritsland 1982, Hurst et al. 1982). However, because polar bears occur dispersed in the study region, only a few bears are likely to be affected by an oil spill, and population effects are not likely.

5 Data gaps

No data gaps (in an oil spill sensitivity mapping context) have been identified in relation to fish and invertebrates in winter.

The information available about seabird abundance, distribution and predictability of concentrations during the winter season is very sparse, and is based mainly on anecdotal evidence. The most urgent data gaps in this context are:

- in the offshore areas: distribution (temporal and spatial) and abundance of the different flyway populations of thick-billed murre, little auk and king eider exploiting the region,

- and in the coastal areas: distribution (temporal and spatial) and abundance of the same populations and including common eider.

Similar information is required for great cormorant, mallard, harlequin duck, red-breasted merganser and white-tailed eagle.

Information on distribution and abundance is most efficiently achieved by aerial and boat surveys. Satellite telemetry, supplemented with analysis of recoveries of ringed birds, can provide information about origin of the winter populations as well as how these populations exploit the winter habitats.

No urgent data gaps (in an oil spill sensitivity mapping context) regarding marine mammals have been identified. However, improved data on the timing, location and relation to ice conditions of the hooded seal whelping ground in Davis Strait will be useful.

Moreover, will information on the winter distribution and possible concentrations areas for harbour seals be useful. Information about the migration routes, timing of migration and numbers of bowhead whales in the Greenland part of Davis Strait/Baffin Bay would also be useful.

This report only considers the impacts in relation oil pollution. There are other potential impacts from exploration, exploitation and transport of oil at sea. Disturbance associated with underwater noise created by drilling rigs, oil carriers and seismic surveys is of particular importance to marine mammals. Underwater noise can both scare animals and interfere with their communication and orientation. Studies associated to these issues is in demand.

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Appendix

Potential impacts of oil spill on marine fish and invertebrates

By Anders Mosbech

1. Introduction

Oil exploration, production and transportation at sea presents a risk of accidental oil spills.

Oil exploration in the Arctic may present serious environmental hazards if a major oil spill occurs, particularly if the oil spill coincides with the occurrence of concentrations of ecologically important and vulnerable species in the ice or at the coast. However, because the impact of a spill depends on numerous more or less unpredictable events, which interact in a complex fashion, a high degree of uncertainty in assessing the potential impact of an oil spill is inevitable.

The total volume of oil released to the marine environment in the Arctic from accidental spills is small compared to inputs from river transport, atmospheric transport and sewage (Futsæter et al. 1991). Nevertheless, accidental spills constitute a significant environmental threat because they imply a high oil concentration, even though the impacts will mainly be local or regional. Chronic pollution from many minor marine oil spills in heavily populated regions south of the Arctic can also represent a serious environmental threat (Mosbech 1990).

The natural degradation of oil in the Arctic will generally be slow due to low temperatures, and the possibilities of recovery and cleanup can be hampered by the harsh climatic conditions and lack of infrastructure. Furthermore, if oil is spilled in broken ice, it will tend to pool in the open leads, and wind may keep it in the ice edge area (Futsæter et al. 1991).The leads and ice edges are utilised by high concentrations of birds and mammals during their northward migrations in spring.

Oil is toxic to almost all organisms. The toxic effect depends on the composition and concentration of the oil, and the sensitivity of the species affected. A species may have a high individual sensitivity and a low population sensitivity if individuals are evenly distributed and have a high reproductive capacity. This is the case for many species in lower trophic levels. The effect of oil on fish and some important invertebrates are reviewed here.

2. Oil toxicity to fish, eggs and larvae

Oil can affect fish in many ways. Fish readily take up oil components into their tissues after exposure to oil in water, food or sediment. Oil may cause a number of physiological and histopathological effects depending on the concentration and composition of the oil. Indicators of oil exposure in fish include increased concentrations of hydrocarbon metabolites in bile and increased monooxygenase activity in the liver tissue. Oil components are unlikely to bioaccumulate to high concentrations in fish tissue because fish are able to metabolise and excrete these contaminants.

In laboratory studies several fish species have been exposed to the water soluble fraction (WSF) of different crude oils. The WSF of crude oils consists mainly of aromatics and are dominated by benzene, toluene and xylenes (Serigstad 1992). The toxicity to fish appears to be functionally related to the total aromatic hydrocarbon concentration in the WSF (Rice 1985). As a broad generalisation, lethal effects (LC50) among adult fish are found in the range 1 - 10 mg/kg of water soluble aromatics and sublethal effects in the range 0.1 - 1 mg/kg (Rice 1985). Fish eggs and larvae are generally more sensitive than adult fish. Lethal effects (LC50) of water soluble aromatic hydrocarbons on larvae have been estimated to be in the range 0.1 - 1 mg/kg (Rice 1985).

In Norwegian field and laboratory experiments different groups of marine organisms were exposed to the WSF of crude oil (Booman et al. 1995). Organisms were exposed to 10 - 70 µg/kg BTX of WSF for up to 24 hours (BTX stands for benzene, toluene, xylene and ethylbenzene, which constitutes approx. 80 % of the WSF of crude oil). These are concentrations and periods of exposure that would be realistic in an offshore oil spill situation. The threshold for effect on oxygen consumption of yolk-sac larvae of cod lies within a concentration range from 20 to 80 µg /kg BTX of WSF. The critical concentration range for effect on larval first feeding would be somewhat higher. Adult Arctic cod (*Boreogadus saida*) react to concentrations between 10 and 25 µg /kg-BTX with an increase in activity and oxygen consumption. Thus, adult fish will be able to detect low concentrations of water soluble components and try to avoid contaminated areas. Considerable variation was found in sensitivity between species, and sensitivity was also found to be temperature dependent. Cod (*Gadus morhua*) and saithe (*Pollachius virens*) eggs and larvae seem to be particularly sensitive to oil, while herring eggs and larvae are less sensitive, and capelin eggs and larvae are intermediate (Føyn 1992).

Booman et al. (1995) concluded that even though the effects of exposure to the water soluble fraction of crude oil varies with species developmental stage and temperature, the effects will normally be negligible at the concentration ranges found after accidental oil spills in open water. However, fish eggs and larvae could be exposed to harmful concentrations of these components in polar areas as a result of the use of dispersants (because of the low evaporation rate which increases aquatic exposure) (Booman et. al 1995) or in coastal areas.

Although concentrations of oil that are lethal to adult fish rarely build up in the open sea following an oil spill, sublethal oil concentrations may stress fish, especially during long term exposure. The metabolism and excretion of aromatic hydrocarbons in fish can result in the modifications of aromatic hydrocarbons into reactive intermediates, which have been associated with DNA-damage. Chronic exposure to elevated oil concentrations may impose an additional form of stress which could interact with natural stress factors and result in increased mortality, reduced growth, and susceptibility to parasites and other types of effects which are difficult to document in nature (National Research Council 1985, Futsæter et al. 1991, Stagg and McIntosh 1996).

Field experiments including acute toxicity tests on important *copepods* in the Barents Sea food chain showed that these invertebrates are relatively resistant to oil pollution. Copepods can tolerate concentrations at least six times higher than earlier reported values for fish eggs and larvae (6 mg/kg-BTX of WSF vs. 0.1-1 mg/kg WSF for fish larvae) (Booman et al. 1995).

Experiments with the *deep sea shrimp* (*Pandalus borealis*) exposed to Cook Inlet crude oil in water (Stickle et al. 1990) showed a short-term tolerance to aromatic hydrocarbon at the same concentrations as reported for adult fish (LC50 1-10 mg/kg see above). LC50 declined from 1200 µg/kg of water soluble aromatic hydrocarbon with two days exposure, to 28 µg/kg with 28 days of exposure. Shrimp sensitivity after three months of exposure to oiled sediment (2% crude oil) was much lower than exposure to water soluble aromatic hydrocarbons and did not result in significant shrimp mortality or alter their scope for growth. Bioaccumulation of aromatic hydrocarbons into the cephalothorax of the shrimps was significantly greater than bioaccumulation into the abdominal tissue (the edible muscle), which generally did not accumulate significant concentrations during either form of oil exposure (water or sediment). The shrimps exposed to oiled sediment showed little bioaccumulation in all tissues, probably reflecting the low availability of hydrocarbons in the water from the oiled sediment. Levels of oil in shrimp tissues declined with time, suggesting biodegradation. Crustaceans have detoxifying systems which are capable of metabolising aromatic hydrocarbons (mixed-function oxygenase or cytochrome p-450 monooxygenase). These systems may not be induced by hydrocarbon exposure, however, the low natural levels may be sufficient to contribute to degradation and elimination of hydrocarbons from tissues.

3. Fish mortality during an oil spill in the open sea

Extensive fish kills after oil spills have not been documented (National Research Council 1985). This is primarily because in the open sea, toxic concentrations are seldom reached in significantly large areas and depths. Furthermore adult fish are mobile and can avoid the oil. Avoidance behaviour has been observed in salmon and cod exposed to oil (Ernst et al. 1989; Serigstad 1992). In coastal areas where oil can be trapped in shallow bays and inlets, toxic concentrations can build up to levels where adult fish kills can occur. However, fish usually avoid oil by swimming away. During the "Braer" spill in Shetland in 1993, a storm dispersed the oil and caused very high oil concentrations in the water column near the coast. After the grounding, the concentration of oil in the water was 'some hundreds' of mg/l in the area close to the tanker (The Scottish Office 1993). Ten days after the spill, 4.3 mg/l was measured in a bay within a few kilometres of the wreck. Subsequent monitoring programs found no evidence of major effects on fish populations (Richie & O'Sullivan 1994). Work not yet completed indicates that there may have been some subtle effect on larval growth and on the proportion of sexually mature sandeels in given length classes (Richie & O'Sullivan 1994).

In model work from the Barents Sea (Børresen et al. 1988), the oil concentration in the water column just below the oil spill was estimated at 0.3 mg/kg WSF, with the level decreasing to 0.1 mg/kg WSF at a depth of 5 m. Field experiments on Haltenbanken showed concentrations up to 0.09 mg/kg of Statfjord crude oil at a depth of 1 m 10 hours after the release of the oil. This concentration was reduced to 0.02 mg/kg 170 hours after the release (Serigstad 1992). In the Ekofisk blowout, where c. 12 000 ton crude oil was spilled, aromatic hydrocarbon concentrations in the water column ranged between 0.002 - 0.8 mg/kg, however, most concentrations were less than 0.1 mg/kg (Rice 1985). No extensive fish kill was associated with this spill, which never reached the coast.

Payne (1989) stated that there were no evidence that fish stocks had been affected by oil spills. It is disputed whether this also holds true for the "Exxon Valdez" spill in Prince William Sound in 1989; the most studied oil spill ever. Many conflicting impact result were published with respect to this spill (Wells et al. 1995, Rice et al. 1996). Although no massive fish kills were observed outside sheltered areas following the "Exxon Valdez" spill, several effects which may have had an effect on the population level were documented (Rice et al. 1996). Armstrong et al. (1995) concluded that the bottom fish and crustaceans fisheries remained unimpaired after the spill, as far as could be seen for large natural population fluctuations. There was no significant difference in deep sea shrimp (*Pandalus borealis*) catch per unit effort (CPUE) between oiled and non-oiled areas (Armstrong et al. 1995). In general, few effects of the "Exxon Valdez" oil spill were detected on bottom fish and crustaceans, despite the hydrocarbon sensitivity of crustacean larvae noted above (Armstrong et al. 1995).

Damage to eggs, larvae and juveniles in coastal habitats may, however, have significantly affected recruitment to some fish populations (e.g. salmon and herring). There is agreement that a concern for the herring and salmon fishery is justified (Wells et al. 1995), although there are disagreement about the assessment of the possible damage. The total adult return of both hatchery and wild pink salmon to Prince William Sound were at record levels in 1990 (one year after the spill). The return numbers were, however, estimated to be 1.9 million fish fewer than would have appeared without the effect of the spill on the growth on juvenile salmon in 1989 (Geiger et al. 1996, Templin et al. 1996) (See next chapter "4. Impacts in coastal environments").

4. Impacts in coastal environments

Oil that enters intertidal and subtidal shore zones can have an effect on the benthic fauna. After an experimental oil spill on a sheltered beach on Baffin Island, it was concluded that effects were mainly temporary, and apparently without serious consequences. After a two year post-spill monitoring period it was further concluded that there was no evidence of large-scale mortality of subtidal benthic biota attributable to the oil spill (Sergy & Blackall 1987). The natural removal of the oil from the shoreline slowed down over time, and after a period of eight years, approximately 5 % of the original spill volume remained on the beach in a highly weathered state (Humphrey et al. 1991). After the "Exxon Valdez" oil spill, most surface deposits of oil on the shorelines of Prince William Sound decreased by a factor 10 in one year. Oil in low-energy sediment areas and in areas of subsurface burial, however, was expected to be retained much longer (Wells et al. 1995). Wolfe et al. (1994) estimated that 3 years after the spill approximately 2 % of the spilled oil remained on the intertidal shorelines, much of it being highly weathered, biologically inert residues.

Oil that is trapped in an unweathered state and is slowly released into the environment can cause chronic pollution. Research in Prince William Sound after the "Exxon Valdez" oil spill has shown that oil can be trapped in the sediment beneath mussel beds on protected shorelines without being cleaned by wave action (Babcock et al. 1996, Harris et al. 1996). Because the underlying sediment often is anaerobic, oil can remain there in a relatively unweathered state. Oiled mussel beds in Prince William Sound, still contained high concentrations of relatively unweathered oil 3 years after the spill. The oil was distributed unevenly within these beds. Concentrations as high as 30 000 - 40 000 µg/g wet weight of total hydrocarbons were found within two metres of concentrations two orders of magnitude less. The "Exxon Valdez" crude oil contains 0.8 % total polynuclear aromatic hydrocarbons (TPAH). TPAH in mussels generally averaged 1% or less of the TPAH in the underlying sediment. Contaminated mussel beds are suspected to have caused chronic intoxication of harlequin ducks (*Histrionicus histrionicus*), which feed on the mussels (Rice et al. 1993, Patten 1993a, 1993b). However this question is unresolved, and other scientists estimate that the average oil dosage is well below the 'no-effect' level for wildlife feeding on the mussels, and for the mussels themselves (Hartung 1995, Wells et al. 1995).

Toxic concentrations can build up in coastal areas where oil can be trapped in shallow bays and inlets. Adult fish kills have occurred in such spill situations. In Greenland, both the lumpsucker and the capelin which spawn in localised areas just below the shoreline, are likely to be quite vulnerable in the spawning period.

If oil is trapped and persists for longer periods of time, the local and stationary fish may suffer from a number of sublethal effects. After the Amoco Cadiz oil spill, estuarine flat fish and mullets suffered fin rot disease, and showed reduced growth, fecundity and recruitment (Conan 1982). A comparison of sculpins from oil free and oil contaminated sites following the "Exxon Valdez" oil spill showed that the prevalence and intensity of parasitism (*Trichodina*) was significantly higher in the oil exposed group (Kahn 1990). In Prince William Sound cutthroat trout (*Oncorhynchus clarki*) and Dolly Varden (*Salvelinus malma*) use nearshore and estuarine areas for feeding during summer. Tagging studies of both species have demonstrated reduced growth in oil contaminated areas; a difference which persisted for two years after the spill in the case of cutthroat trout (Hepler et al. 1996). There was also a tendency for reduced survival during the first year after the spill, however, this difference was not statistically significant. Cutthroat trout and Dolly Varden, which belong to the salmon family, are anadromous as are Arctic char (*Salvelinus alpinus*) in Greenland. There are conflicting results on the effects on herring and salmon populations in Prince William Sound, primarily due to large natural fluctuations. Wells et al. (1995) concluded that only continued studies of the fish populations will clarify the true causes of the changes in these fish populations. By comparing oiled and non-oiled areas, Brown et al. (1996) found indications that oil caused increased larval abnormalities in Pacific herring (*Clupea pallasi*). A study of health and condition of Pacific herring from Prince William Sound in 1994, on the other hand, did not reveal any such trends in herring health and condition that could reasonably be attributed to the oil spill in 1989 (Elston et al. 1997). Elston et al. concluded that without a better understanding of herring population ecology, no definitive conclusions on disease linkage with the oil spill can be drawn.

Pink salmon (*Oncorhynchus gorbuscha*), which spawn in streams in the intertidal zone, had significantly higher egg mortality in oiled compared to non-oiled streams from 1989 through 1993; however, there was no difference after 1993 (Bue et al. 1996). The egg mortality study provides the most compelling evidence of long-term damage to fish from the oil spill. It has instigated a series of studies, still in progress, to determine the possible inheritance of damage by progeny from oil-impacted adults (Spies et al. 1996).

5. Impact of oil spill induced egg and larvae mortality on fish stocks

Oil spills which coincide with spawning or larval concentrations can cause significant egg and larval mortality, because these are very sensitive and immobile. Most species of fish produce large numbers of eggs, and only a relatively small number reach adulthood due to natural mortality. The importance of oil spill induced mortality compared with the high natural mortality of fish eggs and larvae is disputable. In a consensus statement, Canadian scientists (Longhurst 1982 from Rice 1985) suggest that as much as 50 % oil induced mortality among eggs and larvae may have little effect on the fish stock. In contrast, Norwegian scientists (Berge et al. 1978 from Bjørke et al. 1991), state that egg and larvae mortality due to human activities will induce a similar decrease in the yearclass.

American model work simulated the impact of a 10,000 m^3 crude oil spill on George Bank, south of Nova Scotia. The impact on cod was estimated in a worst case simulation. It was estimated that the mean impact was a loss of 0.5 % of a year's catch when the simulated oil spill coincided with peak spawning (Reed & French 1989). Norwegian model work simulated a blow-out in the Barents Sea (duration 10 days, total spill 24,000 m^3). With respect to cod spawning, a worst case scenario will be a spill occurring in April, which could result in a 10 - 15 % reduction of the size of the yearclass. A spill simulated in July gave a reduction of less than 0.5 % of the yearclass (Børresen et al. 1988). In a study simulating the potential effects of spilled oil on commercial fisheries in the Bering Sea, Laevastu et al. (1985 quoted in Meyer & Geiselman 1989) concluded that a large blow-out in the eastern Bering Sea would have no measurable effect on offshore fishery resources. This study did not address the potential effects on coastal fishery resources.

6. Sea-food tainting and health concern

The development of an atypical flavour - tainting - in fish tissue is caused by natural spoilage or by assimilation of contaminants. Oil spills may affect the fisheries by tainting the fish, making the fish unmarketable. Tainting of fish by oil and the potential effects on human health has been reviewed by GESAMP (1993). Experimental studies show that the minimum concentration of oil components in water that will induce tainting in fish is in the range 0.01- 1.0 mg/l. Tainting therefore occurs at concentrations below those which causes acute effects in adult invertebrates and fish, but similar to those causing acute and sublethal effects in their embryonic and larval life stages. The water soluble fraction of the oil is the most important in causing tainting. Tainting of cod by petroleum hydrocarbons has been investigated in laboratory experiments by Ernst et al. (1989). Their study suggests that the risk of tainting of cod and related species due to offshore blowouts is minimal. Even under a chemically dispersed offshore oil slick, fish will rarely encounter oil concentrations sufficiently high to cause tainting. Furthermore, experiments suggests that cod show avoidance behaviour. In the experiments, depuration following tainting generally occurred within 24 hours (Ernst et al. 1989). However, the risk of tainting of fish will be larger in shallow coastal waters, where oil concentrations may build up. When the oil disappears fish depurate the hydrocarbons taken up. In the "Braer" spill, tainting and contamination of fish and shellfish occurred around southern Shetland and a fisheries exclusion zone was established (Richie & O'Sullivan 1994). Contamination in fish samples from the exclusion zone fell rapidly, and three months after the spill, the ban on fishing was lifted. However, one year later, there were still areas with elevated levels of oil in the sediment. Some species of shellfish, which are more exposed to oil in the sediment than fish because of their close association with sediments, still had low levels of contamination present. Fishing of these species remained prohibited.

Acute oil spills will usually taint fish before they have accumulated oil concentrations that are toxic to humans. However, a lesson learned from the "Exxon Valdez" spill in 1989 was that it should be part of a (national) oil spill contingency plan to be prepared to handle human health concerns over contaminated seafood, especially in areas with subsistence fishing (Walker & Field 1991).

The US Food and Drug Administration assessed the long-term health hazard associated with subsistence seafood following the "Exxon Valdez" Oil Spill (Bolger et al. 1996). They focused on polynuclear aromatic hydrocarbons (PAH). Of all the components in crude oil, the PAHs are toxic at the lowest doses. These hydrocarbons are the most likely to be passed through the marine food chain and are well characterised as carcinogens. The ability of fish to metabolise PAHs, make the consumption of fish of considerable less concern as a dietary source of PAHs compared to molluscan bivalves; the marine organisms where PAH bioaccumulation occurs to the greatest extent. Bolger et al. (1996) concluded that the risk of contracting cancer from eating finfish from the spill area was so low that it could not be calculated, and therefore is, for practical purposes, equal to zero. The risk of acquiring cancer from a lifetime of eating mussels collected from even the most heavily impacted site where mussels were sampled in 1989 was extremely low; lower than eating smoked salmon. Furthermore recent samples have demonstrated a significant decrease in PAH levels since the oil spill.

7. Closing of fishing areas

The closing of fishing areas during an oil spill, may be necessary because there is a potential for fouling of fishing gear and catches by oil, tar balls and oiled debris. The closing of fishing areas is a complex issue with both health, economic and social implications (Meyer & Geiselman 1989).

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