SEABIRD POPULATIONS IN THE NORTHERN BARENTS SEA

Source data for the impact assessment of the effects of oil drilling activity

EDITORS: KJELL ISAKSEN AND VIDAR BAKKEN

MEDDELELSER NR. 135
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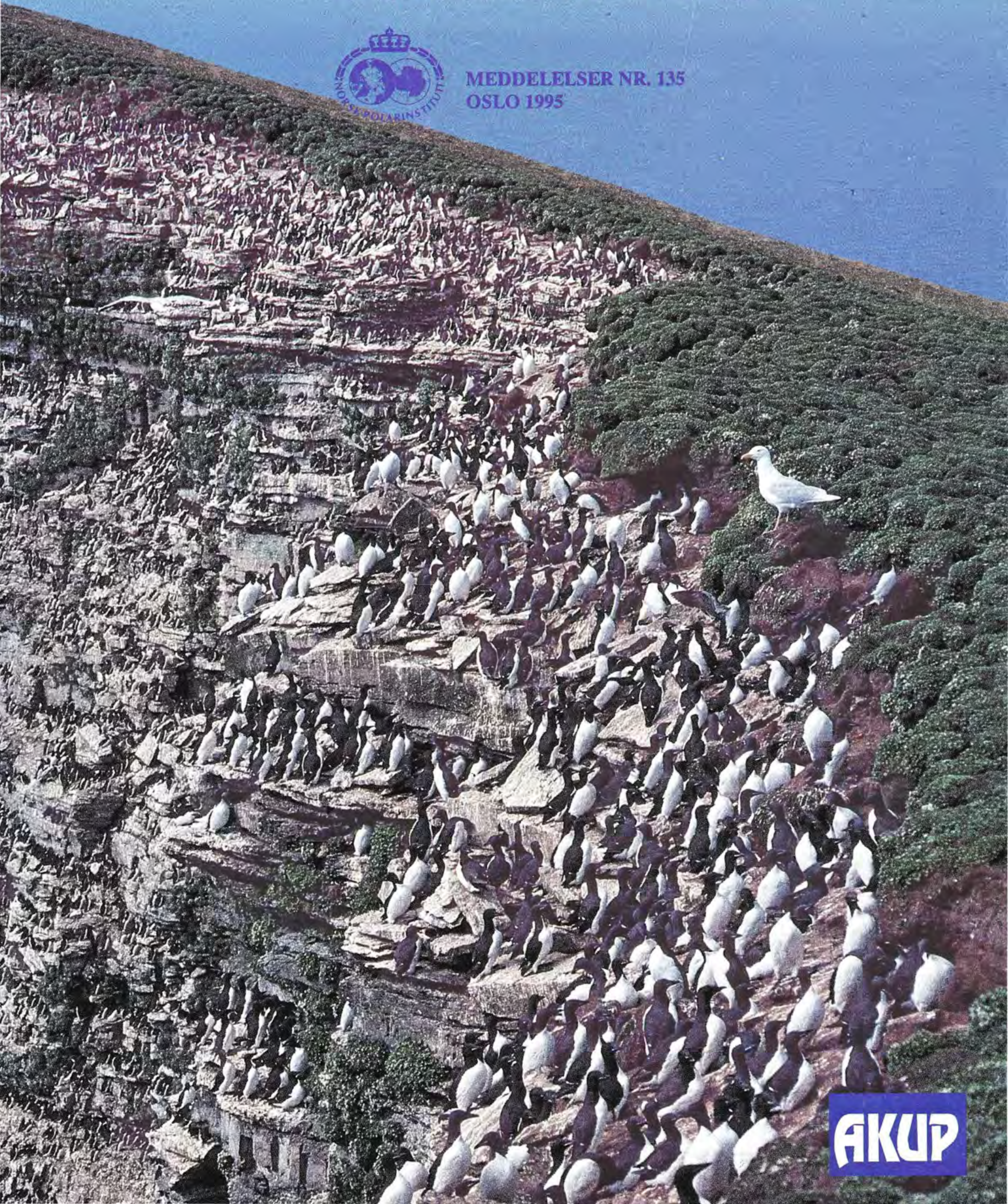

AKUP

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Editors: Kjell Isaksen and Vidar Bakken

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Reviewer: Wim Vader, Tromsø Museum.
Cover photo: Bird cliff on southern Bjørnøya. Photo: Vidar Bakken.

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PREFACE

This report presents the source data for the final impact assessment of oil and seabirds in the northern Barents Sea. The work is based on a study by Fjeld and Bakken (1993) who carried out an assessment of the oil vulnerability and conservation value of marine birds occurring in this area. They also presented proposals for additional field work which would improve the source data for the final assessment. In the present work we have prepared all data on a standard data format which can be used as direct input to the assessment part of the project. In the assessment, which still remains to be completed, possible effects on the marine birds will be analysed in relation to oil drift, vulnerability of seabirds to oil, conservation value and distribution of the seabird populations in the area of risk.

This work was allocated to the Norwegian Polar Institute (NP) in collaboration with the Norwegian Institute for Nature Research (NINA). NINA was responsible for preparing a report describing the predictability of the occurrence of guillemots at sea in the Barents Sea and has supported the database with additional data describing the occurrence of marine birds at sea in winter in the area of risk. The entire project was financed by the Ministry of Industry and Energy.

Many persons have taken part in the project. We are grateful to Per Espen Fjeld, Kurt Jerstad, Frode N. Bye, Runar Jåbekk and Jon Erling Skåtan for excellent assistance in carrying out the supplementary field work in 1993 and 1994. Many thanks to Reidar Hindrum, the Governor of Svalbard, who organised transportation of the field groups and also assisted in the field work. We are also grateful to NINA for permission to use their distribution data of seabirds at sea for inclusion on the maps for the winter period.

Wim Vader, Tromsø Museum, reviewed and made valuable comments on the manuscripts on short notice.

INTRODUCTION

AKUP Programme

Test drilling for oil and gas in the northern Barents Sea will possibly be a reality in the future. According to the Act of 22 March 1985 relating to petroleum activity (The Norwegian Petroleum Directorate 1985), impact assessments analysing the potential effect of this activity on the environment must be made before the area is opened for drilling. The responsibility for planning and carrying out the assessments lies with the Working Group on Environmental Impact Assessments of Petroleum Activities on the Norwegian Continental Shelf (AKUP), an independent intergovernmental group under the Ministry of Industry and Energy. In addition, a steering committee for the northern Barents Sea has been established.

Area of risk

The present work required a defined area of risk. As no official area of risk had been defined in advance, we used the area proposed by Fjeld & Bakken (1993). This area is limited in the south from 73°N, in the north 82°N, in the west 5°E and in the east 35°E (Fig. 1).

Performed work

This work is primarily based upon the assessment of vulnerability and conservation value of seabirds in the area (Fjeld & Bakken 1993), where populations at risk in relation to oil spills were identified. Fjeld & Bakken's (1993) suggestion to carry out additional field work to supplement the data for selected species was followed, and four different field studies were conducted:

- Registration of breeding and moulting populations of ducks and geese in northwestern Spitsbergen (1993)
- Development of methods for censusing breeding Little Auks in colonies (1993, 1994).
- Conducting censuses in selected colonies of Little Auks in the western part of Spitsbergen (1994), using the methods developed above.
- Make investigations on the occurrence and distribution of seabirds in ice-covered waters in spring (1994).

All other relevant data to be used in the impact assessment are in addition prepared to be used directly in the *SIMPACT* model (Anker-Nilssen 1987; Anker-Nilssen et al. 1992). These are data on breeding populations and the distribution of seabirds at sea and along the coasts of Svalbard.

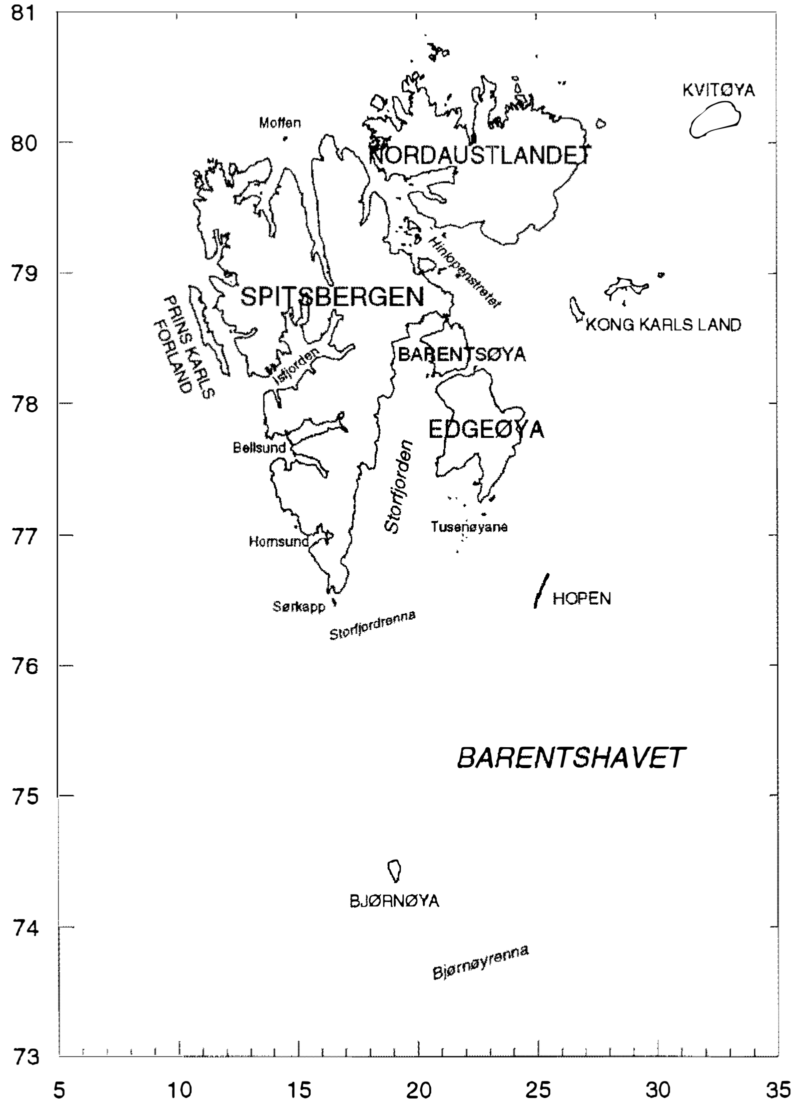

Fig. 1. The defined area of risk used in this report.

This report is divided into seven sections, each of which describes the different projects:

- Breeding populations of seabirds in Svalbard
- Estimation of the breeding density of Little Auks (*Alle alle*)
- The breeding density of Little Auks (*Alle alle*) in colonies in Hornsund and northwestern Spitsbergen
- Important moulting areas for seabirds in Svalbard
- Distribution of seabirds at sea in the northern Barents Sea
- The predictability of the spatial distribution of guillemots (*Uria* spp.) in the Barents Sea
- Occurrence of seabirds in the marginal ice zone

Additional analysis

During the work with this report new data have become available which should be taken into consideration for the final impact assessment of seabirds and oil. The vulnerability of three new populations to oil spills has been considered: the summer population of Sabine's Gull (*Larus sabini*) and the winter populations of Common Guillemot (*Uria aalge*) and Puffin (*Fratercula arctica*).

The Sabine's Gull has been found breeding in Svalbard only a few times and was not considered by Fjeld & Bakken (1993). In 1986, 1993 and 1994 some breeding pairs were found at Moffen, a small island north of Spitsbergen. This is the only Norwegian area where this species has been found breeding recently. We have considered the breeding population in relation to oil vulnerability and conservation value according to the method described by Anker-Nilssen (1987). The species was classified in vulnerability category 2 (Table 1) and as of national conservation value.

The Common Guillemots in the area probably migrate south in winter and stay closer to the Norwegian coast, whereas the Puffins probably migrate southwest to areas in the Atlantic. Winter counts in open sea have, however, shown that some individuals of both species stay in open waters in the northern Barents Sea in winter. The Common Guillemot and the Puffin are among the most vulnerable species in relation to oil. The winter populations of these species in the area were classified in vulnerability category 3 (Table 1), and we have included them for further analysis.

Table 1. Assessment of the vulnerability of the summer population of Sabine's Gull, the winter population of Common Guillemot and the winter population of Puffin to oil spills. Indexes of vulnerability are listed with the resulting values of individual vulnerability (IV) and population vulnerability (PV). The method of assessment and each individual index of vulnerability is explained by Anker-Nilssen (1987).

	TO	TS	AU	AS	LA	RM	FY	KO	RE	EX	BS	FO	UA	RP	BU	SP	PI	IV-tot	PV-tot	IV-value	PV-value
Sabine's Gull	3	2	3	3	2	2	1	2	1	1	3	3	3	2	2	1	3	28.1	162.0	2	2
Common Guillemot	3	3	3	3	1	3	2	2	3	2	1	2	2	3	2	1	3	108.9	753.9	3	3
Puffin	3	3	2	3	1	3	3	2	3	3	1	1	2	2	2	1	2	121.5	616.9	3	3

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BREEDING POPULATIONS OF SEABIRDS IN SVALBARD

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Common Guillemots (*Uria aalge*) breeding at Bjørnøya. Photo by Vidar Bakken.

Abstract – The breeding distribution, estimates of population size and a brief summary of the biology of the breeding seabirds in Svalbard are given. For most species maps showing the known breeding colonies are given. Estimates of colony size are presented for the best known species. Most of the data is from the database of Barents Sea seabird colonies developed by the Norwegian Polar Institute. Presently more than 500 colonies from Svalbard are registered in the database. Knowledge on size, development and breeding distribution of the seabird populations in Svalbard is most comprehensive for some of the typical colony-breeding species, such as Barnacle Goose (*Branta leucopsis*), Kittiwake (*Rissa tridactyla*), Common Guillemot (*Uria aalge*) and Brünnich's Guillemot (*U. lomvia*). Other species are less well known due to methodological difficulties with censusing breeding colonies (Fulmar *Fulmarus glacialis* and Little Auk *Alle alle*) or due to their dispersed breeding pattern (e.g. Long-tailed Duck *Clangula hyemalis* and Glaucous Gull *Larus hyperboreus*).

INTRODUCTION

The breeding period is an important period for all arctic seabirds, as successful reproduction is a prerequisite for a positive or stable population development. Large resources are invested in migration to the breeding areas, in eggs and in caring for young. Breeding must be accomplished during the short arctic summer, and some species must also rebuild resources for subsequent migration to wintering areas. Arctic seabirds, which at other times of the year are often dispersed over large areas at sea, assemble on the islands in the Svalbard area to breed. The breeding site makes the birds attached to one specific locality, and many species breed concentrated in small areas close to the sea. Breeding birds of many species, nevertheless, cover large areas at sea in search of food for their young. Thus, the breeding period with the subsequent moulting is the period in which the seabirds are most vulnerable to disturbances, whether it be from human traffic, noise or pollution. When assessing the possible impacts of oil drilling on seabird populations the summer is therefore of special importance

Svalbard (including the island Bjørnøya) is the only land area within the Norwegian region of the northern Barents Sea, and consequently all breeding seabirds within this area breed in Svalbard. Non-breeding seabirds from other areas, mainly North Norway and North Russia, are also found within the Norwegian region of the northern Barents Sea, both in the breeding season and at other times of the year, and may be affected by an oil spill in this area.

Vulnerability to oil spills in the breeding period differs among species. Especially important here is the species' feeding behaviour, i.e. area used in search of food and time spent at sea. These aspects have been thoroughly dealt with in an earlier assessment of the vulnerability to oil spills and conservation value of the seabird populations in the northern Barents Sea (Fjeld & Bakken 1993). In Fjeld and Bakken's (1993) assessment twenty species of seabirds breeding in Svalbard were classified as vulnerable to oil spills in the breeding period, and three additional species were classified as having special conservation value (Table 1). The breeding distribution and population status of these species in Svalbard are dealt with below. The Sabine's Gull was not treated by Fjeld & Bakken (1993). It is considered in this report as it has recently been found breeding in Svalbard. In a separate assessment in the *Introduction* to this volume, the population of the Sabine's Gull breeding in Svalbard was found to be both vulnerable to oil spills and of special national conservation value. It is as such also included here. In addition to the breeding populations, the male Common and King eiders were found to be highly vulnerable to oil spills when moulting in flocks in summer (Fjeld & Bakken 1993). These populations are treated separately in this volume (Isaksen & Bakken 1995).

Table 1. Species of seabirds breeding in Svalbard found either to be vulnerable to oil spills in the summer (long-term effects, vulnerability category 2 and 3), or to have special national (N) or international (I) conservation value (after Fjeld & Bakken 1993 and, for the Sabine's Gull, the *Introduction* to this volume).

SPECIES	VULNERABILITY	CONSERVATION VALUE
Red-throated Diver *Gavia stellata*	3	N
Great Northern Diver *Gavia immer*	2	N
Fulmar *Fulmarus glacialis*	3	I
Pink-footed Goose *Anser brachyrhynchus*	3	I
Barnacle Goose *Branta leucopsis*	3	I
Brent Goose *Branta bernicla*	3	I
Common Eider *Somateria mollissima*	3	I
King Eider *Somateria spectabilis*	3	I
Long-tailed Duck *Clangula hyemalis*	3	–
Grey Phalarope *Phalaropus fulicarius*	(1)	N
Arctic Skua *Stercorarius parasiticus*	2	–
Great Skua *Stercorarius skua*	(1)	N
Sabine's Gull *Larus sabini*	2	N
Glaucous Gull *Larus hyperboreus*	2	N
Great Black-backed Gull *Larus marinus*	2	–
Kittiwake *Rissa tridactyla*	3	I
Ivory Gull *Pagophila eburnea*	(1)	I
Arctic Tern *Sterna paradisaea*	3	N
Common Guillemot *Uria aalge*	3	I
Brünnich's Guillemot *Uria lomvia*	3	I
Razorbill *Alca torda*	2	–
Black Guillemot *Cepphus grylle*	3	I
Little Auk *Alle alle*	3	I
Puffin *Fratercula arctica*	3	–

MATERIAL AND METHODS

The maps presented in Appendix 1 represent the data recorded in the seabird colony database at the Norwegian Polar Institute (NP). The database was developed by Vidar Bakken. Currently, 501 seabird colonies from Svalbard are registered in the database. Censuses performed by the staff at the NP form the basis in the database. Records from the literature (see *References*) and data gathered by the Governor of Svalbard are also included. Although the database contains a huge amount of information, it does not yet comprise a complete account of all the seabird colonies in Svalbard because some colonies remain to be censused. In addition some colonies reported in older literature have not yet been entered, but this lack will not have any significant influence on the source for the impact assessment. The database concentrates on colony-breeding species such as the Common Guillemot, the Brünnich's Guillemot and the Kittiwake; the coverage of lesser colonial species such as the Black Guillemot and the Glaucous Gull is far from complete. However, the maps presented in this report give, for most species, a very good picture of their breeding distribution in Svalbard. Specific shortcomings in the data material are outlined in the species accounts. Some of the species are not colonial and breed dispersed in single pairs. These are Great Northern Diver (*Gavia immer*), Red-throated Diver (*Gavia stellata*), Pink-footed Goose (*Anser brachyrhynchus*), Long-tailed Duck (*Clangula hyemalis*) and Arctic Skua (*Stercorarius parasiticus*). For these species, and for the Arctic Tern (*Sterna paradisaea*), the breeding distribution is outlined in the text; no maps have been made for these species.

The maps have been prepared in a beta-version of *SIMPACT* 3.0 (Anker-Nilssen et al. 1992). Two different types of maps are presented. For species where detailed censuses of a large proportion of the colonies exist, maps showing the actual number of breeding pairs are used. The number of breeding pairs present at the time of the latest census in the colonies is aggregated within 25x25 km squares. For species where the number of individuals in the colonies has been counted instead of pairs, these numbers are divided by two. The number of pairs within each square is shown as circles more or less filled with black. The value of a filled circle is indicated by the scale at the lower left of each map. Colonies where no censuses of the species are available are indicated by small black dots.

For species for which only a small proportion of the colonies has been censused in detail, no information about the numbers of breeding pairs is given on the maps; only the position of the colonies are indicated.

Short comments to each species are given below. Emphasis is placed on population size and relative distribution, and also on the species' behaviour and the period of stay in the Svalbard area. Information about the biology of the species has been found in Blomqvist & Elander (1981), Cramp (1985), Cramp & Simmons (1977, 1983), Løvenskiold (1964), Mehlum (1990a, 1991a), Mehlum & Ogilvie (1984), Nettleship & Birkhead (1985) and Norderhaug (1989). The distribution of the species on a wider scale and a general species account have been given earlier by Fjeld & Bakken (1993).

SPECIES ACCOUNTS

RED-THROATED DIVER *Gavia stellata*

The Red-throated Diver breeds over most parts of Svalbard, but the main breeding grounds are in the western part of Spitsbergen. Red-throated Divers are solitary breeders and nest on small islands in freshwater lakes and ponds or on the shore of these. No good population estimates exist for this species in Svalbard, and the development of the population is not known. Red-throated Divers are very shy at the breeding site, and vulnerable to disturbances.

While waiting for the ice to break up at the breeding lakes in spring, the divers remain at sea. The time of egg laying is most often in late June, but varies depending on the melting of ice and snow. Incubation time is about four weeks, and the fledging period is six to seven weeks. Both parents take part in incubation and chick care. Although they breed in freshwater, the adults often spend considerable time at sea during the breeding season. Red-throated Divers arrive at the breeding grounds in Svalbard in May/June and leave in September/October. Most birds probably winter in more southerly coastal areas.

GREAT NORTHERN DIVER *Gavia immer*

Bjørnøya is the only known breeding area for this species in Svalbard. Only two or three pairs are found here. Nests are placed at the water's edge of freshwater lakes when the ice has melted in June. Incubation time is 25 days and the chicks most likely fledge when about 75 days old. The birds probably arrive in the area in May and leave in September/October. Great Northern Divers from Bjørnøya probably move south to winter in the North Sea and along the Norwegian coast.

FULMAR *Fulmarus glacialis* (Map 1)

The Fulmar breeds on coastal cliffs and on inland nunataks. Breeding sites are distributed over most areas of Svalbard, being more scarce in the northeastern parts. Fulmars breed both scattered and in large colonies, often mixed with other species. The largest colonies are found on Bjørnøya and along the western coast of Spitsbergen. The Fulmar is a difficult species to survey, and no detailed estimates or information about the development of the population are available. Mehlum and Bakken (1994) estimated the total breeding population in Svalbard at between 100,000 and 1,000,000 pairs.

Outside the breeding period, Fulmars are highly pelagic in their way of life, roaming over large areas in search for food. Breeding birds have strong fidelity to their nesting places, which are often also visited outside the breeding period. Fulmars arrive at the breeding sites already in late winter, long before the egg-laying starts in late May. The Fulmar is a long-life species with a very low reproductive rate. A single egg is incubated for about 50 days and the hatched young stays in the nest for about 45 days. Parents use very large feeding ranges in their search for food; up to 320 km has been reported from other areas. After the breeding period Fulmars stay in the areas around Svalbard; later when the ice freezes around Spitsbergen, they move to more southern areas of the Barents Sea.

PINK-FOOTED GOOSE *Anser brachyrhynchus*

This is the most numerous goose species in Svalbard. It breeds mainly in the western part of Spitsbergen, but also in other parts of the area. Pairs can either breed solitarily or in loose colonies. Nests are often placed on mountain slopes and in association with seabird colonies.

In 1993 the Svalbard population of Pink-footed Geese wintering in Denmark was estimated at 34,000 individuals. The population has increased during recent decades.

Pink-footed Geese arrive in Svalbard in late May. The eggs are laid when nesting places are free from snow in June. The female incubates the eggs for four weeks while the male guards the nesting area and defends the eggs against the Arctic Fox (*Alopex lagopus*) and other predators. Chicks leave the nest soon after hatching and the family stays in areas with rich vegetation, often below seabird colonies. During this period the adults moult and are flightless for more than three weeks. In September the geese leave Svalbard for the wintering areas in Denmark, Germany, The Netherlands and Belgium.

BARNACLE GOOSE *Branta leucopsis* (Map 2)

The Barnacle Goose breeds on the western coast of Spitsbergen and on Tusenøyane, south of Edgeøya. Most of the population breeds in colonies on small islands, but some pairs also breed on cliffs on the 'mainland'. The population has increased since the 1940s, when it numbered probably only a few hundred birds. In 1993 the winter population was estimated at about 13,700 birds. Colonies registered in the database contained 3,100 pairs at the latest censuses. Most colonies have been censused relatively recently and the map probably gives a good picture of the relative distribution of breeding Barnacle Geese in Svalbard. About 75% of the population breeds in the bird sanctuaries along the western coast of Spitsbergen.

Barnacle Geese arrive at the breeding grounds in May and start breeding when there is open water around the breeding islands. The male guards the nest while the female incubates the eggs. After hatching, the whole family often swims to areas with luxuriant vegetation on the coast. Here the young grow, and the adults moult and rebuild fat reserves for the migration to the south in September. On their way to the wintering areas in Scotland and England, the birds rest on Bjørnøya. On their northward migration in spring, the birds rest on the coast of Helgeland.

BRENT GOOSE *Branta bernicla* (Map 3)

Most of the population of the Brent Goose in Svalbard breeds on Tusenøyane, south of Edgeøya. Some pairs also breed on small islands along the western and northern coasts of Spitsbergen; Moffen in the north being the most important of these islands. The Brent Goose was probably formerly the most numerous species of goose in Svalbard, but today it is the rarest. Counts in the wintering areas in Denmark in 1993 resulted in estimates of about 5,800 birds. In addition a smaller proportion of the population winters in England. This proportion varies from year to year. The population in Svalbard winters, however, in the same areas as the population from Zemlja Franca Iosifa, and the size and development of this population are not known. At the latest censuses colonies registered in the database contained 418 pairs and 80 individuals.

The geese arrive at the breeding grounds in May/June. Only the female incubates, while the male keeps close to the nesting site. Both parents participate in rearing the young. The adults moult in the chick period, and they are then unable to fly for several weeks. In this period the birds are very shy and vulnerable to disturbances. The concentration of the breeding population in the small area of Tusenøyane, where they live in close proximity to the sea, also makes the population very vulnerable to oil spills in this area. The Brent Geese leave Svalbard for the wintering areas in Denmark and England in early September.

COMMON EIDER *Somateria mollissima* (Map 4)

The Common Eider breeds both in colonies on small islands and more dispersed along the coast of the mainland. About 70–95% of the population breeds on islands (Prestrud & Mehlum 1991). Only the main breeding sites on the western part of Svalbard and on Tusenøyane are shown on the map. In addition many colonies exist in the eastern parts, on Bjørnøya and on Hopen, where detailed censuses are not available. The main part of the population breeds, however, in the censused colonies on the western and northwestern coasts of Spitsbergen and on Tusenøyane (the censused colonies registered in the database represent 18,500 pairs). Prestrud & Mehlum (1991) estimated that of the total breeding population of 13,500–27,500 pairs in Svalbard, only 1,500–3,500 pairs bred in the eastern parts (Sørkapp–Gråhuken). The proportion of the population breeding varies greatly from year to year depending on ice conditions in spring and early summer. Extensive collection of down and eggs probably reduced the population during the first part of this century. Although protection measures and bird sanctuaries were established in 1963 and 1973, no marked increase in the population has occurred since. About half of the registered population breeds in the bird sanctuaries along the western coast of Spitsbergen.

The Common Eiders arrive at the breeding grounds early in spring, but most often do not start breeding before the ice around the breeding islands has disappeared. Male Common Eiders leave the females 1–2 weeks after the start of incubation and gather in flocks which later move to coastal areas were moulting takes place. Before hatching, the females spend most of their time on the nest. The chicks are led to the sea by the female shortly after hatching, and several family groups assemble at sea. In this period the female moults. Common Eiders from Svalbard probably winter mainly along the coast of northern Norway.

KING EIDER *Somateria spectabilis* (Map 5)

Tundra plains with small ponds are typical breeding areas for King Eiders, which breed in a dispersed pattern. The King Eider breeds scattered along most of the western coast of Spitsbergen, but the most important breeding areas are from Bellsund to Prins Karls Forland (Nordenskiöldkysten, Daudmannsøyra and Forlandssletta) and on Reinsdyrflya in northwestern Spitsbergen. Only these main known breeding areas are shown on the map, which is modified from Prestrud (1991). Female King Eiders are difficult to separate from female Common Eiders. This, combined with the dispersed breeding pattern, makes the King Eider a difficult species to census on the breeding grounds and easy to overlook. Migrating flocks have been observed flying south along the eastern coast of Spitsbergen in autumn, and it is possible that there are unknown breeding areas in the northern and eastern parts of

Svalbard. The total autumn population in Svalbard has been estimated at 2,500–5,000 individuals (Prestrud 1991). The development of the population is not known.

The King Eiders arrive in the Svalbard area in early spring (May) and occupy the nesting grounds as soon as they are free of snow and ice. The eggs are incubated by the female for about 23 days, and the female stays with the young after hatching. Male King Eiders leave the female before the eggs hatch and congregate in shallow areas along the coast where they moult. The females do not moult until later in the autumn. The King Eiders leave Svalbard in September–October and probably winter along the coast of northern Norway.

LONG-TAILED DUCK *Clangula hyemalis*

The Long-tailed Duck breeds in low numbers in Svalbard, mainly in the western parts of Spitsbergen and on Bjørnøya. Solitary pairs breed here on small islands and on the mainland close to freshwater ponds. The nests are often placed in colonies of Arctic Terns. There are no good estimates of population size, and the development of the population is unknown.

Long-tailed Ducks arrive in Svalbard in May, and start breeding as soon as breeding areas are free from ice in late June. The female incubates the eggs for four weeks, whereas the male leaves the female early in the incubation period. In the subsequent period the males moult along the coast, either singly or in small flocks. The young follow the female to the nearest freshwater pond shortly after hatching. They stay here for some time before moving out to sea. The females moult somewhat later than the males. Some Long-tailed Ducks may stay in the areas around Svalbard after the breeding period as long as there is open water. Most birds move to more southern areas in October/November, possibly to areas along the coast of North Norway.

GREY PHALAROPE *Phalaropus fulicarius* (Map 6)

The Grey Phalarope breeds dispersed in single pairs or in small colonies of up to 25 pairs in the western and southern parts Svalbard. The most important breeding areas are indicated on the map, but Grey Phalaropes are also found nesting outside these areas. In the breeding season they prefer wet areas with freshwater ponds and luxuriant, grassy vegetation along the coast or on small islands. Kålås & Byrkjedal (1981) suggested the breeding population in Svalbard to be 150–300 pairs. The development of the population is not known, but there has been a reduction in the number of breeding pairs in several breeding localities during the last decades.

The Grey Phalaropes arrive in Svalbard in the beginning of June, often before the snow has melted on the nesting places. Egg laying takes place from the middle of June to early July, depending on snow melting. The female leaves the nesting area shortly after the eggs are laid, and the eggs are incubated solely by the male for about 18 days. The young leave the nest after hatching and are taken care of by the male. Both before egg laying, while the nesting places are covered by snow, and during the breeding season, the Grey Phalaropes spend much time in the marine environment searching for food. The females start migrating south already in the first half of July, while males and juveniles follow in late July or early August. Outside the breeding period Grey Phalaropes are pelagic. The wintering areas are probably in upwelling areas off western Africa.

ARCTIC SKUA *Stercorarius parasiticus*

The Arctic Skua breeds in single pairs on the tundra along the coast over most of the archipelago but is least common in the northeastern areas. It is often found in connection with seabird colonies, where it obtains food by pursuing other birds, mainly auks and Kittiwakes, and stealing their food. The breeding population of Arctic Skuas in Svalbard is probably about 1,000 pairs (Mehlum & Bakken 1994). The development of the population is not known.

In early June the Arctic Skuas arrive at the breeding grounds in Svalbard. The eggs are laid in late June or early July and are incubated for about 26 days. Soon after hatching the young leave the nest. They stay in the nesting area where they are fed by the parents until fledged about 5 weeks later. The Arctic Skuas leave Svalbard in August–September. Outside the breeding season they are pelagic and probably winter off southwestern Africa.

GREAT SKUA *Stercorarius skua* (Map 7)

The Great Skua is a relatively new breeding species in Svalbard – the first breeding record from Bjørnøya was in 1970 and the first from Spitsbergen was in 1976. It is now a regular breeder in many localities, especially along the western coast of Spitsbergen and on Bjørnøya. The preferred breeding habitat is small islands and tundra ground close to the sea, where the skuas breed in single pairs or in small, loose colonies. The breeding population of the Great Skua in Svalbard is now about 100–200 pairs, and the population is probably still increasing. A relatively large number of non-breeding birds also spend the summer in the area.

Egg laying takes place in late June or in July, depending on snow melting. Both parents incubate the eggs for four weeks. The young stay in the area around the nest and are fed by the parents until fledged, about six to seven weeks later. The Great Skuas leave Svalbard after breeding. Outside the breeding period they are highly pelagic and winter at sea in the Atlantic Ocean.

SABINE'S GULL *Larus sabini* (Map 8)

The Sabine's Gull is a rare species in the Svalbard area. At the beginning of this century it probably bred regularly in Kongsfjorden. Since then relatively few observations have been made both at sea – often in ice-filled waters – and on possible breeding sites. In 1986, 1993 and 1994 the Sabine's Gull was found breeding at Moffen, north of Spitsbergen. In 1993 four pairs probably bred here. Additional breeding sites may well exist, but the number of breeding pairs is in any case very low.

Little is known about the biology of the Sabine's Gull. It breeds most often in colonies of Arctic Terns, where it gains protection from predators. In Greenland and the Canadian Arctic the Sabine's Gulls arrive at the breeding grounds in the first half of June and leave in August and early September. Birds from these areas winter in the waters off southwestern Africa, and the Svalbard birds probably do the same.

GLAUCOUS GULL *Larus hyperboreus* (Map 9)

Glaucous Gulls breed throughout most of Svalbard, either as single pairs or in small colonies. Their breeding places are most often situated close to colonies of other seabirds, where they are important predators on eggs, young and, for some species, also adults. Due to the Glaucous Gull's highly dispersed breeding distribution, the present map of breeding localities is far from complete. The total breeding population in Svalbard has roughly been estimated at 1,000–10,000 pairs (Mehlum & Bakken 1994). Little is known about the development of the population. The findings, especially from Bjørnøya, of a considerable number of dead Glaucous Gulls with high levels of contaminants are an alarming signal that the contamination level may be an important problem lowering survival and possibly also reproduction in some areas.

Egg laying takes place in late May or early June, and the eggs are incubated for four weeks. Both parents take part in the incubation and feeding of the young. After about 50 days the young fledge and then soon become independent. Many Glaucous Gulls stay in ice-free parts of the Barents Sea all year round, but most birds probably migrate to areas in the North Atlantic and Norwegian Sea in winter. There is a gradual arrival to and departure from the breeding grounds, but most breeders arrive in April and leave in September/October.

GREAT BLACK-BACKED GULL *Larus marinus* (Map 10)

The Great Black-backed Gull is a relatively new breeding species in Svalbard. It was found breeding on Bjørnøya for the first time in 1921, and on Spitsbergen in 1930. Today it breeds in small numbers along the western coast of Spitsbergen and on Bjørnøya, mostly on small islands with eider colonies. The total breeding population in Svalbard is estimated at less than 100 pairs.

The migration pattern and breeding biology of Great Black-backed Gulls nesting in Svalbard are insufficiently known. The birds most likely arrive in the breeding areas in April/May and leave in September. Great Black-backed Gulls leave the Barents Sea in autumn and probably winter along the coasts of the North Sea.

KITTIWAKE *Rissa tridactyla* (Map 11)

The Kittiwake is a common breeding bird in all parts of Svalbard, with the largest colonies on Bjørnøya and Hopen. It breeds in colonies ranging in size from tens to tens of thousands in bird cliffs along the coast. The colonies may consist of only Kittiwakes or be a mixture with other species such as the Brünnich's Guillemot. The total breeding population in Svalbard is estimated at 270,000 pairs (Mehlum & Bakken 1994); this is about the same number as was counted in the latest census in the colonies currently registered in the database. Although a decline in the number of breeding pairs has been observed in some colonies, there is reason to believe that the population of Kittiwakes in Svalbard as a whole is increasing.

Some Kittiwakes may arrive in Svalbard already in February, but most birds come in April. The eggs are laid in nests on narrow ledges in early June and incubated for about four weeks. The young are fledged and leave the nest when about six weeks old. Kittiwakes often forage far out in the open sea in the breeding season; they may also use ice-filled waters and areas along glacier faces. Outside the breeding season they have a pelagic way of life. Most birds leave the Svalbard area in September for wintering areas in the North Atlantic.

IVORY GULL *Pagophila eburnea* (Map 12)

The Ivory Gull is an arctic species breeding in small numbers on Spitsbergen, Kong Karls Land and Nordaustlandet, with the largest numbers in the northern and eastern areas. It breeds as single pairs or in colonies of up to more than a hundred pairs, often mixed with Kittiwakes. The breeding places are situated on steep cliffs (occasionally also on flat islands), often on nunataks in remote and seldom visited areas. Several of the colonies indicated on the map are recorded from the literature and represent colonies not recently visited. It is known that Ivory Gull colonies may be unstable with time, and the existence and possible size of these colonies today are therefore uncertain. There are no good estimates of the breeding population of Ivory Gulls in Svalbard, but the population is probably between 200 and 1,000 pairs. The development of the population is not known. Some earlier described colonies have disappeared or been reduced in size, but due to the long time span and the instability of the colonies, care must be taken in drawing conclusions from this evidence.

The migration patterns and breeding biology of the Ivory Gull are insufficiently known. Egg laying probably takes place in late June to early July, and the birds most likely leave the colonies some time after the young are fledged in August–September. Ivory Gulls are closely associated with sea ice and may occur both in open drift ice and in unbroken ice far from the ice edge at all times of the year. They may also come to human settlements in search for food.

ARCTIC TERN *Sterna paradisaea*

The Arctic Tern is a common breeder along the coast of most of Svalbard, in largest numbers on the western and northern parts of Spitsbergen. It breeds as single pairs or, more commonly, in colonies of up to several hundred pairs. Predators entering the colony area are attacked furiously by the terns, and other species like the Common Eider, the Long-tailed Duck and the Sabine's Gull seek protection by nesting in Arctic Tern colonies. The breeding population in Svalbard is probably less than 10,000 pairs, but no reliable estimates are available (Mehlum & Bakken 1994).

In late May or early June, often before the snow has melted, the Arctic Terns arrive at their breeding grounds in Svalbard. The eggs are laid in the last part of June and incubated for three weeks. The young leave the nesting area when fledged three weeks later. Migration starts in the last part of August, and by the middle of September most birds have left Svalbard.

Wintering at sea in the Southern Hemisphere as far south as the Antarctic, the Arctic Tern is one of the species which migrates the longest distance.

COMMON GUILLEMOT *Uria aalge* (Map 13)

Bjørnøya is the most important breeding area for the Common Guillemot in the entire Barents Sea. It breeds in large colonies on ledges and plateaus, often together with Brünnich's Guillemots, which occupy the narrowest ledges. The breeding population on Bjørnøya was in 1986 estimated at 245,000 pairs. In 1987 the number of breeding pairs was reduced to 36,000 pairs; a reduction of 85% compared to the year before. This dramatic decline was most likely largely due to the simultaneous collapse of the Barents Sea Capelin (*Mallotus villosus*) stock; the Capelin being the principal food source for Common Guillemots in the Barents Sea. Many birds probably did not breed when food was scarce after the Capelin collapse. The number of breeding pairs has increased somewhat since 1987, but it is now still less than 50% of the population in 1986. Only about 100–200 pairs breed in Svalbard outside Bjørnøya (Mehlum & Bakken 1994).

The Common Guillemots start arriving on the breeding ledges on Bjørnøya in March–April. A single egg is laid in May/June and incubated for about 32 days. Parents may travel long distances from the colony in search of food. The young leave the breeding ledge at an age of 20 days, before they are able to fly. Departure of the young from a colony is highly synchronised within a few days, and most young leave during the night. At Bjørnøya departure occurs in late July or early August. The young are followed at sea by the male parents who feed and take care of them. Males and young carry out a swimming migration from the colony out to sea. During the following period the parents moult and are unable to fly for 45–50 days. In this period Common Guillemots are very vulnerable to oil spills. The young are capable of flying when 50–70 days old. Common Guillemots from Svalbard winter in the southern part of the Barents Sea and in areas off the coast of northern Norway.

BRÜNNICH'S GUILLEMOT *Uria lomvia* (Map 14)

Having a more northerly distribution than its close relative the Common Guillemot, the Brünnich's Guillemot breeds in large numbers on the northern islands in the Svalbard archipelago as well as on Bjørnøya. It breeds on narrow cliff ledges in dense colonies that may contain more than a hundred thousand pairs, often mixed with Kittiwakes and, on Bjørnøya, Common Guillemots. The largest colonies are on the southeastern part of Spitsbergen, southern Edgeøya, Hopen and Bjørnøya. More than 80% of the Svalbard population breeds in this area. The total population of the Brünnich's Guillemot in Svalbard has been estimated at 1,300,000 individuals. Whereas the number of breeding Common Guillemots on Bjørnøya declined drastically in 1986–1987, the Brünnich's Guillemots on Bjørnøya increased by approximately 20% in a few years following 1986. This difference is due to the fact that the Brünnich's Guillemots are far less dependent upon Capelin as food compared to the Common Guillemots. There has been a general increase in the population of Brünnich's Guillemots in several regions of Svalbard since the middle of the 1980s (Mehlum & Bakken 1994).

The breeding ecology of the Brünnich's Guillemot is similar to that of the Common Guillemot. Breeding ledges are occupied in March–April and the eggs are laid in May/June, depending on snow melting. The eggs are incubated for about 32 days and the young leave the ledge when about 20 days old. The departure is synchronised within the colony and most young leave within a period of a few days in late July or early August. They are followed by the male parents on the swimming migration out to sea. Adult birds moult after the young have left the colony, and in this period both parents and young are unable to fly for several weeks. Oil spills in this period may therefore have serious consequences for these birds. The parents use large feeding ranges at sea during the breeding season. Recoveries of ringed birds indicate that a large proportion of the birds breeding in Svalbard winters off southwestern Greenland. Others stay in the Barents Sea area and winter at sea, along the ice edge and in open leads in the ice. A large proportion of the Brünnich's Guillemots wintering in the Barents Sea consists probably of birds from colonies in Russian areas.

RAZORBILL *Alca torda* (Map 15)

Bjørnøya, Bellsund and Krossfjorden are the only known breeding sites for Razorbills in Svalbard. Here they breed in very small numbers as single pairs or in small colonies. The total breeding population in Svalbard is estimated at about 100 pairs (Mehlum & Bakken 1994).

Little is known about the breeding biology and migration pattern of Razorbills breeding in Svalbard. The birds probably arrive at the breeding colonies in April–May. Laying of eggs probably takes place in the first part of June, and the eggs are incubated for about 35 days. Parents and young leave the colony together when the young are about 20 days old, presumably in late July or early August. The young are then still flightless. The parents moult shortly after departure from the colony and are then also unable to fly. Razorbills from Svalbard most likely winter off southwestern Norway and in Skagerrak.

BLACK GUILLEMOT *Cepphus grylle* (Map 16)

The Black Guillemot is a common breeding bird in most parts of Svalbard. It breeds as single pairs or in small loose colonies in rock crevices, in scree or under boulders. Due to its dispersed breeding pattern, the present map of Black Guillemot breeding sites is not complete. No detailed census has been made, but the breeding population in Spitsbergen has roughly been estimated at 20,000 pairs (Mehlum & Bakken 1994). The development of the population is not known.

Coastal areas of Svalbard are visited by Black Guillemots already in March. Most often two eggs are laid by each pair in June and are incubated for about 30 days. The young stay in the nest for 30–40 days and then leave for the sea. After this the young are independent of the parents. In the breeding period Black Guillemots find most of their food in shallow waters, often close to the breeding site. The birds breeding in Svalbard do not migrate from the Barents Sea in autumn. They can be found in the area all year round where there is open water. Most birds probably winter close to the ice edge in the Barents Sea.

LITTLE AUK *Alle alle* (Map 17)

This is probably the most numerous bird species in the area. It breeds over most of Svalbard except for the most easterly parts. The largest concentrations of breeding birds are in Hornsund, Bellsund and northwestern Spitsbergen. They breed in large colonies in screes or more dispersed in rock crevices. Little effort has been spent in censusing this species, and the size and development of the population is largely unknown. The total breeding population in Svalbard is probably of more than 1 million pairs (Mehlum & Bakken 1994). The population on the northern coast of Hornsund has been estimated at roughly 400,000 breeding pairs (Isaksen 1995).

The Little Auks arrive at the breeding colonies in April and leave in August/September. Laying of eggs takes place in the second half of June or early July, depending on snow melt. The incubation period is 29 days, and the young leave the nest entrance and fly out to sea when 27 days old. Breeding birds may feed in areas far distant from the colony; feeding ranges of up to 100–150 km from the colony have been reported, but this extreme may have involved non-breeding birds. Parents and young leave the colony together, and the adult birds moult shortly after leaving the breeding grounds. A large proportion of the population which breeds in Svalbard probably migrates to areas off southwestern Greenland to spend the winter.

PUFFIN *Fratercula arctica* (Map 18)

The Puffin breeds solitarily or in small colonies in the western parts of the area. Rock crevices and holes among stones are the most common nesting habitats. The largest breeding concentrations are along the western coast of Spitsbergen, especially in the northern part. Although not confirmed, the Puffin probably also breeds at Hopen. The total population in Svalbard is probably about 10,000 pairs (Mehlum & Bakken 1994). No information is available about the development of the population.

Little is known about the general breeding biology of the Puffins breeding in Svalbard, such as the time of arrival to and departure from the breeding grounds. In more southern areas the eggs are incubated for about six weeks and the young leave the colony after six to ten weeks. At Spitsbergen the young probably do not leave for sea before August–September. The Puffins winter out at sea, but little is known about which areas are used by the population which breeds in Svalbard. Some Puffins winter, however, in the ice-free parts of the Barents Sea.

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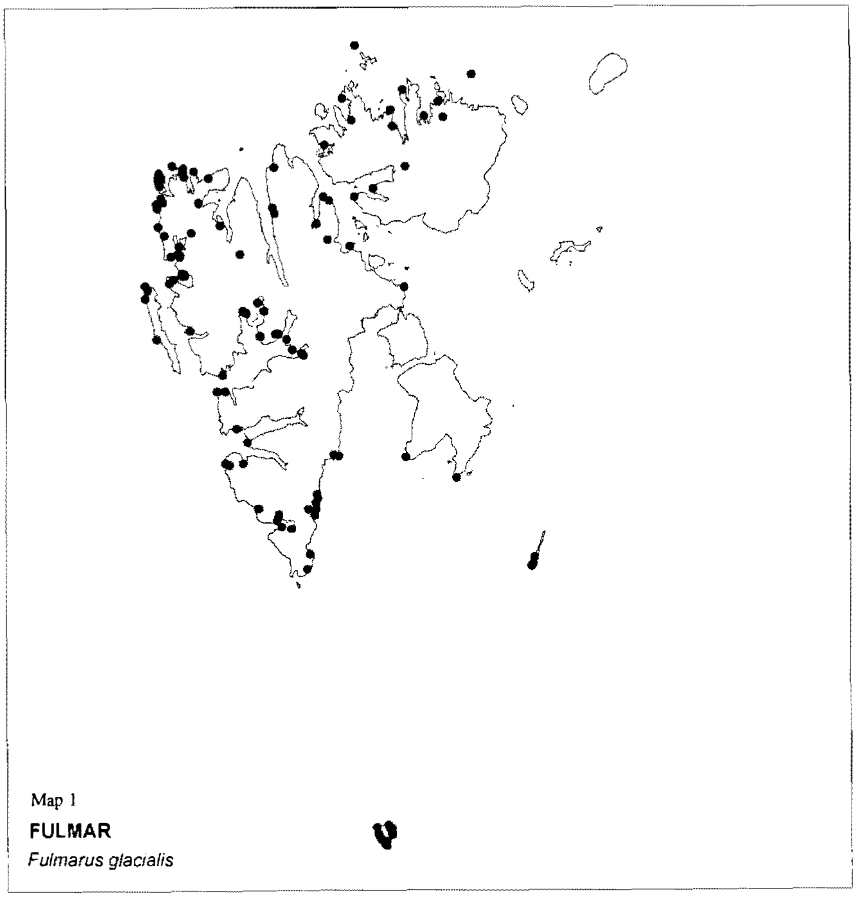
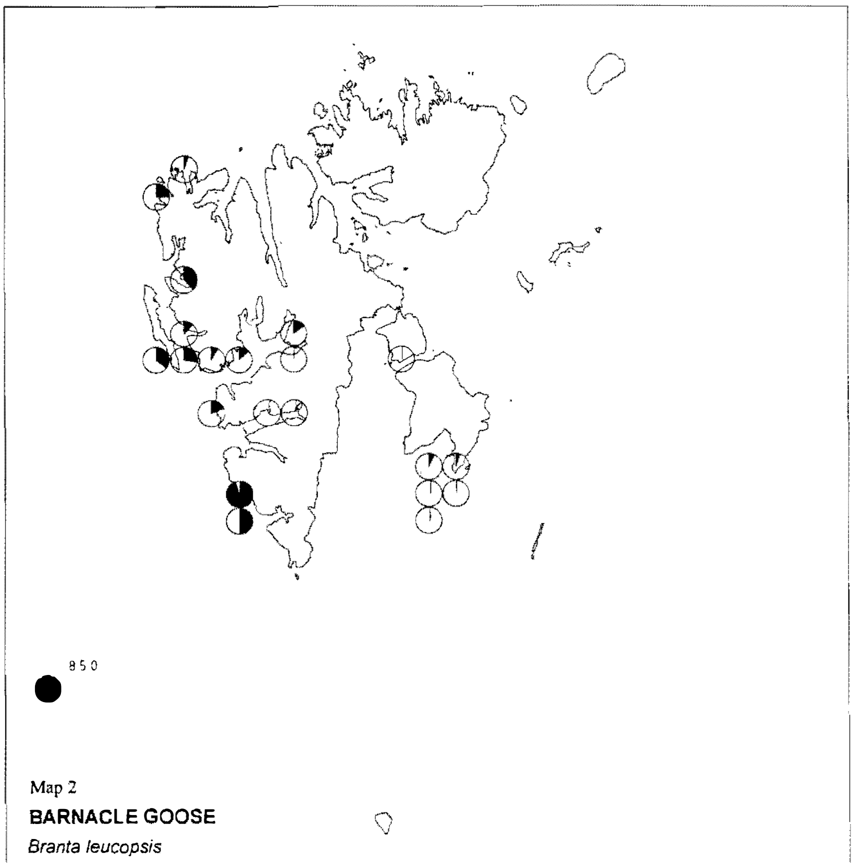
APPENDIX 1. Maps of the main breeding distribution of seabirds in Svalbard. See text for explanation to each map.



Map 1

FULMAR

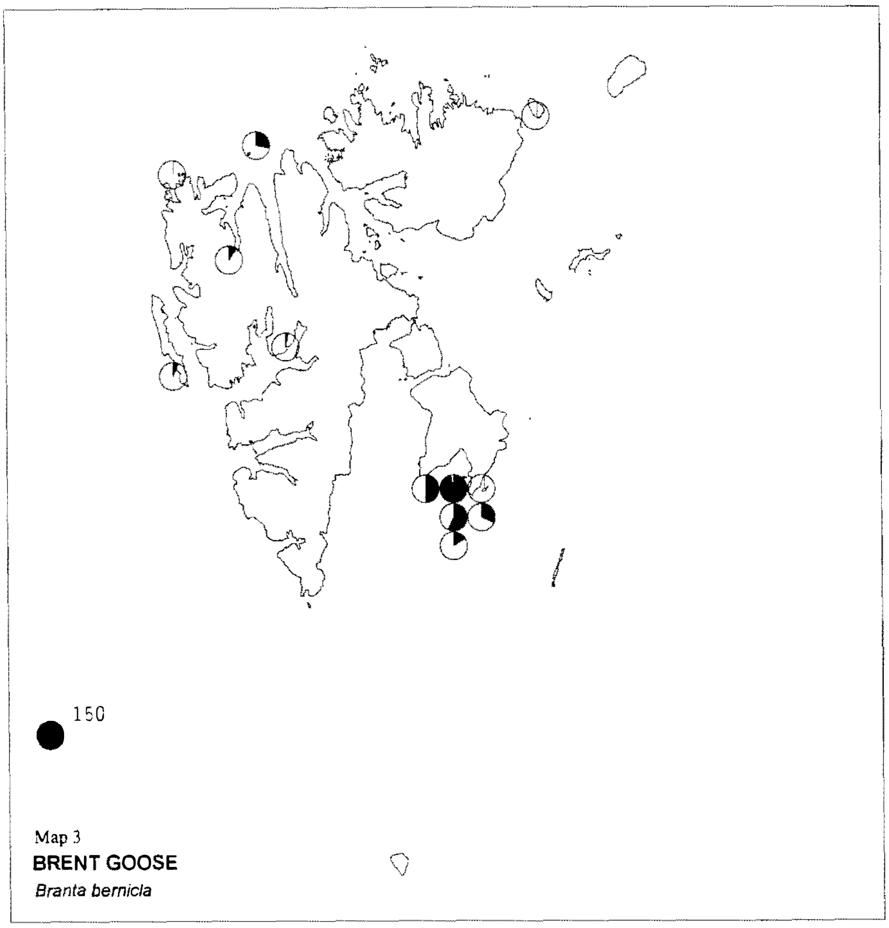
Fulmarus glacialis



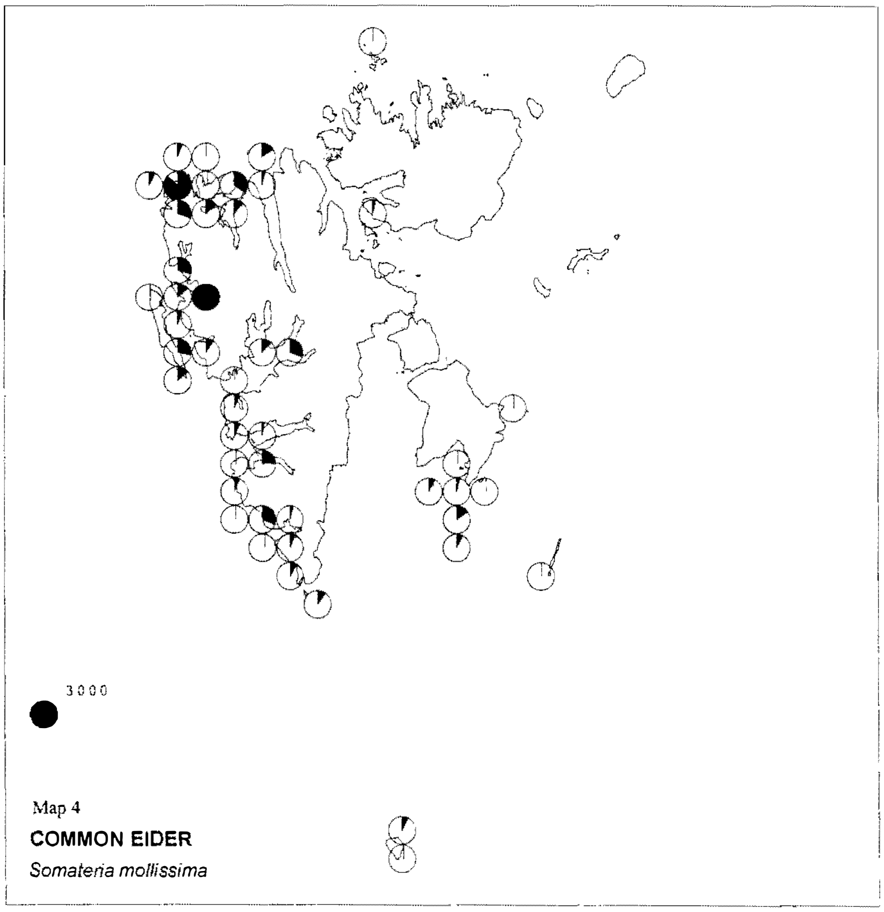
Map 2

BARNACLE GOOSE

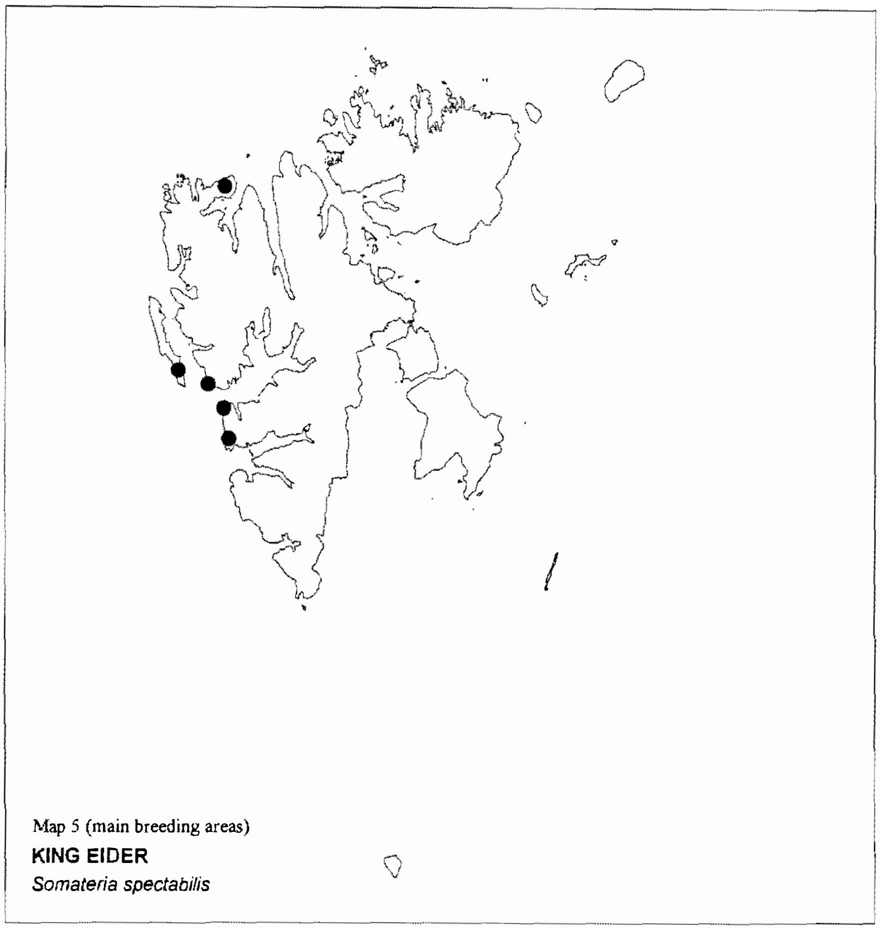
Branta leucopsis



Map 3
BRENT GOOSE
Branta bernicla



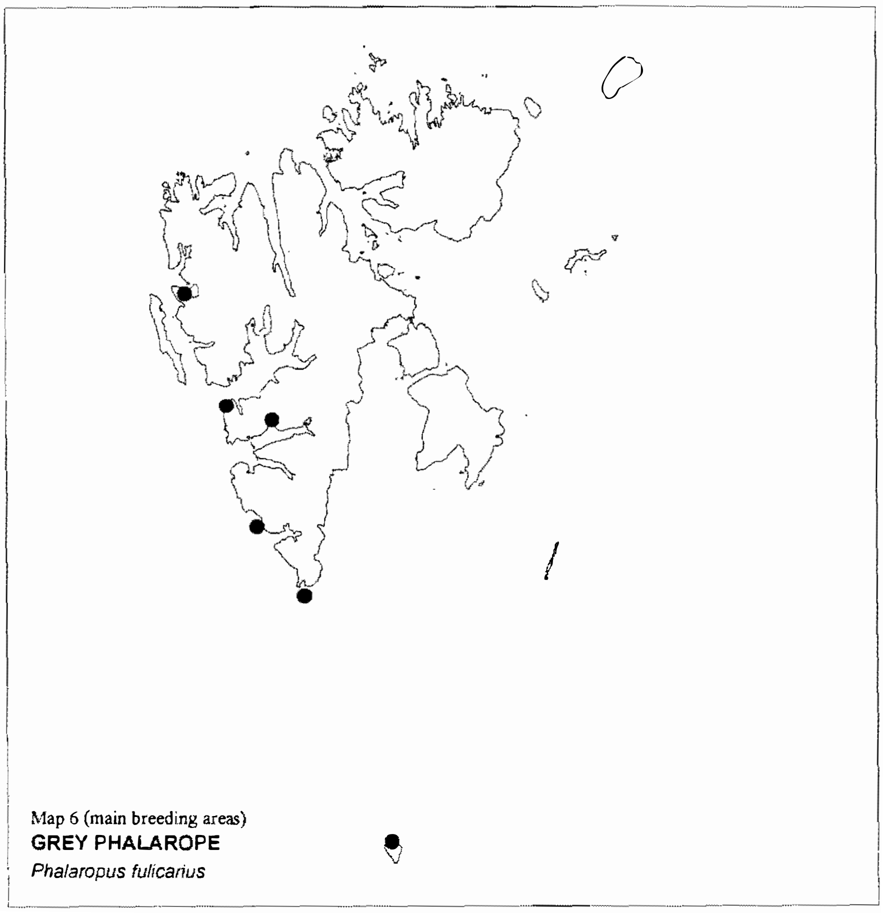
Map 4
COMMON EIDER
Somateria mollissima



Map 5 (main breeding areas)

KING EIDER

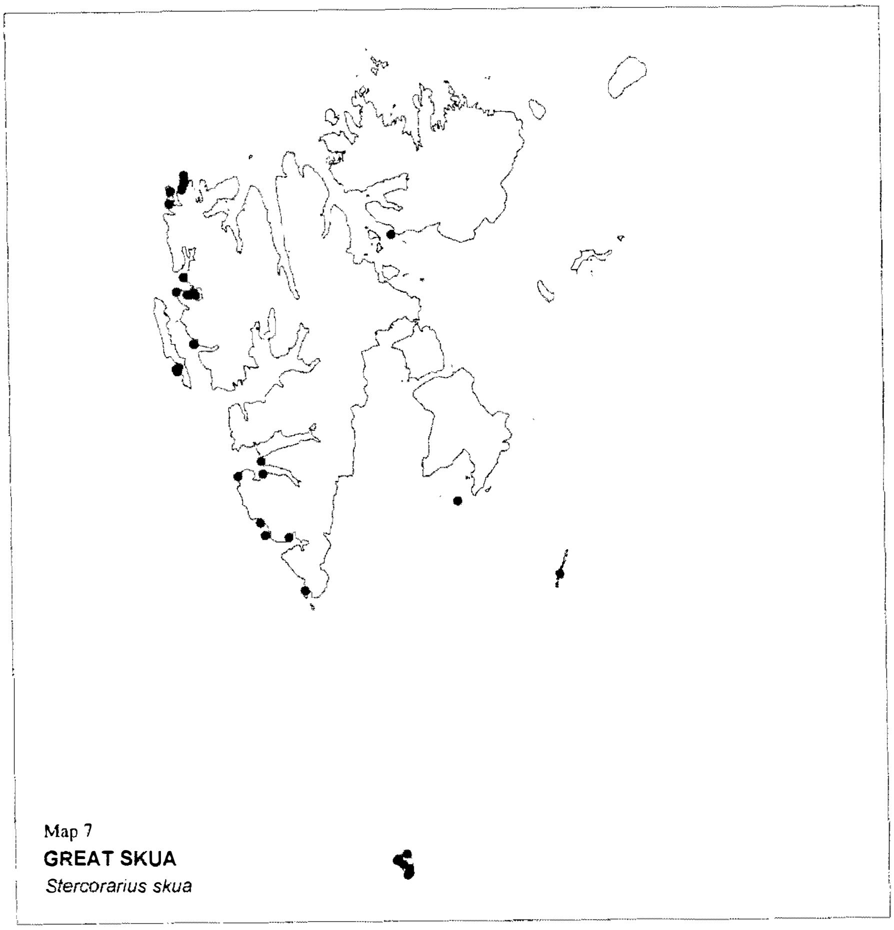
Somateria spectabilis



Map 6 (main breeding areas)

GREY PHALAROPE

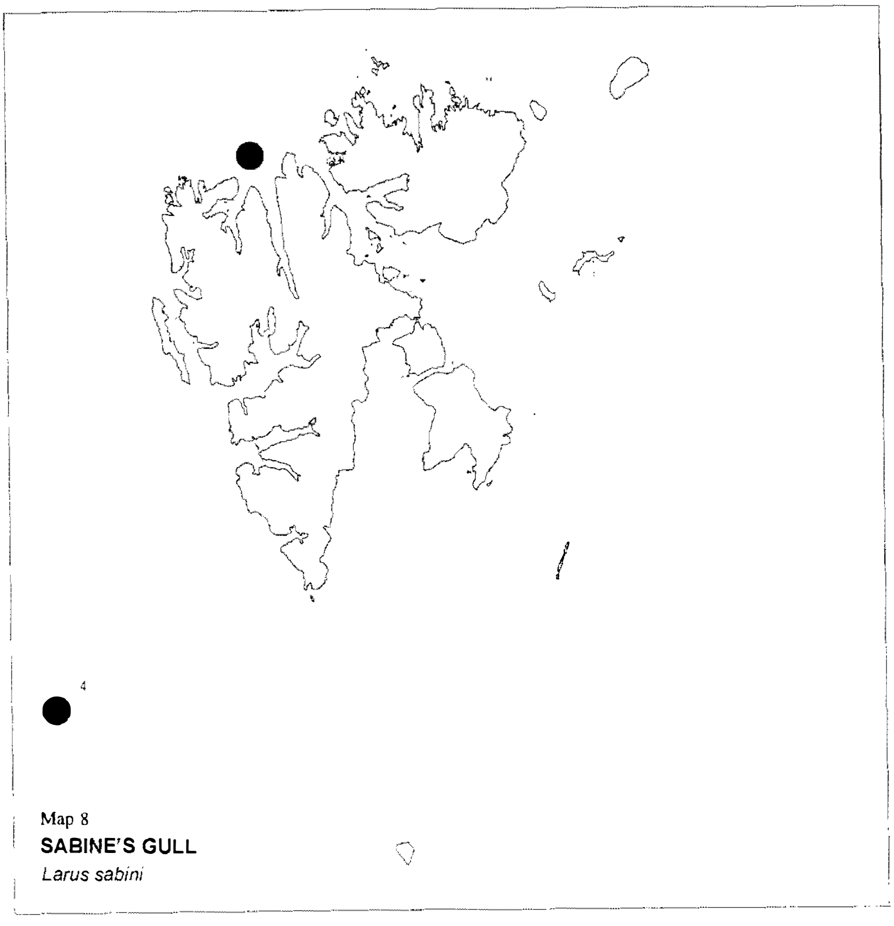
Phalaropus fulicarius



Map 7

GREAT SKUA

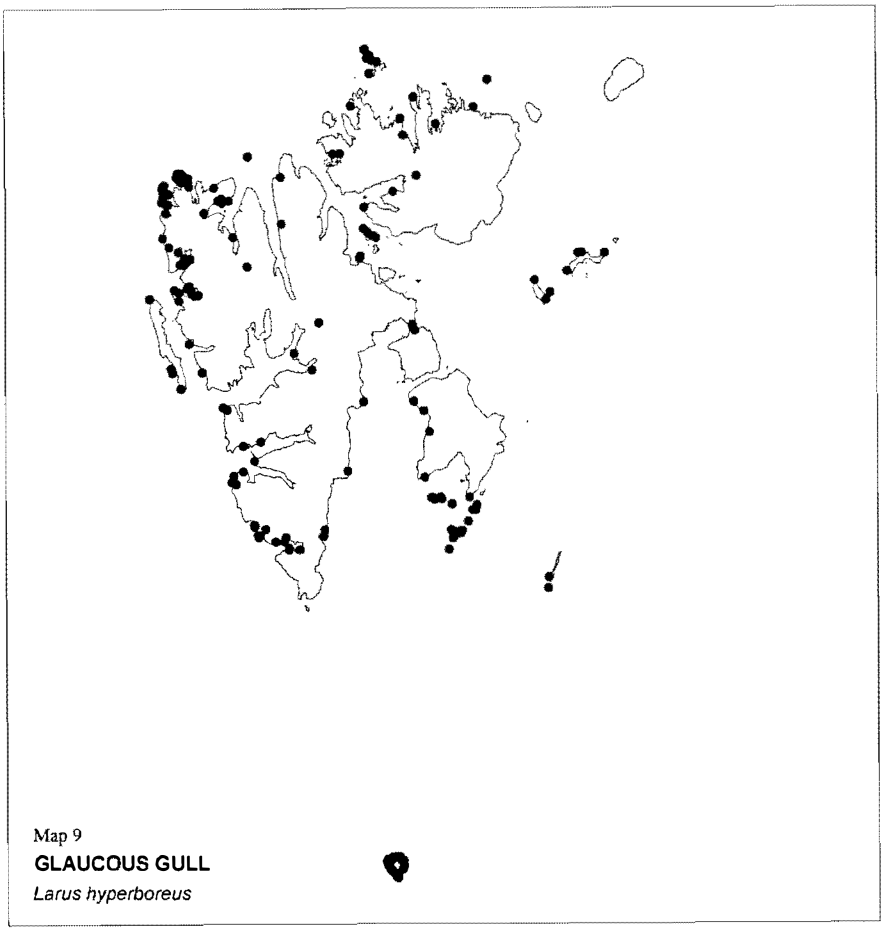
Stercorarius skua



Map 8

SABINE'S GULL

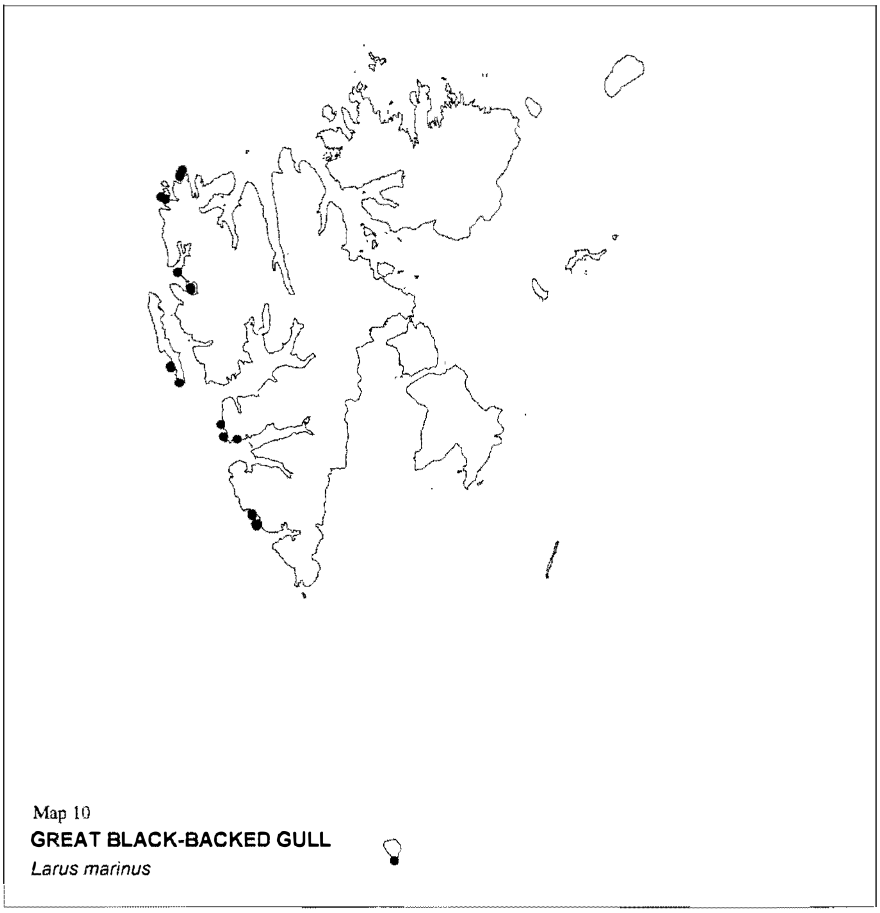
Larus sabini



Map 9

GLAUCOUS GULL

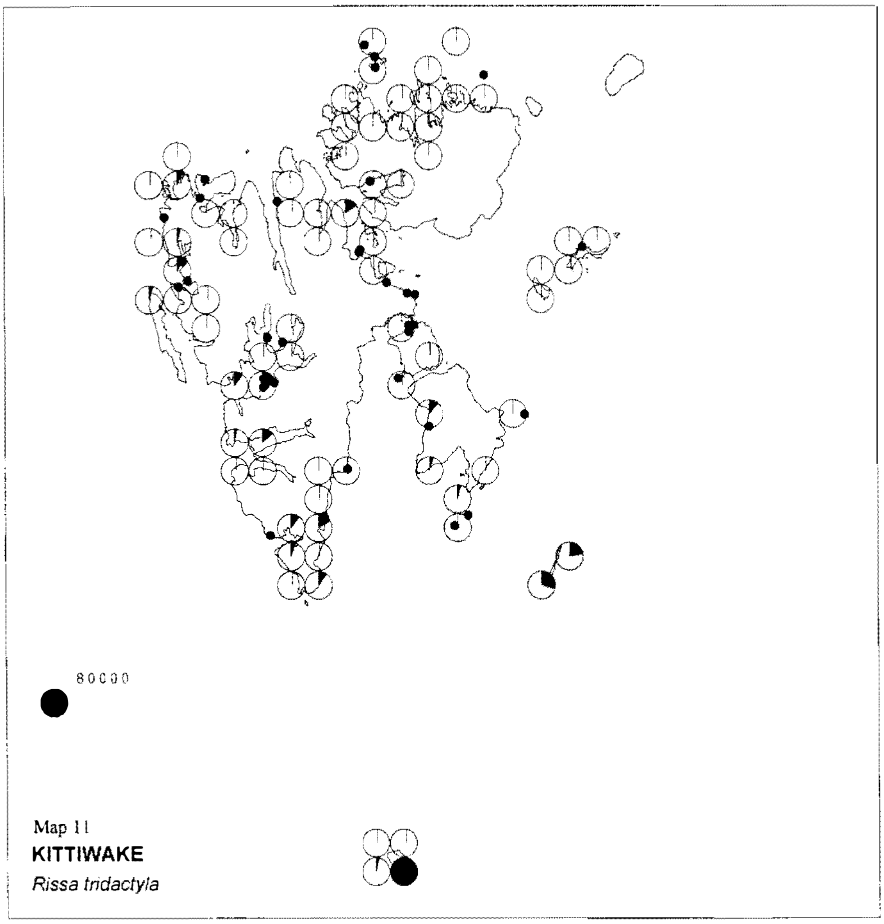
Larus hyperboreus



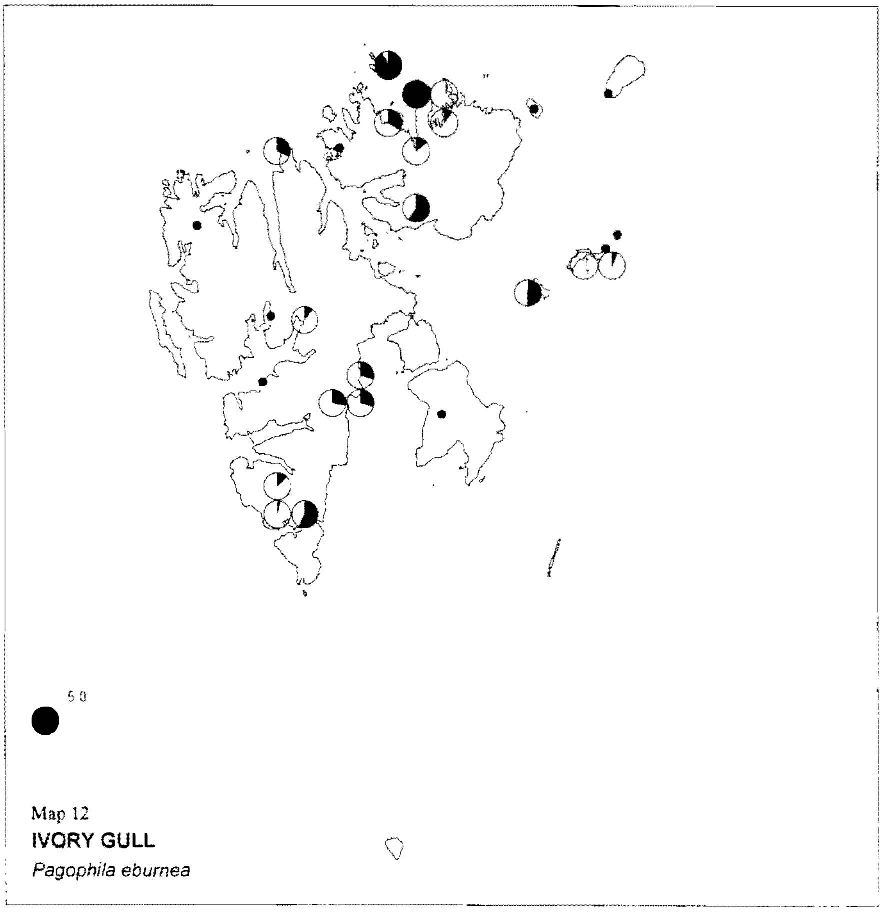
Map 10

GREAT BLACK-BACKED GULL

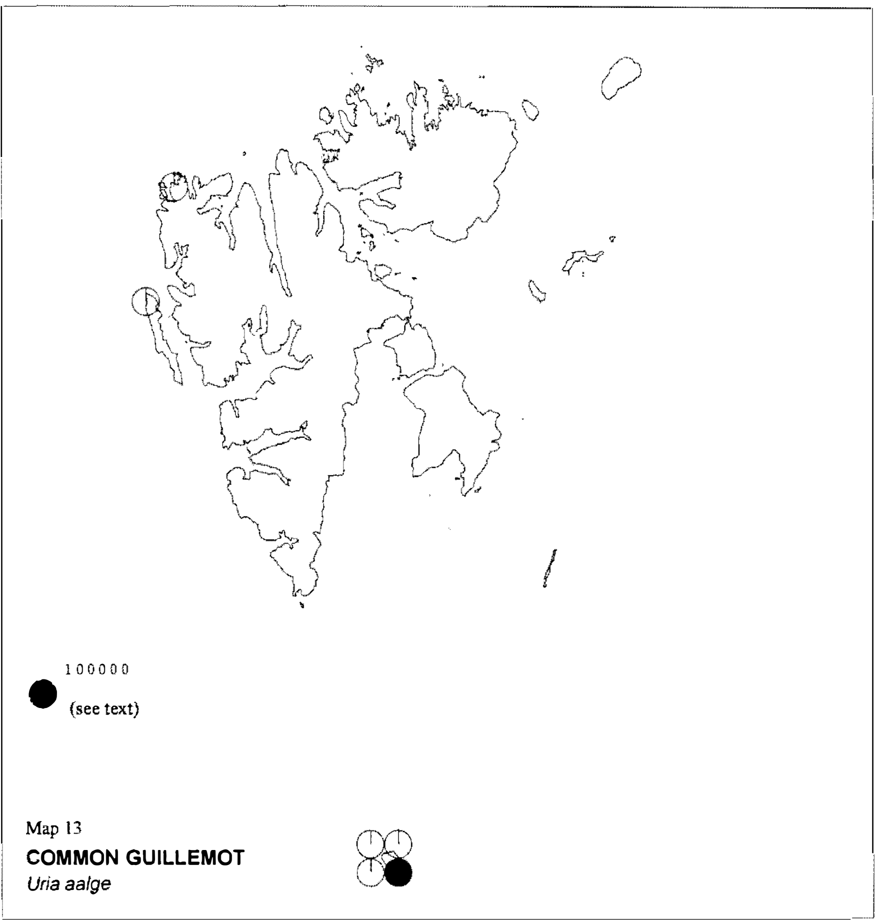
Larus marinus



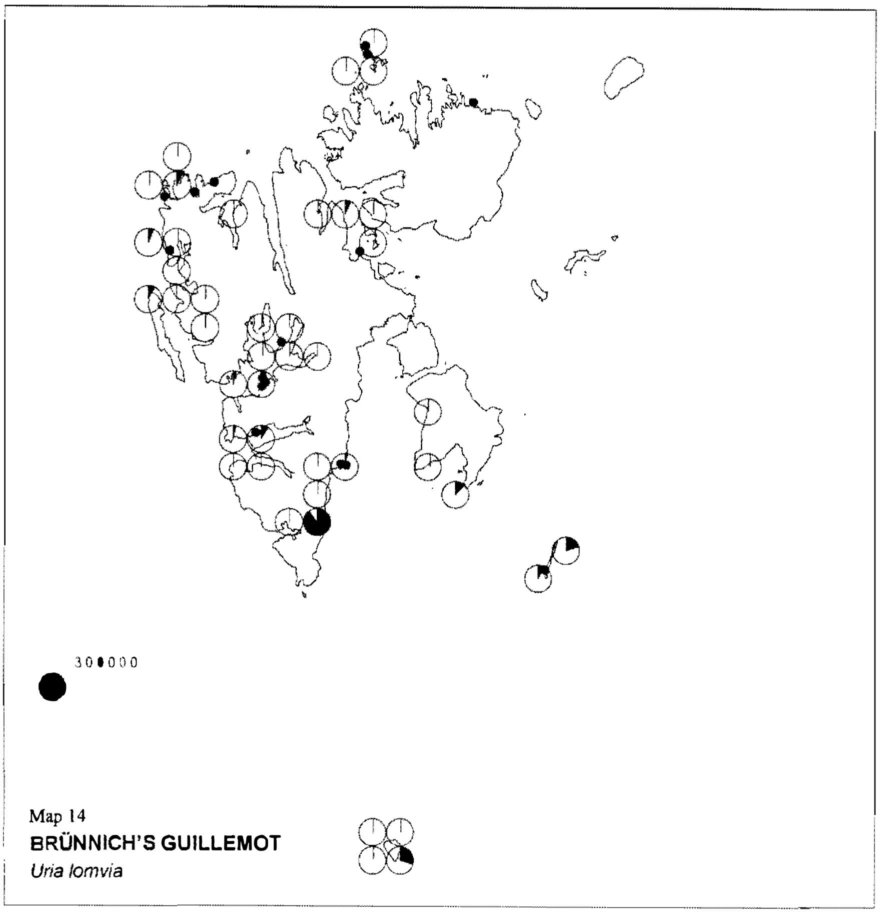
Map 11
KITTIWAKE
Rissa tridactyla



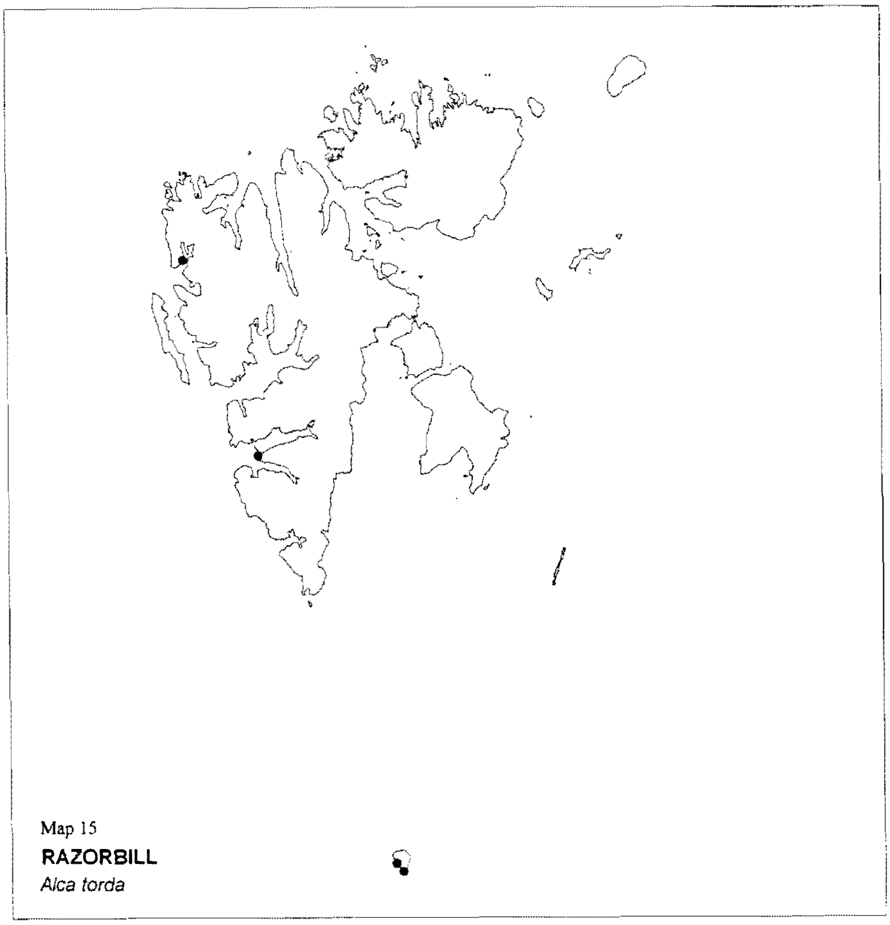
Map 12
IVORY GULL
Pagophila eburnea



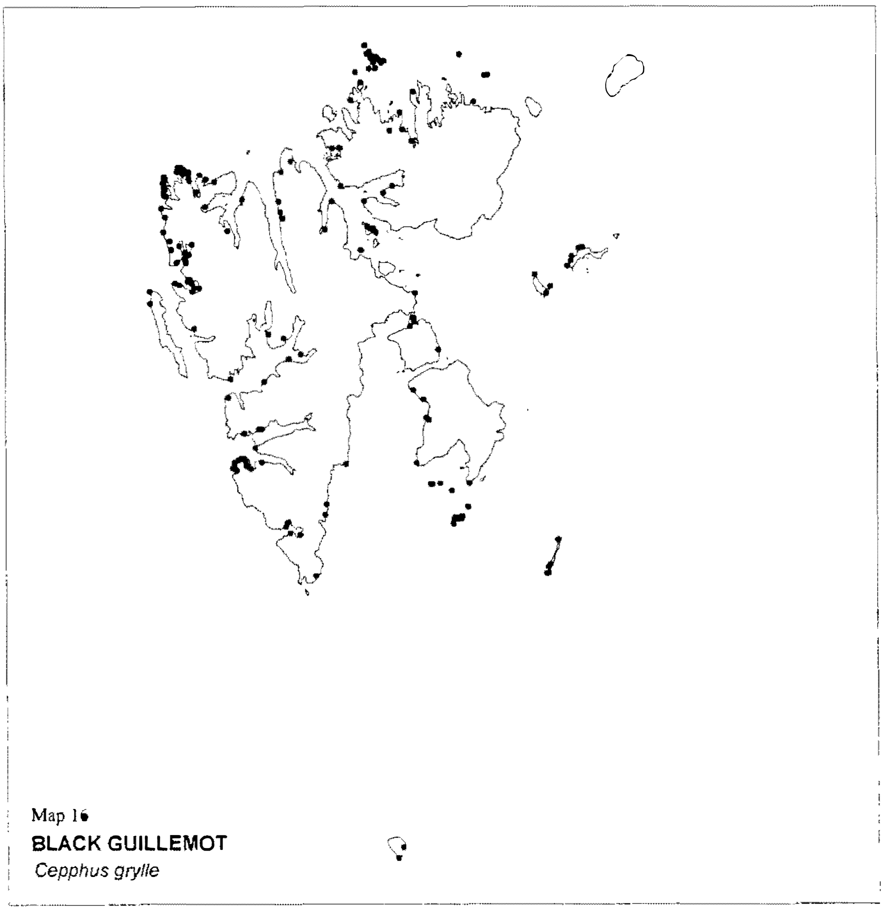
Map 13
COMMON GUILLEMOT
Uria aalge



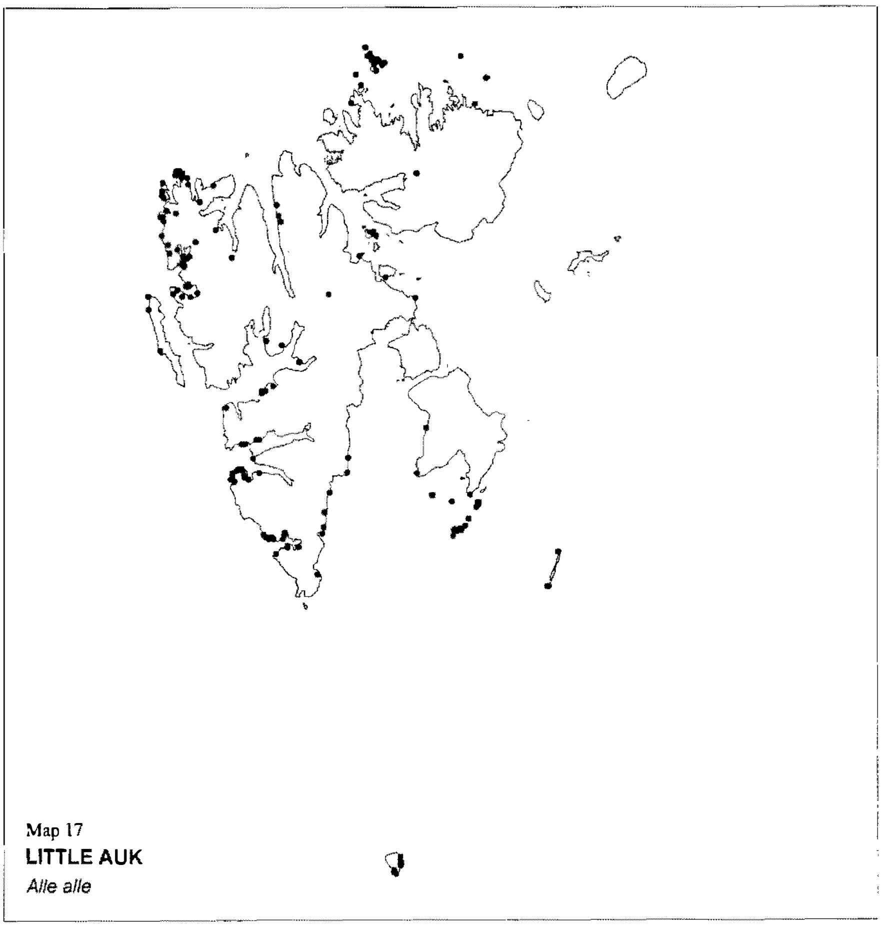
Map 14
BRÜNNICH'S GUILLEMOT
Uria lomvia



Map 15
RAZORBILL
Alca torda



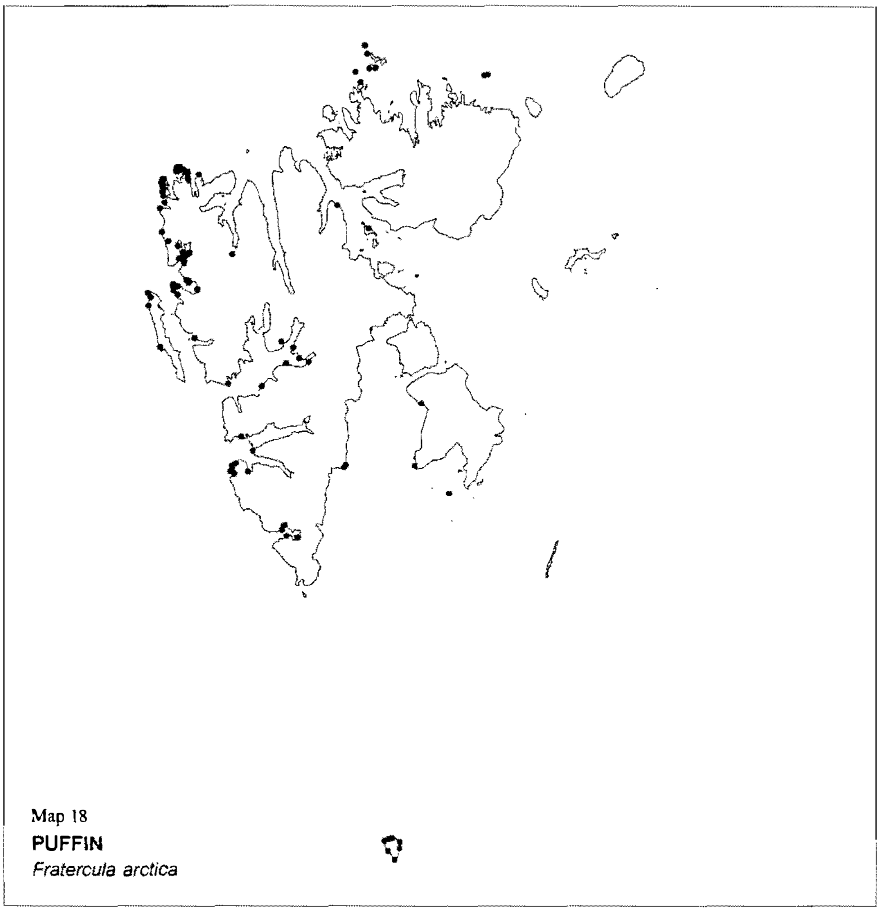
Map 16
BLACK GUILLEMOT
Cepphus grylle



Map 17

LITTLE AUK

Alle alle



Map 18

PUFFIN

Fratercula arctica

ESTIMATION OF THE BREEDING DENSITY OF LITTLE AUKS (*Alle alle*)

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Colour-marked and unmarked Little Auks (*Alle alle*) in a study plot in a breeding colony in Gulliksenfjellet, Hornsund. Photo by Kjell Isaksen.

Abstract – Little is known about the population size and breeding distribution of Little Auks (*Alle alle*) in Svalbard. One main reason for this is the lack of a suitable method for estimation of the number of breeding pairs in colonies, which are situated in screes or in rock crevices. The breeding density in five study plots in Bjørndalen close to Longyearbyen, on Isfjorden, and in two study plots in Gulliksenfjellet, Hornsund, were studied in 1993 and 1994 respectively. A large number of breeding birds in the study plots were captured, colour-marked and released. The ratio between marked and unmarked birds in subsequent counts was used to estimate the total number of breeding birds and the breeding density in the study plots (modified 'Petersen estimates'). The mean breeding density in the study plots in Bjørndalen was about 0.5 pair/m^2 and about 1.5 pairs/m^2 in the study plots in Hornsund. This difference in breeding density is probably largely due to the difference in size of the stones in the breeding scree between the two areas. The accuracy and representativeness of the results and their use in the estimation of population size of Little Auks is discussed.

INTRODUCTION

The Little Auk (*Alle alle*) is probably the most common breeding bird species on Svalbard (Mehlum 1990; Mehlum & Bakken 1994). It breeds in colonies on most of the archipelago, but the largest concentrations are on the southwestern and northwestern parts of Spitsbergen (Isaksen & Bakken 1995). Estimates of the population size of Little Auks in Svalbard are few and unreliable, ranging from 400,000–1,600,000 pairs (Norderhaug 1980) to 10–15 million individuals (Rüppell 1969). The most recent approximation is more than one million pairs (Mehlum & Bakken 1994). This lack of knowledge on population size is partly due to the inaccessibility of many colonies, but more important the problems involved in estimating Little Auk numbers in breeding colonies.

Most of the Little Auks in Svalbard probably breed in screes on mountain sides relatively close to the sea, but they also breed in rock crevices and in colonies far from the sea – for instance near Newtontoppen 1,500 m above sea level, 30 km from the coast (Løvenskiold 1964). The nests are hidden under stones in the scree or in crevices to avoid predation from Glaucous Gull (*Larus hyperboreus*) and Arctic Fox (*Alopex lagopus*). It is therefore not possible to count the actual number of nests or breeding birds in a colony as can be done for many other seabirds. The breeding Little Auks do, however, spend some time sitting visibly on top of the stones in the colony during the breeding season (in the following called colony attendance). Colony attendance is a highly variable behaviour found to be influenced by the stage in the breeding cycle, the time of day, weather conditions and the presence of predators (Stempniewicz 1981, 1986). Isolated counts of the number of birds in Little Auk colonies are thus of little or no value for estimation of population size, at least at the present state of knowledge.

The approach to the problem of estimating numbers of breeding pairs in Little Auk colonies reported here and in the next chapter (Isaksen 1995) is to combine estimates of breeding density from mark-resight studies with estimates of the inhabited area of the colony. Breeding density has been suggested to vary with the composition and structure of the talus

(Norderhaug 1980; Stempniewicz 1981), i.e. the size of the stones in the scree. It is thus necessary to obtain representative density estimates from colonies with different-sized talus.

The population of Little Auks in the northern part of the Barents Sea is considered to be of international conservation value and highly vulnerable to oil spills (Fjeld & Bakken 1993). In connection with the planned environmental impact analysis of oil drilling in this area it is important to improve the knowledge of size and distribution of the Little Auk population in Svalbard. This to improve future predictions about how many birds and what proportion of the total population might be affected by an eventual oil spill in any given area. Development of a relatively simple technique to estimate the numbers of pairs in breeding colonies is an important first step in this process (Fjeld & Bakken 1993). The work reported here has been done by the Norwegian Polar Institute and was financed by AKUP in 1993 and 1994. Preliminary reports from this work are found in Jerstad (1993) and Isaksen (1993).

MATERIAL AND METHODS

Study plots

The field work in 1992 (pilot study) and 1993 (22 June–24 July) was carried out in a relatively small colony in Bjørndalen (78°14'N 15°22'E), close to Longyearbyen, on Isfjorden. Here the Little Auks bred in five well-defined areas which were used as study plots (study plot A–E). Two distinct study plots (1 & 2) in a large colony in Gulliksenfjellet close to Hyttevika, Hornsund (77°03'N 15°11'E), were used in 1994 (9 July–3 August). The field work is mainly from the incubation period in 1993 and from early chick rearing period in 1994.

All plots were measured with a measuring tape and photographed for estimation of area. Dimensions of the stones which formed the scree in the study plots were measured by stretching out a measuring tape and alternately measuring the largest horizontal and vertical diameters (in the plane of the scree) of the stone under each whole metre mark.

Field procedures

The field work was started with intensive trapping of Little Auks using mist nets in the study plots. All birds were ringed, measured and age determined as born the previous summer (subadult) or older (adult). Ageing was based on the colouring of the upper parts of the wing feathers (Bédard 1985). All birds were checked for brood patches. The age of first breeding in Little Auks is not known (Cramp 1985; Hudson 1985). It is, however, supposed here to be at the age of two years (third calendar year), as none of the subadult (one year) birds we captured had brood patches and almost all the adult (two years or older) birds had.

All adult birds captured in the study plots were colour-marked by painting their breast feathers with picric acid (yellow). Subadult birds were marked with waterproof felt-tip pens in different colours (1993) or with Rhodamine B (red, 1994). To allow the dyes to dry after marking, the birds were kept at least 15 minutes in cardboard boxes before being released.

The number of colour-marked and unmarked birds sitting visibly in each study plot were then counted at fixed hours each day (6 a.m., 12 a.m., 6 p.m. and 12 p.m.). Poor visibility, extensive and prolonged disturbance in the colony by the Arctic Fox or the Glaucous Gull, or events in other areas, prevented some counts from being performed. Marked birds showed a tendency to be under-represented in counts the first couple of days after marking as compared with later counts. Only counts carried out more than two days after marking in a specific study plot are included in the analysis of breeding density.

Estimation of breeding density

The relationship between the number of marked and unmarked birds in a count can be used to calculate the total number of birds in a study plot. This is because the proportion of marked birds is expected to be the same in the total 'population' in the plot as in the counts.

$$\frac{m}{n} = \frac{M}{\hat{N}} \Rightarrow \hat{N} = \frac{Mn}{m},$$

where m = number of marked birds counted,

n = number of marked and unmarked birds counted,

M = total number of birds known to be marked in the study plot, and

$\hat{N}$ = total number of birds in the study plot.

This estimate, called a 'Petersen estimate' or 'Lincoln index', has, however, been found to over-estimate the size of populations, at least relatively small ones (Chapman 1951; Seber 1982). Chapman (1951) has proposed the modified estimate

$$N^* = \frac{(M+1)(n+1)}{(m+1)} - 1,$$

which has been found to be an unbiased estimator in most cases if the number of marked birds counted (m) is larger or equal to seven (Robson & Regier 1964). Colony attendance in the study plots was highly variable; in some counts no birds were seen at all. Counts with less than seven marked birds seen were excluded from the analysis of breeding density. This is because counts including few birds produce highly unreliable estimates (Robson & Regier 1964; Seber 1982). All counts from one field were combined in one estimate,

$$\overline{N}^* = \frac{1}{k}\sum_{i=1}^{k}\left[\frac{(M_i+1)(n_i+1)}{(m_i+1)} - 1\right]$$

(Chapman 1952; Seber 1982), where k is the number of counts and $i = 1, 2, ..., k$. The variance of an individual estimate (v_i^*) and of the combined estimate (v^*) is given by Seber (1982, p. 138):

$$v_i^* = \frac{(M_i+1)(n_i+1)(M_i-m_i)(n_i-m_i)}{(m_i+1)^2(m_i+2)}$$

$$v^* = \frac{\sum_{i=1}^{k} v_i^*}{k^2}.$$

Confidence intervals (95%) for $\overline{N}^*$ are obtained by $\overline{N}^* \pm 1.96\sqrt{v^*}$ (Seber 1982).

These methods have important underlying assumptions that must be fulfilled. The most important assumptions pertaining to this study are listed below (modified from Seber 1982 and Krebs 1989):

(a) Colour-marked birds are a representative subset of the population in the study plot. In particular the behaviour influencing colony attendance (proportion of time sitting and visible in the colony) must be the same for marked and unmarked birds.

(b) The population in the study plot is closed; there is no addition of new individuals to the population in the period from the first to the last count. Mortality and nest-desertion are equally distributed between the marked and the unmarked part of the population.

(c) There is no difference in sighting probability between marked and unmarked individuals during counts in the study plots. Dyes do not fade significantly with time and all birds seen are correctly identified as marked or unmarked.

RESULTS

Estimation of number of birds in study plots

The number of birds trapped and colour-marked in the study plots are shown in Table 1a and 1b. Only two resightings of colour-marked subadults were made in 1993 and none in 1994. Colour-marked subadults were therefore not included in the analysis. The mean estimates of the number of birds in the study plots are presented in Fig. 1. There were several high outliers for study plot 1 in 1994, and the median of the individual estimates ($N_m^* = 848$) probably is a more reliable estimate for this plot.

Proportion of non-breeders

The proportion of subadult birds trapped varied greatly from period to period, but was totally 0.06, 0.10 and 0.06 for 1992 (chick rearing period in pilot season), 1993 and 1994 respectively (Table 2). One day in both 1993 and 1994 had high proportions of subadults in captures (0.52 and 0.20), but here total number of birds captured was low (30 or less). Very few adults captured lacked brood patch (4% in 1994). The proportion of non-breeding birds thus seems to have been about 10–15 percent of the birds present in the colonies.

Table 1a. Cumulative numbers of adult (3y+) and subadult (2y) colour-marked Little Auks in the five study plots (A–E) in Bjørndalen 1993.

	A		B		C		D		E	
	Ad.	Subad.	Ad.	Subad.	Ad.	Subad.	Ad.	Subad.	Ad.	Subad.
23.06.93	16		32							
24.06.93	19		104							
26.06.93			132				14			
28.06.93					33	5				
29.06.93					54	10	36	4		
30.06.93							83	11		
12.07.93									56	5
21.07.93							96	25		

Table 1b. Cumulative numbers of adult (3y+) and subadult (2y) colour-marked Little Auks in the two study plots (1 & 2) in Gulliksenfjellet 1994.

	1		2	
	Ad.	Subad.	Ad.	Subad.
11.07.94	37	1		
12.07.94	80	6		
13.07.94			11	[illegible]
14.07.94			56	2
20.07.94	104	12		

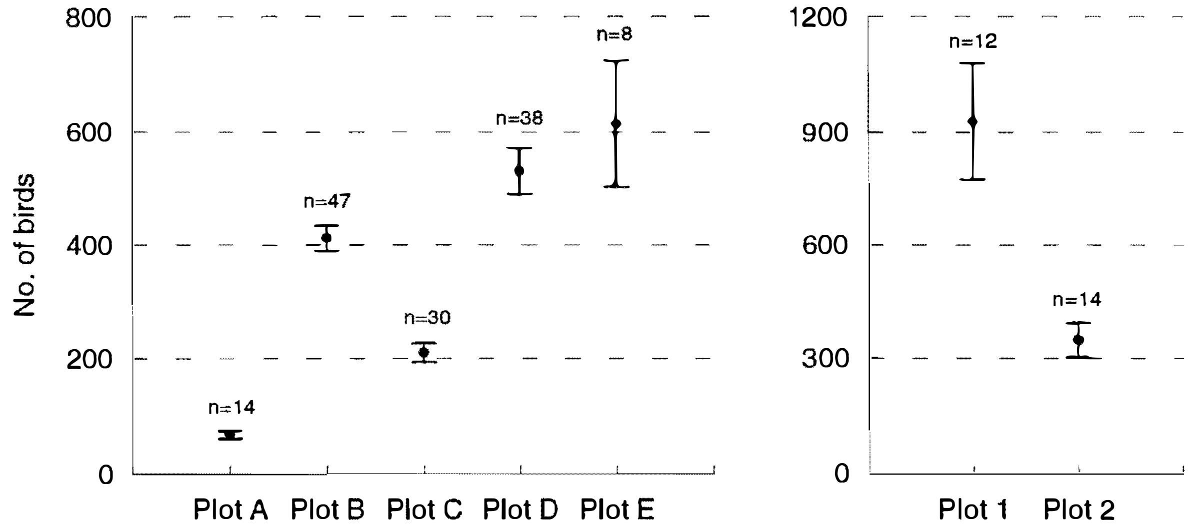

Fig. 1. Estimated number of birds ($\bar{N}^*$ with 95% confidence intervals) in the five study plots in Bjørndalen in 1993 (left) and the two plots in Gulliksenfjellet in 1994 (right). Sample size (number of counts used in calculation of the estimate) is shown for each field. Note the different scales in the two figures.

Table 2. Proportion subadults of birds captured in mist nets in Bjørndalen 1992 and 1993, and in Gulliksenfjellet 1994.

	Ad.	Subad.	Proportion subad.
25–29.07.92	*188*	*11*	*0.06*
22–30.07.93	288	21	0.07
12.07.93	56	5	0.08
21.07.93	13	14	0.52
Total 1993	*357*	*40*	*0.10*
11–14.07.94	136	8	0.06
20.07.94	24	6	0.20
02.08.94	91	2	0.02
Total 1994	*251*	*16*	*0.06*

Breeding density

Assuming the mean proportion of non-breeders in the counts to be 15%, the estimates of the number of breeding Little Auks in the study plots ($\overline{N}^*$) must be reduced by approximately 15%. The estimated areas of the plots from field measurements with the resulting breeding densities are presented in Table 3. The estimated areas from the study plots in Bjørndalen are considerably higher compared with the approximations reported earlier (Jerstad 1993), which were under-estimates.

Table 3. Estimated number of birds, breeding area and breeding density in the study plots.

	1993					1994	
	A	B	C	D	E	1	2
Estimated no. of ind. ($\overline{N}^*$)	67	411	210	530	613	848[a]	348
No. breeding pairs [($\overline{N}^*$÷15%)/2]	29	175	89	225	261	360	148
Area (m^2)	164	363	189	485	862	186	129
Breeding density (pairs/m^2)	0.2	0.5	0.5	0.5	0.3	1.9	1.2

[a] The median of the individual estimates is used instead of the mean for plot 1 (see text).

Diameter of stones

There was no significant difference in the diameter of the measured stones between the study plots nor in Bjørndalen ($\bar{x}$=25, 27, 25 and 23 for plot A, B, C and D respectively; P=0.3, Kruskal-Wallis 1-way ANOVA) nor in Gulliksenfjellet ($\bar{x}$=43 and 32 for plot 1 and 2 respectively; P=0.12, Mann-Whitney U test). Plot 1 in Gulliksenfjellet had, however, more large stones than plot 2 (Fig. 2). When combining the plots, the plots in Gulliksenfjellet had larger stones than the plots in Bjørndalen (P<0.0001, Mann-Whitney U test).

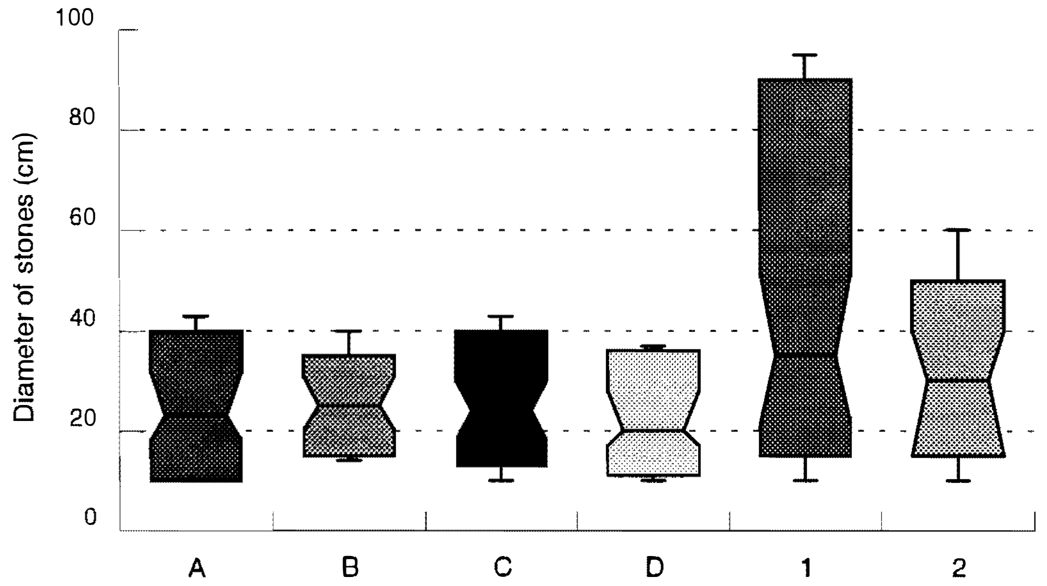

Fig. 2. Diameter of stones from the study plots (A–D in 1993 and 1 and 2 in 1994; n≥40 for all plots). Box-Whisker plot showing the median and the range of 90% (5th–95th percentile), 80% (10th–90th percentile) and 50% (25th–75th percentile) of the data.

DISCUSSION

Estimation of number of birds in study plots

Mark-resight methods have important underlying assumptions that must be filled (cf. points a–c in *Material and methods*). The birds which are colour-marked must be a representative subset of the population in the study plot, this must especially apply for colony attendance. Marked birds were under-represented in counts up to two days after marking as compared to later counts. In this period marked birds therefore seem to have behaved differently, probably as a reaction to being caught and marked. After this initial period (which was excluded from the analysis), marked and unmarked birds probably behaved similarly.

Mortality and nest-desertion are assumed to be the same for marked and unmarked birds. It is, however, possible that marked birds for instance experienced higher predation rates than unmarked birds. This would lead to an over-estimate of the number of birds in the study plots.

All study plots were relatively small and easy to survey. Presumably very few birds were overlooked, and there was likely no difference in this respect between marked and unmarked individuals. The colouring of the marked birds was very durable when correctly applied, and marked birds were easy to distinguish from unmarked birds. Sighting probability is therefore assumed to be similar for marked and unmarked birds.

Proportion of non-breeders

The proportion of non-breeders in the counts is potentially a main source of error in the estimates of breeding density in the study plots. The suggested mean proportion of 15% non-breeders in the counts may be somewhat inaccurate, possibly being too low. Several factors may contribute to this. Catching birds with mist-nets in the breeding colonies inevitably leads to some disturbance of the birds in the study plots. Non-breeders are probably less attached to a specific subcolony (and to the breeding area as a whole) than are breeding birds, and might avoid areas with disturbances and thus avoid being caught. Little Auk colonies are, however, more or less constantly disturbed by other factors. Glaucous Gulls patrolling back and forth over the colonies pose a permanent threat to the Little Auks (it seemed as though this disturbance was larger in the huge colonies in Gulliksenfjellet than in the rather small colonies in Bjørndalen). Although nervous and always on guard, the Little Auk is a rather trusting and curious bird, and very bound to what the rest of the flock is doing. This might influence the behaviour of non-breeders which join flocks of breeding birds.

Some effort was made to determine the proportion of subadults in counts from close range in the study plots in the hatching period in 1993. The results from these counts support the general results from trapping; of the birds successfully aged, 5–10% were subadults.

The age of first breeding in Little Auks is not known (Cramp 1985; Hudson 1985). Neither is it known whether birds with relatively small brood patches in the breeding season are breeders or not. The development of the brood patch is probably associated with large energetic costs for arctic seabirds, and it is reasonable to assume that this trait is not developed if not needed. In this study all birds with brood patches have been treated as breeders. Roby et al. (1981) claimed, however, that birds with small or medium sized brood patches were non-breeders. If this is correct, the estimated breeding density probably must be further reduced.

Subadults and other non-breeders probably have a highly variable occurrence in the breeding colonies. Differences in the proportion of non-breeders between counts may account for much of the variation in the estimates of numbers of birds in the plots (cf. Fig. 1). In spite of this high variability, the mean of the estimates with 15% reduction presumably gives a reasonably good picture of the number of breeding birds in the study plots.

Breeding density

The breeding density in the five study plots in Bjørndalen was very low (from 0.2 to 0.5 pairs per m^2). This is probably a consequence of the small and relatively flat stones in this scree, which leaves few burrows large and deep enough for Little Auks to breed in. No Little Auks bred in the scree around the study plots where stones were somewhat smaller. This indicates that the size of the stones and the structure of the scree in the study plots in Bjørndalen represent about the lower limit of what is suitable as breeding habitat for Little Auks.

The stones were larger and more heterogeneous in size in the study plots in Gulliksenfjellet than in Bjørndalen. Breeding density was also much higher (1.9 and 1.2 pairs per m^2). The reason behind the relatively large difference in density between the two plots is not clear. Plot 1 had, however, more very large stones than plot 2, and this may have resulted in more suitable nesting sites and a higher density of nests. Plot 1 was counted with a 20–60x telescope, whereas plot 2 was counted with 10x40 binoculars. The angle of observation was also somewhat different between the plots. These minor methodological differences are not judged to have influenced the results.

No previous studies have addressed breeding density of Little Auks specifically. Norderhaug (1980) reported that 'more than one nest per square metre has been observed in some colonies' (probably from Hornsund). Evans (1981) found a mean density of 0.25 nest/m^2 in his study from Greenland, and Stempniewicz (1981) found a density of 1 pair per 1.5–2.0 m^2 in Ariekammen (0.5–0.7 pairs/m^2). The authors do not specify how these densities have been estimated, but they are probably all obtained by searching for nests within a small area in the scree. This is probably an inaccurate method which results in, as Evans (1981) puts it, 'a minimum estimate, since some nests were almost certainly missed'.

Due to predation of eggs, young and breeding adults, the actual breeding density decreases during the season. The estimated breeding densities from Bjørndalen in 1993 are from the incubation period, whereas the densities from Gulliksenfjellet in 1994 are from early chick rearing period. The amount of the loss due to predation and other causes during the season is not known. Nor is it known whether or not unsuccessful breeders leave the colony. It is therefore not possible to 'standardise' the breeding densities by controlling for the effect of the time of season.

CONCLUSION

The aim of the work reported here has been to find representative breeding densities of Little Auks for use in a broad management-oriented survey in some of the main breeding areas of this species in Svalbard. The densities will be combined with inhabited area of colonies to produce rough estimates of numbers of pairs in the colonies.

Breeding densities seem to vary with the mean size of the stones in the talus, but the distribution of sizes is probably also important. In Bjørndalen, where stones were rather small, the density was low, and 0.5 pairs per m^2 is probably a representative mean density for the talus of this structure. In Gulliksenfjellet stones were larger and densities higher than in Bjørndalen. At least some of the difference in density between the two plots here may probably be explained by the difference in talus structure. A mean density of 1.5 pairs per m^2 is suggested for talus in this size range, which seemed to predominate in the large colonies in Gulliksenfjellet and most other places in Hornsund.

Several aspects of Little Auk demography and colony attendance are not known, and other factors than size of stones are probably also important for breeding density in colonies. Density estimates from more study plots and from other parts of Svalbard are needed to clarify the generality of the densities found here. It must be emphasised that there are uncertainties in the application of these densities to obtain estimates of the numbers of breeding pairs in colonies. The estimates will, nevertheless, most likely be large improvements as compared to previous knowledge.

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THE BREEDING POPULATION OF LITTLE AUK (*Alle alle*) IN COLONIES IN HORNSUND AND NORTHWESTERN SPITSBERGEN

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Breeding colony of Little Auks (*Alle alle*) in Gulliksenfjellet, Hornsund. One of the study plots is seen in the foreground. Photo by Kjell Isaksen.

Abstract – Hornsund and northwestern Spitsbergen are known to be main breeding areas for Little Auks (*Alle alle*) in Svalbard. The size of the population in these areas or the relative distribution of the breeding population in Svalbard is, however, not known. The inhabited area of scree in colonies in Hornsund and northwestern Spitsbergen was mapped in the breeding season in 1994. Prevailing unfavourable weather conditions influenced both on colony attendance and the field workers' ability to map the colonies, and only parts of the areas were mapped. The number of square metres found to be inhabited by Little Auks in each colony is multiplied with a suggested representative breeding density which varies with the size of the stones in the breeding scree. Although the resulting estimates of the numbers of breeding pairs in colonies are uncertain, they are probably large improvements compared to the present state of knowledge.

INTRODUCTION

Although the Little Auk (*Alle alle*) is probably the most common breeding bird species in Svalbard (Mehlum 1990; Mehlum & Bakken 1994), little work has been done to census breeding colonies or to estimate the total population. The knowledge of the size of the population and how it is distributed between different regions in Svalbard is consequently very poor. The Little Auk is considered to be very vulnerable to oil spills, and investigations to improve the knowledge on abundance and distribution of this species in Svalbard were identified as fields of priority by Fjeld & Bakken (1993). Such knowledge will be valuable in the planned impact assessment of test drilling for oil and gas in the northern Barents Sea. In this assessment it is important to have information about the distribution of the species of concern to be able to assess what proportions of the populations might be affected by an oil spill in any given area.

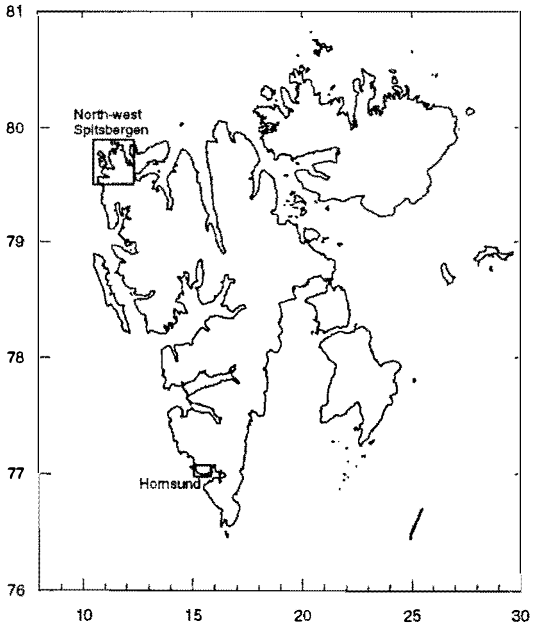

Fig. 1. Map of Svalbard (without Bjørnøya) showing the two areas were censuses of Little Auk colonies took place in 1994.

Hornsund and northwestern Spitsbergen (Fig. 1) are known to be main breeding areas of Little Auks in Svalbard. Werenskiold (1923) made a rough guess of 10 million birds in the Hornsund area. Løvenskiold (1964) regarded this as an overestimate and stated that to be on the safe side one should not put the number of Little Auks in this area at more than one to two million. More recently Stempniewicz & Weslawski (1992) suggested the population in the same area to be 200,000 individuals. This is, however, a very rough estimate and should only be treated as an order of magnitude (L. Stempniewicz pers. com.).

Norderhaug et al. (1977) placed two colonies (or more correctly two areas) in northwestern Spitsbergen in the size category of more than

100,000 breeding pairs of Little Auk (Magdalenefjorden and Dei Sju Isfjella). Gulliksenfjellet, Torbjørnsenfjellet and Rotjesfjellet on the northern side of Hornsund were all placed in the category of 10,000–100,000 breeding pairs, and Ariekammen and Skoddefjellet were placed in the category of 1,000–10,000 breeding pairs (Norderhaug et al. 1977).

The numbers given by Norderhaug et al. (1977) and Stempniewicz & Weslawski (1992) are very vague and not based on representative counts or other methods of estimation of population size. This report deals with results from registrations of Little Auk colonies in Hornsund and in northwestern Spitsbergen from the breeding season (July–August) in 1994. The work in northwestern Spitsbergen was carried out by field parties organised by the Governor of Svalbard, and the work in Hornsund was done by the Norwegian Polar Institute and financed by AKUP. The basis for the method used, and an introduction to the biology and behaviour of the Little Auks, are presented in Isaksen & Bakken (1995).

MATERIAL AND METHODS

All colonies censused were situated in screes on mountain sides. In some areas these colonies stretch more or less continuously for kilometres along the mountain. In these cases the mountain side was split into areas manageable to work with (in the following called subcolonies). Each subcolony was first photographed from a suitable distance (50–300 m, depending on area) with a Polaroid camera. Then some time was spent observing the birds sitting in the colony to decide which areas of the scree were inhabited (contained Little Auk nests). The time needed for this depended on the size of and activity in the colony (see below). The work could only be done in periods of relatively high colony attendance, otherwise the risk of overlooking or underestimating inhabited areas was too large. The colour of the stones in the scree could often be used as a good indicator of inhabited areas; the stones in these areas were paler and less covered with lichens than stones in areas without nests. Inhabited areas were marked on the Polaroid pictures with a fine-pointed waterproof felt-tip pen.

Three white bed sheets were laid out in the scree in an L-form with 20 m between sheets before the photograph was taken. These served as horizontal and vertical scales for later estimation of the inhabited area. In some cases distances between conspicuous objects in the scree were measured and indicated on the photo instead of, or in addition to, the sheets. It is important to obtain both horizontal and vertical measures on the photo, and for larger colonies also measures from different heights in the scree. The outline of the inhabited areas was later transferred to millimetre paper for estimation of area. In this process both information about the inclination of the scree and the difference in height between the photographer and the upper and lower part of the colony were used in addition to the focal length of the Polaroid camera.

Breeding density in Little Auk colonies probably varies with the size of the stones (and the distribution of sizes) in the nesting scree. The density was found to be about 0.5 pairs/m^2 in colonies in Bjørndalen with relatively small stones, and about 1.5 pairs/m^2 in colonies in

Gulliksenfjellet with relatively large stones in the breeding scree (Isaksen & Bakken 1995). The estimated inhabited area of each subcolony are here combined with a suggested representative breeding density for each colony to produce rough estimates of the number of breeding pairs.

RESULTS

Hornsund

The colony attendance of the Little Auks varied highly during the day in Hornsund, with the highest attendance in the evening and at night. In periods of low attendance the colony seemed to be more or less deserted, with only very few scattered birds flying in to or out from the colony. A few hours later the same area could literally boil with birds flying around or sitting in the breeding area. Colony attendance was also influenced by weather conditions. In periods with heavy fog or rain, attendance was generally low. This phenomenon has also been noted by others (e.g. Stempniewicz 1986).

The weather in the period of field work in Hornsund was very bad with prevailing fog and rain. In addition to lowering colony attendance, fog and rain made both observations and especially photographing of the colonies difficult. As a result of the general daily variation in colony attendance and the effects of the unfavourable weather conditions, the time suitable for censusing Little Auk colonies was limited. Only Gulliksenfjellet and Skoddefjellet were covered in the Hornsund area.

Gulliksenfjellet: On the eastern side of the mountain, by the southern edge of Myrktjernet, there was one medium sized colony. Further north we saw two very small colonies on the western side of Myrktjernet. There was no sign of activity of Little Auks in other parts of Bratteggdalen. In 1952 Løvenskiold (1954) found Little Auks to be 'numerous on both sides of the valley'. The weather was rainy and foggy when we were in Bratteggdalen, and there is a small possibility that we may have missed some colonies here. From the northern end and around to the southern end of Gulliksenfjellet there are almost four kilometres of more or less continuous screes with Little Auk colonies. These colonies are very large, especially those from Hyttevika and further south. In Hyttevika there is also a rather flat hill at the foot of the mountain where Little Auks breed in large numbers. The size of the stones in the breeding scree seemed to be comparable between the subcolonies and also with that of the study plots in the same area (see Isaksen & Bakken 1995). An exception is the hill in Hyttevika, where most subcolonies seemed to have smaller stones and lower breeding density than the study plots. In the estimates in Table 1 the mean density of 1.5 pairs/m^2 found in the study plots is used in all subcolonies in Gulliksenfjellet and in one subcolony in the northern part of the hill in Hyttevika. In the rest of the area in Hyttevika a density of 1 pair/m^2 is used. Using these numbers the total breeding population in the colonies in Gulliksenfjellet (including the hill in Hyttevika) is estimated at 176,000 pairs (Table 1).

Skoddefjellet: The colonies here are on the western and southwestern sides of the mountain. Most of the upper parts of the mountain were covered by fog when the census was made. Inhabited areas in these upper parts may therefore have been left undetected. The scree in the colonies seemed to be less homogeneous between the subcolonies here than in Gulliksenfjellet, and the stones also somewhat smaller. The breeding density is therefore probably lower than in Gulliksenfjellet. As a rough approximation, a breeding density of 1.0 pair/m^2 is used for the colonies in Skoddefjellet. The estimated number of breeding pairs in Skoddefjellet is then 57,000 pairs (Table 1).

Table 1. Estimated inhabited area and estimated number of breeding pairs of Little Auk in Gulliksenfjellet and Skoddefjellet, Hornsund. 'Gulliksenfjellet, Hyttevika' refers to a hill at the foot of Gulliksenfjellet close to Hyttevika.

	Inhabited area (m^2)	No. of pairs
Gulliksenfjellet E	1,300	2,000
Gulliksenfjellet N, W & S	104,900	157,000
Gulliksenfjellet, Hyttevika	15,000	17,000
Skoddefjellet W & SW	57,100	57,000

Rotjesfjellet, Torbjørnsenfjellet and Trulsenfjellet: No censuses were made in this area, but it is clear that a very large number of Little Auks bred here. Especially the southern and southeastern part of Rotjesfjellet and southeastern part of Torbjørnsenfjellet contained large colonies. The colonies in Trulsenfjellet probably contained relatively few pairs as compared to other colonies in the area. Only 1–2 relatively small colonies were found on the western side of Revdalen (Skoddefjellet is on the eastern side). Løvenskiold (1954) states that 'all the hills around this valley were populated with enormous numbers of little auks'.

Ariekammen and Fugleberget: The fog was extremely thick when we were in this area, and our observations only indicate that there must be a large number of birds in Ariekammen and probably very few on the southern part of Fugleberget. Stempniewicz (in press) estimated the population in Ariekammen to be 15,000 breeding pairs. The southwestern part of Fugleberget contains about 100 pairs according to Stempniewicz (1992).

Northwestern Spitsbergen

The weather conditions were unfavourable in some of the period. The field parties were also engaged in other activities and available time for Little Auk censuses was limited. The following summary of the registrations includes only colonies in screes.

Biskayerhuken–Raudfjorden–Fuglepynten: The only colony in scree was found at Biskayerhuken.

Nordvestøyane and Fugløya: Small colonies were found on Fugløya, Klovningen, Ytre Norskøya and Indre Norskøya. Fuglesangen was not censused, but colonies were observed there.

Smeerenburgfjorden E: Colonies were found in the western parts of Röhssberget, in the western parts of Blessingberget and in the western part of Sverdrupfjellet.

Amsterdamøya & Danskøya: No colonies were found on Amsterdamøya. Only a relatively small colony was found on Danskøya in the southwestern part of Wellmankollen (on the northern side of Kobbefjorden).

Magdalenefjorden: Large colonies were localised in Ytstekollen, Skarpegga, Høystakken and Alkekongen on the northern side of the fjord. Alkekongen especially contains a large number of pairs. Only parts of Høystakken and a small part of Alkekongen were censused. This includes only a small part of the Little Auk population in the area. Little Auks breed in large numbers in other parts of the area, also at some distance from the fjord.

Hamburgbukta: Colonies were localised in Hoelfjellet and Aasefjellet. Only a part of Aasefjellet was censused.

The estimated inhabited area of the censused colonies in northwestern Spitsbergen is presented in Table 2. Relatively little information is available on the size of the stones in the colonies, but the size seemed to be similar to that in the colonies in Gulliksenfjellet or somewhat smaller for most colonies. A mean breeding density of 1 pair/m^2 is therefore used as a rough approximation for the colonies in northwestern Spitsbergen. The estimated number of breeding pairs in the colonies will with this be the same as the estimated inhabited area. This gives a population of 83,000 breeding pairs in the censused colonies. Little Auks breeding in rock crevices occur in large numbers over most of the area. These birds are not included here.

DISCUSSION

The size of the stones in the scree is probably an important determinant for the breeding density in a colony (Isaksen & Bakken 1995). The dimensions of the stones in the breeding areas in Hornsund were generally comparable to those in the study plots in Gulliksenfjellet. Exceptions from this were parts of Skoddefjellet, where the size of the stones seemed to be intermediate between those in Gulliksenfjellet and those from the other study plots in Bjørndalen.

It is unlikely that Little Auks sit for longer periods in areas not containing nests. Exceptions are when one part of the colony is disturbed by predators for a longer period of time, and birds gathering on preferred resting sites outside breeding areas. A large number of birds were seen on several occasions in the northern part of the hill in Hyttevika. The stone structure and the colour and vegetation on stones in the area indicate that only a few pairs bred here. A majority

Table 2. Estimated inhabited area (= estimated number of breeding pairs) of Little Auk in the colonies censused in the northwestern part of Spitsbergen.

	Inhabited area (m^2)
Biskayerhuken	700[a]
Nordvestøyane; Ytre Norskøya	270[a]
Indre Norskøya	1,100[a]
Klovningen	250[a]
Fugløya	100[a]
Smeerenburgfjorden E; Röhssberget	11,200
Blessingberget	2,200
Sverdrupfjellet	5,900
Danskøya; Wellmankollen	1,200
Magdalenefjorden; Høystakken	50,000[a,b]
Alkekongen	4,100[b]
Hamburgbukta; Aasefjellet	5,900[a,b]

[a] Whole or parts of the inhabited area approximated without measurements.

[b] Colonies not censused but known to be present on other parts of the mountain.

of the birds seen here probably were non-breeders or breeders from other areas using the large stones in the area as resting places.

Most estimates of inhabited areas are relatively rough approximations, especially those from colonies in northwestern Spitsbergen approximated without measurements (see Table 2). This is also true for the relatively flat hill in Hyttevika, where the inhabited area was difficult to estimate.

The estimated total number of breeding pairs in the censused colonies in Hornsund (Gulliksenfjellet and Skoddefjellet) is about 230,000 pairs. Ariekammen is estimated by Stempniewicz (in press) to contain 15,000 breeding pairs. The other main colonies of Little Auks on the northern side of Hornsund are situated on Rotjesfjellet and Torbjørnsenfjellet. These colonies have not been censused. Our short visits in these areas give a very poor basis for estimation of the population in the area. The colonies on both of these mountains seemed, however, to be smaller than the colonies on Gulliksenfjellet. Making a rough *guess* of somewhat less than 100,000 pairs on each of these mountains, the total breeding population of Little Auk on the northern side of Hornsund numbers very roughly about 400,000 pairs.

In northwestern Spitsbergen the censused colonies are estimated to contain about 80,000 breeding pairs. Very large colonies, especially in Magdalenefjorden and Hamburgbukta, remain to be censused. In addition Little Auks breeding in rock crevices are not included in the numbers presented here. These birds probably constitute an insignificant part of the breeding population in Hornsund compared to the huge numbers breeding in the screes. This is not true for northwestern Spitsbergen, where birds breeding in rock crevices and between stones outside screes occur scattered over large areas. These factors make even a rough guess of the population in northwestern Spitsbergen unwarranted.

The uncertainties in the estimates presented here must be stressed. The uncertainties of the representative breeding densities used are discussed by Isaksen & Bakken (1995). In addition, breeding areas used here are far from exact. Being a product of two uncertain estimates, the resulting estimate of the numbers of breeding pairs is consequently connected with large uncertainties.

The numbers presented here only relate to the breeding part of the Little Auk population. In addition comes non-breeding adults and subadults. Little is known about what proportion these birds constitute of the total population. Isaksen & Bakken (1995) found the proportion of subadults attending study plots in a breeding colony in Gulliksenfjellet to be about ten percent. The corresponding proportion of non-breeding adults (birds without brood patches) was probably about five percent. However, being less attached to the breeding colony, non-breeding birds probably attend colonies at a much lower rate than the breeding birds and spend more time at sea. Much basic knowledge on Little Auk demography is lacking (e.g. age at first breeding and adult survival), and further speculations on the non-breeding proportion of Little Auk populations is largely premature.

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IMPORTANT MOULTING AREAS FOR SEABIRDS IN SVALBARD

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Moulting Barnacle Geese (*Branta leucopsis*) north of Hornsund. Photo by Kjell Isaksen.

Abstract – Geese, ducks and auks undergo synchronous moulting of the flight feathers in summer or autumn. During this 3–7 week period the flightless birds often gather in flocks and are very vulnerable to disturbances and oil spills. Pink-footed Geese (*Anser brachyrhynchus*), Barnacle Geese (*Branta leucopsis*) and Brent Goose (*B. bernicla*) moult while rearing their chicks in coastal areas with rich vegetation. The male eiders (*Somateria mollissima* and *S. spectabilis*) and Long-tailed Ducks (*Clangula hyemalis*) leave the females in the incubation period and gather in moulting flocks in shallow areas along the coast. Common Guillemot (*Uria aalge*) and Brünnich's Guillemot (*U. lomvia*) young leave the breeding colony before they are able to fly. They are followed by the male parents in the swimming migration from the colony out to the rearing areas at sea. Maps showing the distribution of moulting eiders and guillemots with young observed during helicopter and ship surveys in the Svalbard area are presented.

INTRODUCTION

All birds moult; the old, worn feathers are shed and replaced by new ones. The frequency of moulting varies among species and feather-types. Geese, eiders and auks undergo synchronous moulting during summer or autumn, in which all flight feathers (primaries) are shed simultaneously. The birds are then flightless until the new feathers are more or less fully-grown, a process which may take up to four weeks for the geese and 50 days for the auks (Cramp & Simmons 1977; Cramp 1985).

In this report we give a brief account of the moulting biology and the main moulting areas of the species of geese, ducks and auks thought to be most vulnerable during this period (see Fjeld & Bakken 1993). The swimming migration of the Brünnich's Guillemot (*Uria lomvia*) and Common Guillemot (*U. aalge*) is also dealt with as they start moulting in this period. Even though the adult guillemots following their flightless chicks from the breeding colony are still able to fly, they are probably very reluctant to leave their chicks and are therefore effectively flightless.

The breeding distribution of the species treated here is described by Isaksen & Bakken (1995).

SPECIES ACCOUNTS

PINK-FOOTED GOOSE *Anser brachyrhynchus*, BARNACLE GOOSE *Branta leucopsis* and BRENT GOOSE *Branta bernicla*

All three species of geese breeding in Svalbard moult in coastal areas in July–August, and they are then unable to fly for 3–4 weeks (Cramp & Simmons 1977). After hatching, the young are taken by the parents to areas with rich vegetation where they feed on grass and moss. The parents start moulting in this period and are very shy. They keep close to the sea, freshwater ponds or lakes, and at any sign of danger (e.g. Arctic Fox *Alopex lagopus*, humans or the noise from helicopters) they rush to the water. The Pink-footed Goose is larger than the two *Branta*-species and is able to defend itself and its young more successfully against the

Arctic Fox (Løvenskiold 1964; Frafjord 1993). It is therefore less restricted to areas close to water (or islands inaccessible to foxes) than the two other species and may remain on mountain slopes throughout the summer.

The geese generally moult in areas relatively close to their nesting sites (see Isaksen & Bakken 1995). A large proportion of the Barnacle Geese in Svalbard breed on small islands along the western coast of Spitsbergen. Here they may moult on the islands or move to coastal plains with luxuriant vegetation. Most Brent Geese in Svalbard breed on Tusenøyane and they also moult on these small islands. The Pink-footed Goose has a more dispersed breeding pattern in Svalbard than the two other species and is most numerous in the western parts of Spitsbergen.

How much time the geese spend at sea varies from area to area, depending on the availability of freshwater lakes and ponds in the vicinity of the feeding areas, and also on how much they are disturbed. The geese may, however, spend much time at sea, resting and swimming between feeding areas.

COMMON EIDER *Somateria mollissima*

Tusenøyane and the western and northern coasts of Spitsbergen are the main breeding areas for Common Eiders in Svalbard. The male eiders leave the females during the incubation period and gather in flocks in shallow coastal areas (most often within 200 metres from the coast), where moulting takes place. Later in the season flocks of females with young also gather in these areas. Helicopter surveys of moulting eiders have been conducted by the Norwegian Polar Institute (NP) in the late 1970s to the early 1990s (see Jepsen 1984; Karlsen & Mehlum 1986; Bakken & Mehlum 1988 and Knutsen et al. 1988 for some of the surveys). The results from the most recent surveys in each area are shown in Fig. 1, somewhat modified to fit into the matrix system. The areas without matrix-symbols have not been surveyed. With the exception of the northwestern parts of Spitsbergen, these areas are probably less important as moulting areas for Common Eiders.

KING EIDER *Somateria spectabilis*

The main breeding areas for King Eiders in Svalbard are the coastal plains between Bellsund and Prins Karls Forland and on Reinsdyrflya. Male King Eiders leave the nesting sites before the eggs hatch and gather in areas along the coast where they moult. The main moulting areas are shown in Fig. 2. The moulting congregation starts in July, but flocks may also be found at sea off the main breeding areas in June. Prestrud (1991) suggested that post-breeding King Eiders congregating between Bellsund and Kongsfjorden in June/July move southward to the area between Sørkapp and Hornsund in August and September before the autumn migration begins. The moulting areas of the King Eiders breeding on Reinsdyrflya and other northern areas are not known, but the eiders may move to the southern areas after breeding. Knutsen et al. (1988) observed a large number of King and Common Eiders migrating south along the western coast of Storfjorden (in Kvalvågen) in late July.

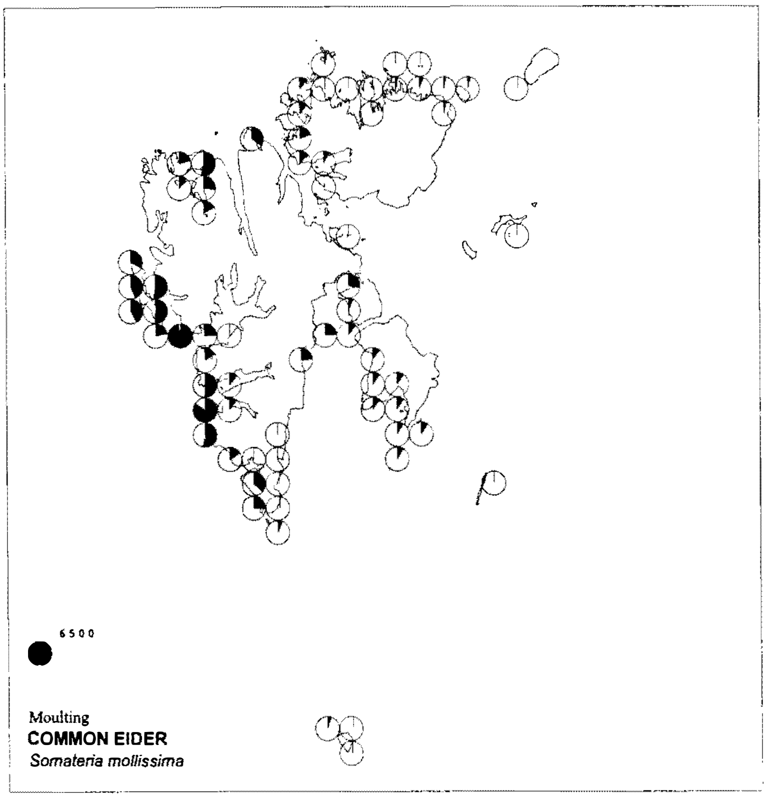

Fig. 1. Moulting areas of Common Eiders (*Somateria mollissima*) in Svalbard. The data are from helicopter surveys in the period 1979–1992. A filled circle represents 6,500 individuals.

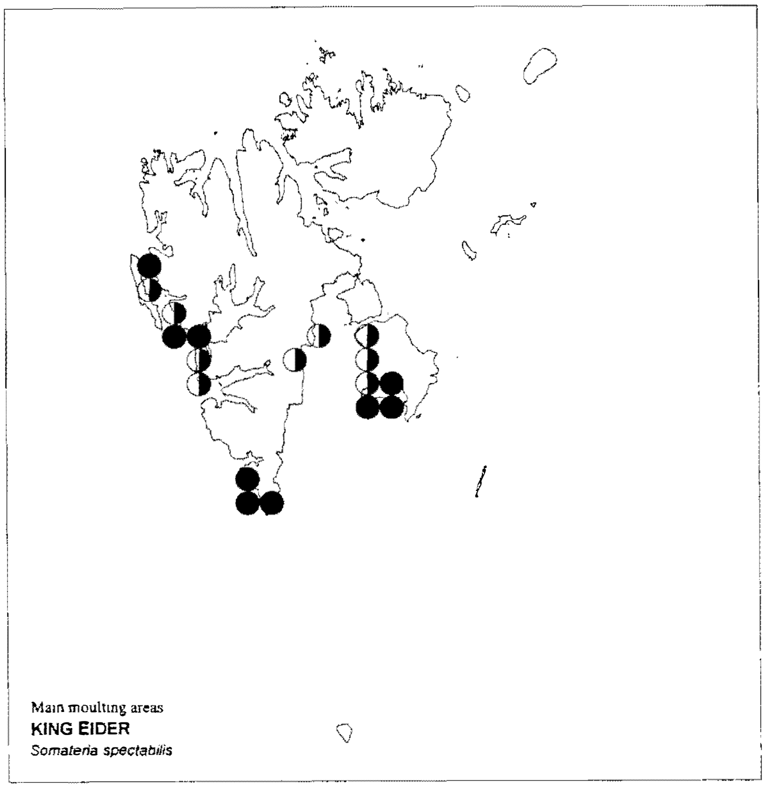

Fig. 2. Main moulting areas of King Eiders (*Somateria spectabilis*) in Svalbard. The matrix symbols indicate probable relative importance of the areas, not actual densities. Data from Løvenskiold 1954, 1964; Knutsen et al. 1988; Prestrud 1991; unpublished results from helicopter surveys conducted by NP and registrations in the fauna database at NP.

LONG-TAILED DUCK *Clangula hyemalis*

As for the eiders, the male Long-tailed Duck leaves the female soon after the start of incubation. Most males move to coastal areas and start moulting either singly or in small flocks. After hatching the female and the young stay at freshwater lakes or ponds for a period before moving out to sea. The female probably does not start moulting before reaching the sea. The Long-tailed Duck only breeds in relatively small numbers in Svalbard, most commonly in the western areas. Moulting Long-tailed Ducks have been recorded along the western and northern coasts of Spitsbergen, often in the same areas as eiders, but little is known about the relative importance of the areas. Løvenskiold (1954, 1964) saw flocks of up to 200 birds in the areas between Kapp Borthen (south of Bellsund) and Sørkapp from mid July to mid August. He also observed a large number of moulting birds in the freshwater lakes on Dunøyane (Hornsund).

COMMON GUILLEMOT *Uria aalge* and BRÜNNICH'S GUILLEMOT *Uria lomvia*

The breeding adults of these species start moulting after the chicks have left the breeding ledges for the sea. The chicks are then about three weeks old, weighing approximately 25% of the adults and are still unable to fly. One of the parents, most often the male, swims together with the chick from the colony towards the rearing and wintering areas. The chick is cared for and fed by the parent for several weeks after departure from the colony; it is able to fly when about 50–70 days old. The parents are unable to fly for about 45–50 days during the moulting period (Cramp 1985; Harris & Birkhead 1985).

The timing of the departure of the chicks from colonies in Svalbard varies among colonies and from year to year but is normally from late July to mid August in the more southern areas. In 1987 the breeding season was about 14 days later at Hopen than at Bjørnøya (Bakken & Mehlum 1988). The departure is synchronised within colonies, and most chicks leave within a relatively few days.

Bakken & Mehlum (1988) studied the departure of chicks and the swimming migration from the colonies at Bjørnøya (both Brünnich's and Common Guillemots), Hopen and on the western coast of Storfjorden (Brünnich's Guillemots only) in 1987. The behaviour of the two species at Bjørnøya seemed to be similar. There was a marked daily rhythm in the departure of chicks from the colonies; most chicks left during the darkest period of the day (see also Williams 1975 and Daan & Tinbergen 1979). The chicks are exposed to heavy predation from Glaucous Gulls (*Larus hyperboreus*) and Arctic Foxes, especially in colonies where the chicks must walk some distance to reach the sea.

Counts of parent guillemots with chicks were made during ship line transects outside the breeding colonies in the period of departure of the chicks (Bakken & Mehlum 1988). The direction of the swimming migration from the colonies at Bjørnøya was southwest to southeast. There did not seem to be any stable aggregations of birds in this area. Transect counts later in the autumn indicate that areas further east of Bjørnøya are important rearing and feeding areas in this period. The main direction of the swimming migration from the large

Brünnich's Guillemot colonies on the western coast of Storfjorden (Kovalskifjella and Stellingfjellet) was southeast. The outer parts of Storfjorden also seemed to be an important rearing and feeding area for Brünnich's Guillemots later in the autumn. From the colonies at Hopen the main direction of the swimming migration was in a northern and eastern direction. The ice edge was relatively close to the island on the northern side and very high densities were found along the ice edge.

The main directions of the swimming migration from the colonies coincided well with the main directions the adults flew from the colonies in search of food. The adults probably lead the chicks to areas which they have experienced as food-rich. The swimming migration is probably also influenced by the surface currents at sea. The registrations of parent guillemots with chicks during ship line transects are shown in Fig. 3.

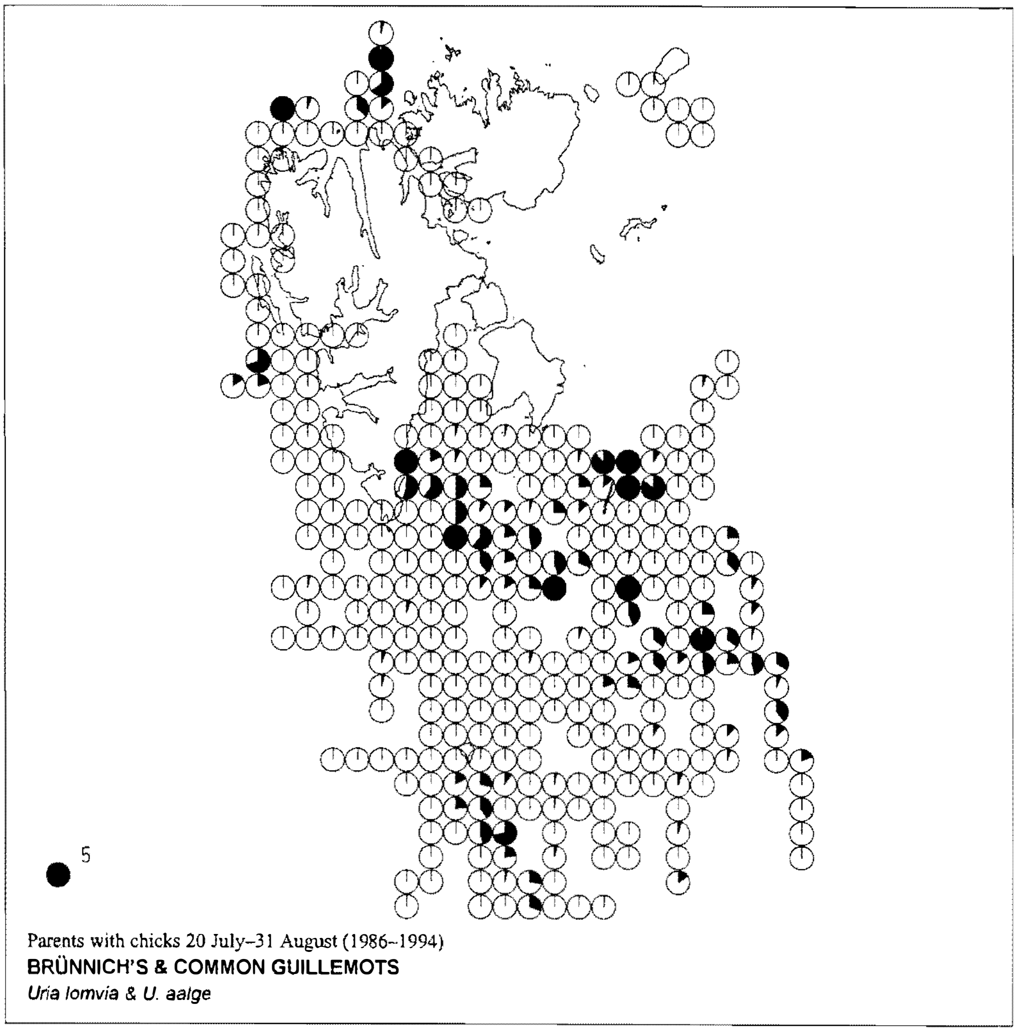

Fig. 3. Brünnich's (*Uria lomvia*) and Common Guillemot (*Uria aalge*) parents with chicks observed in the Barents Sea in the period of departure of the chicks from the colony and shortly after (20 July–31 August). Common Guillemots are only represented by a relatively small proportion of the observed individuals around Bjørnøya. The observations are from the ship line transects in the period 1986–1993 which are described by Isaksen (1995). A filled circle represents five or more individuals per square kilometre.

DISCUSSION

As shown in the previous section moulting birds are often concentrated in areas at sea or in coastal areas and are also often accompanied by the young of the year. Both adults and young are very vulnerable to oil spills in this period as they are unable to fly and their ability to avoid oil on the sea is thus reduced. An oil spill affecting these areas in this critical period may therefore have serious effects on the populations concerned.

The eiders, the Long-Tailed Ducks and the Common and Brünnich's Guillemots may be specially vulnerable because the sexes tend to be segregated, at least in the first part of this period. The males of these species concentrate in flocks either while the females are incubating and caring for the young (ducks and eiders), or during swimming migration and the subsequent chick rearing period (guillemots). Eiders and guillemots are monogamous (Cramp & Simmons 1977; Birkhead 1985) and start breeding at a high age (3 years for eiders and from 3–4 years for guillemots; Cramp & Simmons 1977; Hudson 1985; Harris et al. 1994). An oil spill which kill a significant part of the males in the population may therefore have more serious effects on the reproductive potential of the population than if the mortality was distributed evenly between the sexes.

After the main moulting period (late August–September) the geese and eiders congregate in flocks preparing for the southern migration. They start moving south along the coast, and large concentrations have been observed especially in the area between Sørkapp and Kapp Borthen (south of Bellsund) (see Løvenskiold 1954, 1964; Knutsen et al. 1988; Prestrud 1991).

The Razorbills have similar behaviour as Brünnich's and Common Guillemots in the period after departure from the breeding colony (Harris & Birkhead 1985). However, the population of this species in Svalbard is very small (Isaksen & Bakken 1995) and little is known about the biology of these birds in Svalbard. The young of the other species of auks which breed in Svalbard (Black Guillemot *Cepphus grylle*, Little Auk *Alle alle* and Puffin *Fratercula arctica*) are able to fly when they leave the colony and are probably independent of their parents from this time (Harris & Birkhead 1985). The adults of these species also moult after the breeding season, but they are most likely more dispersed in this period than the *Uria*-species.

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DISTRIBUTION OF SEABIRDS AT SEA IN THE NORTHERN BARENTS SEA

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Brünnich's Guillemots (*Uria lomvia*) at sea close to the coast. Photo by Fridtjof Mehlum.

Abstract – The distribution of seabirds at sea in the Barents Sea has been mapped during ship line transects in the period 1980–1994. Distribution maps showing the results from these transects are presented by season together with species accounts. The methods of observation used before 1985 differ from those after 1985, and the results from the two periods are presented separately. Only species common in offshore areas and previously assessed as vulnerable to oil spills or of special conservation value in the northern Barents Sea are treated.

The extension of the sea ice in the Barents Sea varies highly both between seasons and between years. Several species are connected to ice-filled waters or show especially high concentrations in these areas at certain times of the year. Some species are attracted to ships and may follow them for a long period of time. The species treated also have different sighting probability at sea. These and other factors that may influence on the calculated densities are discussed.

INTRODUCTION

This report deals with the distribution at sea of seabird species that may be affected by petroleum activity in the Norwegian part of the northern Barents Sea. Information on the distribution of seabirds at sea is crucial when assessing what proportions of the populations in the area may potentially be affected by an oil spill at a given locality. No specific geographic limits have been defined by the authorities for the area that may potentially be opened for test drilling. In their assessment of the vulnerability to oil spills and the conservation value of seabird species in the northern Barents Sea, Fjeld & Bakken (1993) limited the area of concern to 73°–81° north and 5°–35° east. This approach will be followed here.

Common for all seabirds is their close connection to the marine environment. Most species go to land only for breeding and spend the rest of the year on the open sea, in areas with sea ice or in coastal areas. The amount of direct contact with the water varies among species and with the season. Outside the breeding period auks typically spend most of their time diving, swimming or resting on the sea surface, while Fulmars (*Fulmarus glacialis*) and also gulls and skuas spend more time in flight, roaming over large areas. In the breeding period, breeding auks spend more time on land incubating eggs and caring for young, and also spend more time flying between the colony and feeding areas than they do at other times of the year. Fulmars, gulls and skuas may in contrast in this period spend more time feeding on the water to supply their young with food. Higher availability of food during the breeding season will modify this simplification. These and more factors are considered in the analysis of the vulnerability to oil spills of the seabirds in the area conducted by Fjeld and Bakken (1993).

The Barents Sea has a high production of biomass and supports large populations of seabirds especially in the breeding season, but also at other times of the year (Sakshaug et al. 1992, 1994; Mehlum & Bakken 1994). The period of stay in the Barents Sea varies highly between the species. Many species migrate from the area in autumn and spend the winter in more southerly areas; some seabirds, such as the Grey Phalarope (*Phalaropus fulicarius*), the Sabine's Gull (*Larus sabini*) and the Arctic Tern (*Sterna paradisaea*), winter in waters off

West Africa or in the Antarctic Ocean. Arriving at their breeding grounds in Svalbard in the beginning of June and starting the southern migration already in the middle of July, the female Grey Phalaropes stay the shortest time in the area of the breeding birds. Other species, such as the Brünnich's Guillemot (*Uria lomvia*), the Kittiwake (*Rissa tridactyla*) and the Ivory Gull (*Pagophila eburnea*), may stay in the area all year round.

Large populations of seabirds breed in the Arctic areas in Russia (Norderhaug et al. 1977; Golovkin 1984). Birds from breeding colonies on for instance Zemlja Franca Iosifa, Novaja Zemlja and the Kola peninsula either winter in the Barents Sea area or migrate through it on their way to and from wintering areas further south and west. Immature and non-breeding birds from these areas may also spend the summer out in the Barents Sea. An oil spill in the Barents Sea may therefore not only affect birds from Svalbard and North Norway, but also birds which breed in Russia.

MATERIAL AND METHODS

The data presented here were collected during ship line transects on cruises in the Barents Sea in the period 1980–1994 (Appendix 1). A large part of the data was collected on cruises organised by the Norwegian Polar Institute (NP), but there have also been cooperative cruises with other institutions and cruises arranged by others with observers from NP. Most of the data from the winter season is collected by observers from the Norwegian Institute for Nature Research which participated in the regular winter cruises of the Institute of Marine Research.

Censusing methods and treatment of data

The methods of observation and registration of the observations used before 1985 differ from those after 1985.

1980–1984

On the cruises in these years all birds observed around the boat were registered. Most observations were, however, made within 300 metres of the ship and in a sector 180° in front of the moving ship. One observer, situated on the top of the bridge, noted all birds seen within 10-minute periods. Other data, such as behaviour of birds seen, geographical position and weather and ice conditions was also recorded.

The data were compiled to give the number of individuals of different species seen within squares of 0.2° N/S and 1° E/W. As the area effectively covered by the observer in any given square (the transect width) is unknown, it is not possible to calculate densities of birds from the observations. The scale on the present maps is therefore number of birds seen per kilometre of transect within each square.

The cruises in this period are all from the summer and early autumn seasons (25 May–26 September) and only one map for each species is prepared for this period. No differentiation between swimming and flying birds has been made on the maps from this period. These data, compiled in a somewhat different way, have earlier been published by Mehlum (1989).

1986–1994

The method and registration format used in the Seabird project at the Directorate for Nature Management was followed on the cruises in these years (see also Method I of Tasker et al. 1984). Birds seen within 300 metres in a sector of 90° from the direction of movement of the ship were registered. One observer was standing on or above the bridge; in later years one additional observer had the responsibility of recording the observations either on paper or directly onto a computer. The number and behaviour of all birds within the transect were recorded, together with weather parameters. The position of the ship was recorded every 30 minutes, at changes in course and at each start and stop. Based on these positions and the corresponding hours, the number of individuals of each species observed within squares (0.05° N/S and 0.25° E/W) were computed. The limited width of the transect allowed the numbers to be transformed to densities within each square (number of individuals per square kilometre).

Except for the darkest period of the year (November to the first part of January), all months of the year were covered by one or more cruises during the period. For presentation of seasonal distribution the data have been divided according to the following seasons:

Spring	1 March–31 May
Summer	1 June–31 August
Autumn	1 September–31 October
Winter	1 November–31 February

The data from 1986 to 1988 have earlier been presented by Anker-Nilssen et al. (1988) and Bakken & Mehlum (1988).

Production of maps

Due to the differences in censusing methods, there has so far been no reasonable way to combine the two datasets. Two maps are therefore presented for each species for the summer season; one for the years 1980–1984 and one for 1986–1994.

Fjeld & Bakken (1993) identified those seabird populations in the northern Barents Sea that are vulnerable to oil spills in the different seasons and/or are of special conservation value. Here distribution maps are presented for each season for species found either to be of special conservation value and/or vulnerable to oil spills (vulnerability category 2 and 3 for spring and summer, and vulnerability category 3 for autumn and winter; see Appendix p. 134). Some of the species emphasised by Fjeld & Bakken (1993) are confined to the coastal zone (geese, eiders and Arctic Tern) or occur in low numbers in the area (divers, Long-tailed Duck *Clangula hyemalis*, Great Skua *Stercorarius skua*, Great Black-backed Gull *Larus marinus* and Razorbill *Alca torda*). These species have been registered very few times during the mainly offshore cruises, and no maps have been prepared for them. None of the cruises in autumn or winter travelled in near-shore or ice-filled waters. Being closely associated with

Table 1. Species and seasons (spring, summer, autumn and winter) for which distribution maps are presented. Only observations of birds with the indicated behaviour have been included in the preparation of the maps for the period 1986–1994 (flying, swimming or sitting on ice).

SPECIES	SEASON	BEHAVIOUR
Fulmar *Fulmarus glacialis*	Sp, Su, Au, Wi	Flying, swimming, on ice
Arctic Skua *Stercorarius parasiticus*	Su	Flying, swimming, on ice
Glaucous Gull *Larus hyperboreus*	Sp, Su, Au, Wi	Flying, swimming, on ice
Kittiwake *Rissa tridactyla*	Sp, Su, Au, Wi	Flying, swimming, on ice
Ivory Gull *Pagophila eburnea*	Sp, Su, Au, Wi	Flying, swimming, on ice
Common Guillemot *Uria aalge*	Sp, Su, Au, Wi	Swimming, on ice
Brünnich's Guillemot *Uria lomvia*	Sp, Su, Au, Wi	Swimming, on ice
Black Guillemot *Cepphus grylle*	Sp, Su	Swimming, on ice
Little Auk *Alle alle*	Sp, Su, Au, Wi	Swimming, on ice
Puffin *Fratercula arctica*	Sp, Su, Au, Wi	Swimming, on ice

these habitats, the Black Guillemot (*Cepphus grylle*) has not been registered in these seasons and only maps for summer and spring are presented for this species. The species and seasons covered are listed in Table 1.

The Common Guillemot (*Uria aalge*) and the Brünnich's Guillemot (*Uria lomvia*) are often difficult to distinguish at sea. Some of the observations have therefore been recorded as unidentified guillemot (*Uria* sp.). The Common Guillemot is only common in the southern part of the area, and even here the Brünnich's Guillemot is often more numerous at sea. The unidentified guillemots have therefore been included in the numbers for the Brünnich's Guillemot on the maps. The number of such observations are, however, relatively small.

The observation effort spent in each square is presented on separate maps. This is the number of kilometres travelled for 1980–1984, and the number of square kilometres covered with observations for 1986–1994. The effort is more or less equivalent to sample size, and high effort improves the reliability of the value in each square. If for instance an occasional large concentration of birds is seen on a short visit within a square, the resulting density will be very high.

A beta-version of *SIMPACT* 3.0 (Anker-Nilssen et al. 1992) was used for the preparation of the maps. All presented data are represented on a format ready for use in an analysis with this program.

The size of each square on the maps is 25x25 km. This is much larger than the grid size of the computed densities for the period 1986–1994 (see above). The matrix symbols on the maps represent the mean value of all small squares within the 25x25 km squares. Some squares on a map often had very high values which left the rest of the squares with empty symbols. Such high values were 'scaled down', making more information visible on the maps. Filled symbols on a map may therefore represent higher values than indicated by the scale.

SPECIES ACCOUNTS

The distribution maps are presented by season in Appendix 2 together with maps showing the observation effort for each season (maps no. 1, 11, 22, 33 and 42). Short comments to the maps of each species are given below. A more general description of the species' ecology, population status, migration patterns and distribution in the Barents Sea, with emphasis on the breeding season, is found in Isaksen & Bakken (1995a).

FULMAR *Fulmarus glacialis* (Maps no. 2, 12, 23, 34 and 43)

The Fulmar seems to have a relatively uniform distribution in the censused area. In the breeding period it is common also in areas far from the breeding colonies. These may be predominantly non-breeding birds, but it is known that nesting birds may use large feeding ranges. The Fulmars winter in ice-free areas in the Barents Sea. Outside the breeding season they roam over large areas and they may also visit the breeding sites at these times.

ARCTIC SKUA *Stercorarius parasiticus* (Maps no. 13 and 24)

Arctic Skuas most often breed close to colonies of other seabirds. Breeding skuas attain most of their food by parasitizing on these birds close to the colonies. Consequently they are confined to the coastal zone during the breeding season. This explains the relatively few observations of this species during the cruises. Birds observed at some distance from the coast are probably mainly non-breeding or migrating individuals. The Arctic Skuas arrive in the Barents Sea in June and migrate south to the wintering areas in August–September.

GLAUCOUS GULL *Larus hyperboreus* (Maps no. 3, 14, 25, 35 and 44)

Breeding Glaucous Gulls spend a large proportion of their time in coastal areas preying on eggs, young and also adults of other seabird species. In summer the Glaucous Gulls seem to be most common in the northern areas relatively close to the shore. Outside the breeding season they live mainly pelagically both in partly ice-covered and open waters. The present data do not show any clear pattern in the distribution of the species at these times of the year.

KITTIWAKE *Rissa tridactyla* (Maps no. 4, 15, 26, 36 and 45)

Breeding Kittiwakes make long foraging trips, and feeding as much as 200 km from the colonies has been suggested (Mehlum 1989). This is supported by the high densities observed at large distances away from the major colonies at Hopen and Bjørnøya. The distribution maps show that the areas around these islands, especially the areas east of Hopen and southeast of Bjørnøya, are important for Kittiwakes in summer. In addition high densities were observed at the mouth of Storfjordrenna (south of Sørkapp) and along the western and northern coasts of Spitsbergen. The areas south and east of Hopen seem to be important also in spring and autumn. A large part of the Kittiwakes which breed in Svalbard probably spend the winter in the North Atlantic, but high densities have been observed in the eastern areas in wintertime (see *Discussion*).

IVORY GULL *Pagophila eburnea* (Maps no. 5, 16, 27, 37 and 46)

The Ivory Gulls live in close relation to ice-filled waters at all times of the year. They may be found in areas with unbroken ice and out to the open drift-ice zone. Ivory Gulls seldom occur in open waters, but some breeding colonies have been found in areas normally free of ice in summer in southern Spitsbergen. The distribution maps confirm a northern, ice-connected distribution. Few cruises have travelled extensively in areas with closed ice and it is difficult to assess the relative importance of these areas as compared to areas with drift ice. It is, however, reasonable to assume that the availability of their main food sources (Polar Cod *Boreogadus saida* and seal carcasses; Mehlum & Gabrielsen 1993) is higher in the drift-ice belt than in areas with more continuous ice, and that Ivory Gull densities are also higher in these areas. Mehlum (1990) found no differences in the occurrence of Ivory Gulls between dense and open drift ice in late summer (1/8–8/8 ice cover).

COMMON GUILLEMOT *Uria aalge* (Maps no. 6, 17, 28, 38 and 47)

Bjørnøya is the only major breeding site for the Common Guillemot in the Svalbard area. Also outside the breeding season it has a southern distribution in the area, and it has never been found in ice-filled waters. There are, however, some more northern observations, especially from the autumn. This species is often difficult to distinguish from the Brünnich's Guillemot at sea. Unidentified guillemots (*Uria* sp.) are included on the maps for the Brünnich's Guillemot, and the Common Guillemot may consequently be more common than the maps indicate. The broad distribution pattern should, however, not be affected by this.

Young Common Guillemots leave the breeding ledges when about three weeks old. They are at this stage unable to fly, and they swim out to feeding areas at sea followed by one of the parents. The parents moult their flight feathers during this period and are then unable to fly. During this period both young and adults are very vulnerable to oil spills.

BRÜNNICH'S GUILLEMOT *Uria lomvia* (Maps no. 7, 18, 29, 39 and 48)

The Brünnich's Guillemot has a more northern distribution than the Common Guillemot and breeds on Bjørnøya and in most other parts of Svalbard. It feeds in both ice-filled and open waters at all times of the year, but the concentrations may be especially high in the ice-edge zone and in leads in the ice (see Mehlum & Isaksen 1995).

It is known that breeding Brünnich's Guillemots may feed in areas far from the colony. This is also indicated by the map from the summers 1986–1994. The density of guillemots on the water was high out to about 150–200 km from the colonies at Hopen, where it levelled off. At least some of these birds were, however, non-breeding birds and records from after the main breeding period (late August). The concentrations of birds at the mouth of Storfjordrenna, south of Sørkapp, probably consisted of birds from the large colonies at the western side of

Storfjorden (Kovalskifjella and Stellingfjellet). Especially the areas north, east and south of Hopen, Storfjorden/Storfjordrenna, the areas around Bjørnøya, and Hinlopenstretet had high densities of guillemots on the water in summer. The main flight directions found during the first cruise with 'R/V Lance' in 1993, indicate that the areas north and southeast of Hopen, and east, south and northwest of Bjørnøya were the main feeding areas for the Brünnich's Guillemots breeding on these islands in this period.

As for the Common Guillemot, Brünnich's Guillemot young and one of the parents perform a swimming migration from the colonies at the end of the breeding season in late July or early August. Bakken and Mehlum (1988) investigated this migration from the colonies on Bjørnøya, Hopen and the western side of Storfjorden. A summary of these results is found in Isaksen & Bakken (1995b).

In spring large numbers of Brünnich's Guillemots were observed in the areas around Hopen. These are probably birds which gather in the ice-edge zone to forage. The distribution pattern in autumn and winter is less clear. The guillemots probably have a more variable distribution at these times of the year (see Fauchald & Erikstad 1995). The southeastern part of Spitsbergenbanken seems, however, to be an important area, at least in autumn. In this area there are frontal systems between cold Arctic Water masses and warmer Atlantic Water; the Polar Front (Loeng 1991). High densities of guillemots were observed along this front in the summer of 1993.

Recoveries of ringed Brünnich's Guillemots indicate that a large proportion of the birds breeding in Svalbard probably winters in the areas southwest of Greenland. However, a large number of birds are encountered in the Barents Sea during winter. These may partly be birds which breed in the Russian areas, especially on Zemlja Franca Iosifa and Novaja Zemlja where Brünnich's Guillemots breed in large numbers (Golovkin 1984; Strøm et al. 1994).

BLACK GUILLEMOT *Cepphus grylle* (Maps no. 8, 19 and 30)

The Black Guillemot is mainly associated with coastal and ice-filled waters (Cramp 1985; Mehlum 1989). Breeding birds feed in coastal areas, and birds observed offshore in the breeding season are probably non-breeding birds. The spring and summer maps confirm that Black Guillemots in the area are generally attached to coastal and ice-filled waters. Mehlum (1990) found Black Guillemots to be less frequent in dense ice cover (7/8–8/8) than in areas with less dense ice in late summer. No Black Guillemots were observed during the cruises in autumn and winter. The species is known to winter in ice-filled waters in the Barents Sea (Løvenskiold 1964), and the lack of observations from autumn and winter reflects that the cruises in this period were concentrated in ice-free and offshore areas.

LITTLE AUK *Alle alle* (Maps no. 9, 20, 31, 40 and 49)

The distribution maps from the summer show large concentrations of Little Auks in the areas outside the main breeding colonies in northwestern Spitsbergen and in Hornsund/Bellsund. The only cruise in summer in the areas off northwestern Spitsbergen in the period 1986–1994 took place in late August (the cruise with 'K/V Andenes' in 1988), probably after the Little Auks had left the colonies. This explains the low densities in these areas on the map from this period. In the period 1980–1984 high densities were seen out to 150 km from the colonies in northwestern Spitsbergen. Large concentrations of Little Auks on the water at similar distances from the breeding colonies have also been observed by others (Brown 1976). At least some of the birds may, however, be non-breeding birds or records of birds from after the main breeding season.

In spring the highest concentrations of Little Auks were again found off the main breeding colonies along the western and northwestern coast of Spitsbergen. In addition high densities were found in the areas east of Hopen, which are most often ice-filled at these times of the year (Vinje 1985). Areas along the ice edge have very high densities of zooplankton in spring (Sakshaug & Skjoldal 1989), which is the main food of Little Auks (Mehlum & Gabrielsen 1993). Mehlum (1990) found Little Auks to be less abundant in areas with dense ice (7/8–8/8 ice cover) than in areas with more open ice (1/8–6/8) in late summer. Similar results were obtained by Brown (1984) in spring. In autumn and winter the Little Auks seem to be distributed over large parts of the area. The densities found during winter were relatively low. Ringing recoveries of birds from breeding colonies in western Spitsbergen indicate that a large proportion of these birds winter in areas off southwestern Greenland (Norderhaug 1967). A large number of the Little Auks wintering in the Barents Sea may well be birds from Zemlja Franca Iosifa, where they are found breeding in large numbers (Golovkin 1984).

PUFFIN *Fratercula arctica* (Maps no. 10, 21, 32, 41 and 50)

The main breeding area for Puffins in Svalbard is the western coast of Spitsbergen. The highest densities of Puffins in summer were found off this area. Bjørnøyrenna seems to be an important area for Puffins in the northern Barents Sea both in spring, summer and autumn. In summer Puffins were found on the water out to more than 200 km from the nearest breeding sites at Bjørnøya. Anker-Nilssen & Lorentsen (1990) observed foraging ranges of Puffins of at least 137 km off breeding colonies at Røst, northern Norway. The long distances from Bjørnøya and the relatively small breeding population on this island indicate that the Puffins found in Bjørnøyrenna were mainly non-breeding birds.

DISCUSSION

The extent of the sea ice in the Barents Sea varies very much from year to year (Vinje 1985). The distribution of ice is an important determinant for the distribution of seabirds at sea at all times of the year in this area. Some species, such as the Ivory Gull and the Black Guillemot, are closely associated with ice-filled waters, and are seldom found in open waters far from the ice or off the coast. In spring and summer the ice-edge zone has a very high biological production (Sakshaug & Skjoldal 1989). The high availability of food attracts seabirds and the densities may be very high in these areas (see Mehlum & Isaksen 1995). Areas with closed ice are unsuitable as habitat for most seabirds and this limits their distribution, especially during winter.

The material presented here has been collected during a period of 15 years with highly varying ice conditions between years. This may serve to prevent clear distribution patterns from emerging. In areas affected by ice one should view the distribution of seabirds more in relation to the moving ice edge than connected to geographical positions.

The predictability of seabird distributions at sea in the Barents Sea is further treated by Fauchald & Erikstad (1995).

The species treated here have different behavioural responses to ships. Fulmars, Glaucous Gulls, Kittiwakes, Black Guillemots and Puffins are attracted to ships, and especially Fulmars, Glaucous Gulls and Kittiwakes may follow ships for a long period of time (see Erikstad et al. 1988). Common Guillemots, Brünnich's Guillemots and Little Auks do, however, not seem to be attracted to ships to any extent. For the auks only observations of birds swimming or sitting on ice were included on the maps (cf. Table 1); this will tend to reduce overestimates due to flying auks attracted to the ships.

Fishing activity often attracts large numbers of seabirds, especially gulls and Fulmars. Such activity during the cruises was largely restricted to the cruises organised by the Institute of Marine Research, most of which were winter-cruises (cf. Appendix 1). Even if care was taken not to include birds attracted to the ships during trawling, fishing activities have contributed to the high densities of Kittiwakes and Fulmars found in winter.

Different species have different sighting probability – for instance a white flying gull vs. a dark-backed auk swimming on the dark water surface. In addition auks dive in search of food, and are out of sight for the observers at these times (Tasker et al. 1984). Sighting probability may also vary from season to season due to the seasonal differences in light conditions.

Due to the above mentioned factors, the computed densities should be interpreted with caution, especially for the ship-following species. The relative distribution of single species within a season should, however, not be seriously affected, with the possible exception of Fulmars and Kittiwakes. Using the *SIMPACT*-model in an impact assessment, only these relative distributions will be used (see Anker-Nilssen et al. 1992).

Acknowledgements – A large number of persons have contributed to the cruises during the 15 years, spending long observation hours on, or above, the bridge. All these persons, too numerous to be listed, deserve special thanks. Vidar Bakken and Fridtjof Mehlum at the Norwegian Polar Institute are thanked for supplying data from seabird censuses at sea, and also for advice and assistance during the work. Norwegian Institute for Nature Research (NINA) is thanked for supplying parts of the data from the winter season. The Norwegian Coast Guard is thanked for allowing observers to participate in some of their cruises in the Barents Sea.

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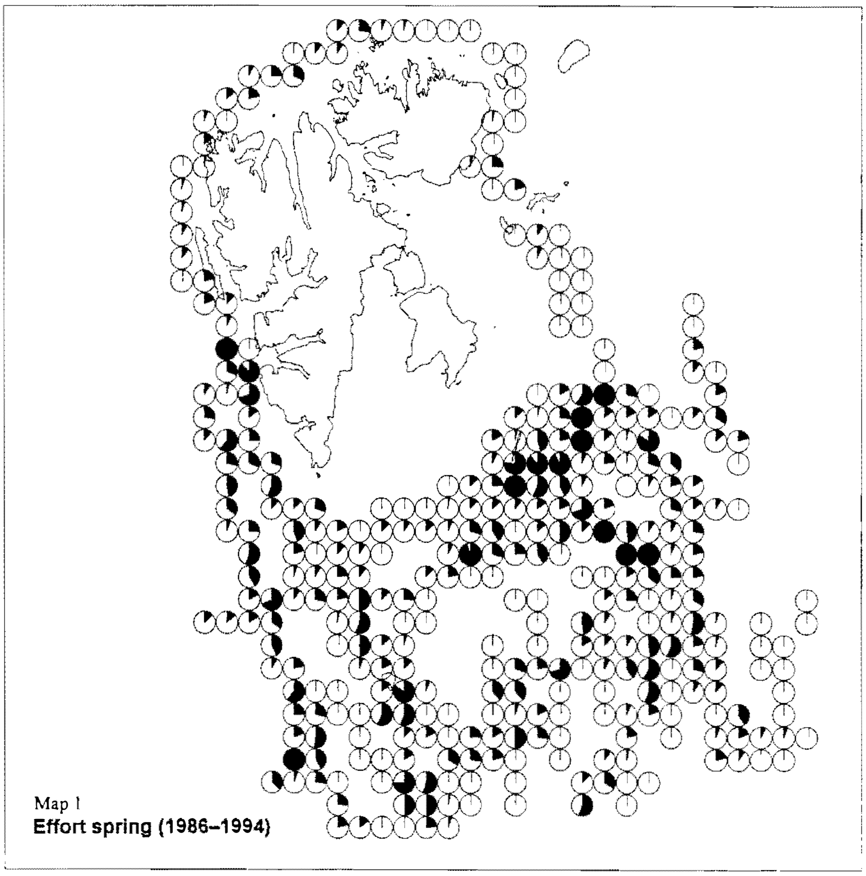
APPENDIX 1

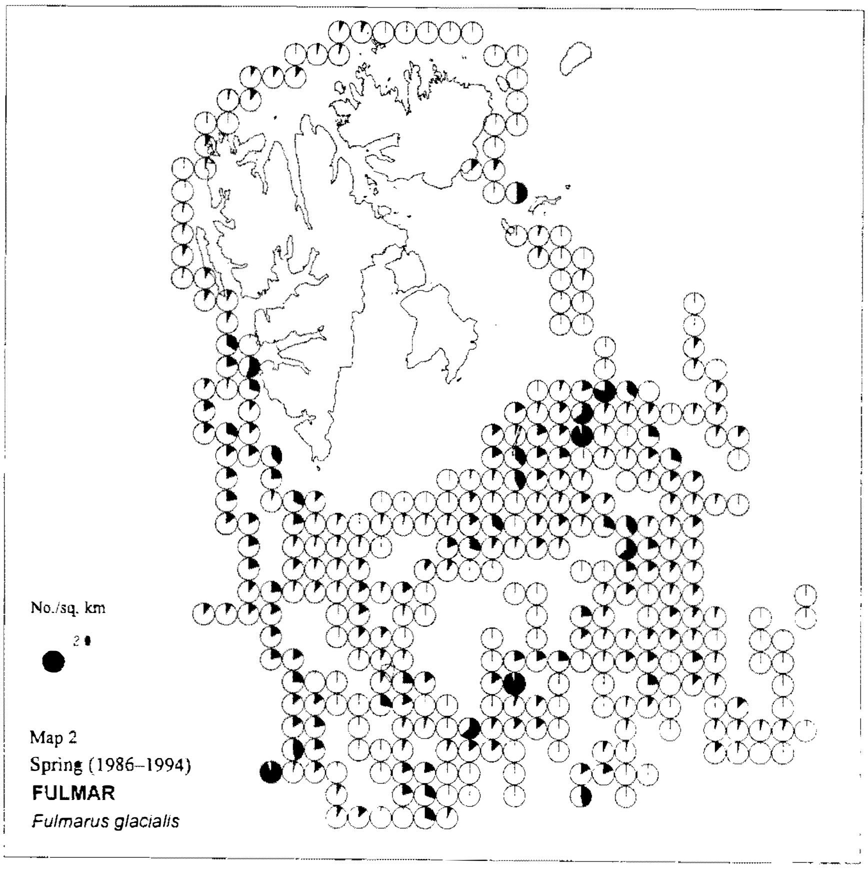
Cruises in the Barents Sea where seabird censuses were conducted. Abbreviations are Alfred Wegener Institute for Polar and Marine Research, Germany (AWI); Institute of Marine Research, Norway (IMR); the Norwegian Coast Guard (NCG); Norwegian Institute for Nature Research (NINA); Norwegian Polar Institute (NP); Norwegian Petroleum Directorate (NPD); Naturhistoriska Riksmuseet, Stockholm, Sweden (NRS); Norwegian Research Programme for Marine Arctic Ecology (Pro Mare); the Swedish Polar Research Committee (SPRC) and Tromsø Museum, Norway (TM). Some of the cruises have travelled extensively outside the area treated here.

Vessel	Cruise organiser	Observers	Census period
Ymer	SPRC	NRS/NP	02.07–26.09.80
Norvarg	NP	NP	22.07–06.08.80
R/V Lance	NP	NP	19.08–31.08.81
R/V Lance	NP	NP	07.08–31.08.82
R/V Lance	NP	NP	24.05–15.06.83
R/V Lance	NP	NP	05.08–01.09.83
R/V Polarstern	AWI	NP	20.07–04.08.84
M/S Endre Dyrøy	NPD	TM	29.01–31.01.86
R/V G. O. Sars	IMR	TM	18.02–27.02.86
M/S Endre Dyrøy	NPD	TM	19.03–23.03.86
R/V Eldjarn	IMR	TM	29.04–15.05.86
M/S Endre Dyrøy	NPD	TM	21.05–24.05.86
R/V Lance	NP	NP	24.05–08.06.86
M/S Endre Dyrøy	NPD	TM	15.07–19.07.86
R/V Lance	NP	NP	12.08.86
K/V Andenes	NCG	NP	21.08–30.08.86
R/V G. O. Sars	IMR	NP/TM	22.08–12.10.86
M/S Endre Dyrøy	NPD	TM	10.09–13.09.86
R/V G. O. Sars	IMR	TM	28.01–21.02.87
M/S Endre Dyrøy	NPD	TM	25.02–22.03.87
K/V Nordkapp	Pro Mare	NP	27.02–08.03.87
M/S Endre Dyrøy	NPD	TM	17.06.87
M/S Endre Dyrøy	NP	NP	30.07–20.08.87
R/V G. O. Sars	IMR	TM	18.08–02.09.87
M/S Endre Dyrøy	NPD	NP	03.10–16.10.87
R/V G. O. Sars	IMR	TM	27.01–15.02.88
R/V Lance	NP	NP	19.03–26.03.88
K/V Andenes	Pro Mare	NP	20.05–31.05.88
R/V G. O. Sars	IMR	NINA	28.01–19.02.89
R/V Polarstern	AWI	NP	25.04–15.05.89
R/V Lance	NP	NP	22.07–07.08.89
R/V G. O. Sars	IMR	NINA	01.02–27.02.90
R/V G. O. Sars	IMR	NINA	05.02–02.03.91
R/V Johan Hjort	IMR	NINA	02.02–03.03.92
R/V Lance	NP	NP	19.07–15.08.92
R/V Johan Hjort	IMR	NINA	29.01–08.03.93
R/V Lance	NP	NP	13.07–01.08.93
R/V Lance	NP	NP	17.08–29.08.93
R/V Johan Hjort	IMR	NINA	02.02–06.03.94
R/V Lance	NP	NP	19.04–05.05.94

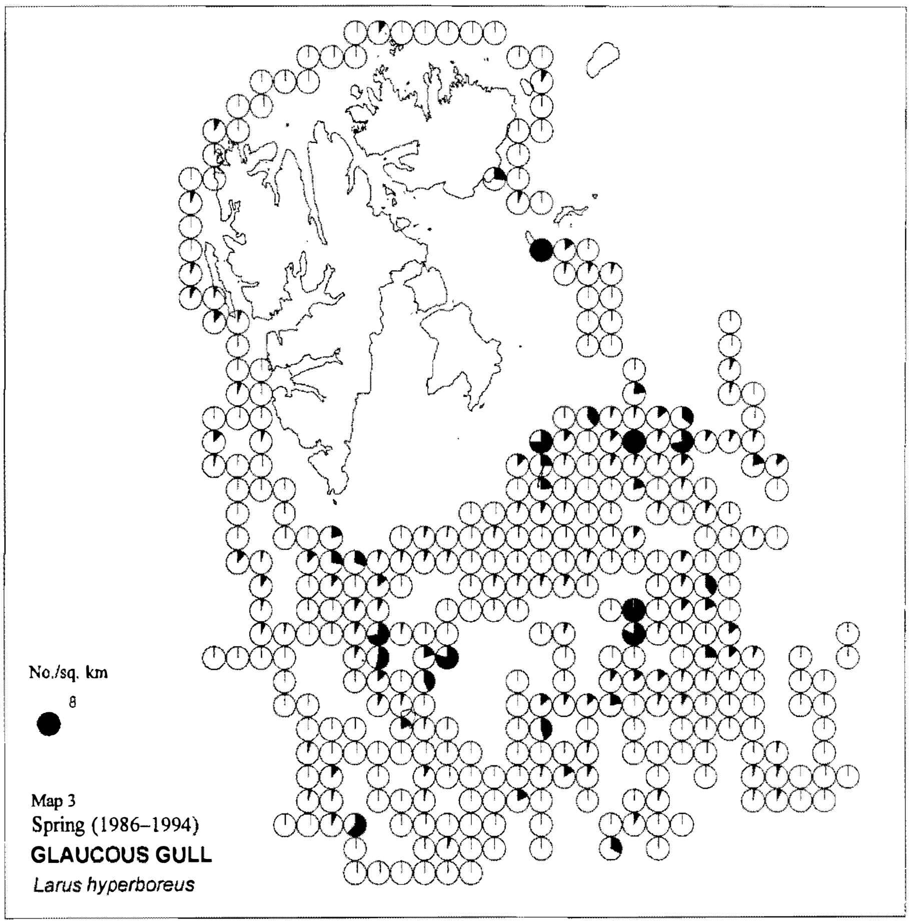
APPENDIX 2. Maps of the distribution of seabirds at sea in the Northern Barents Sea. The maps are presented by season (spring, summer 1980–1984, summer 1986–1994, autumn and winter).



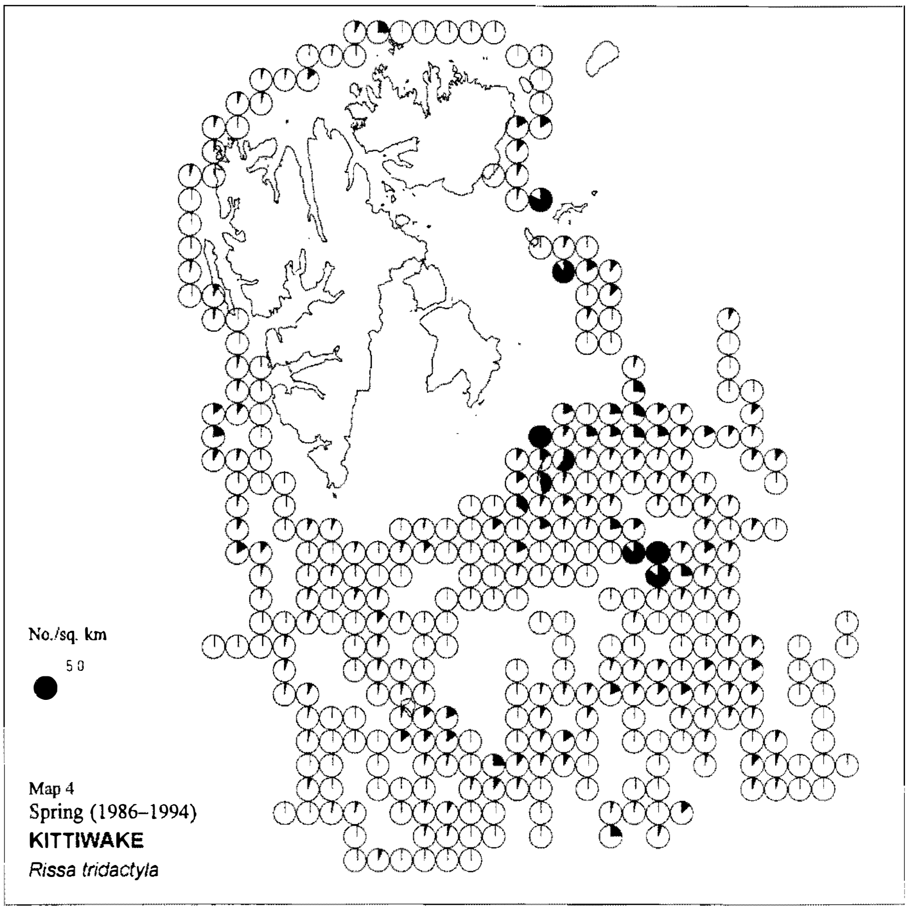
Map 1
Effort spring (1986–1994)



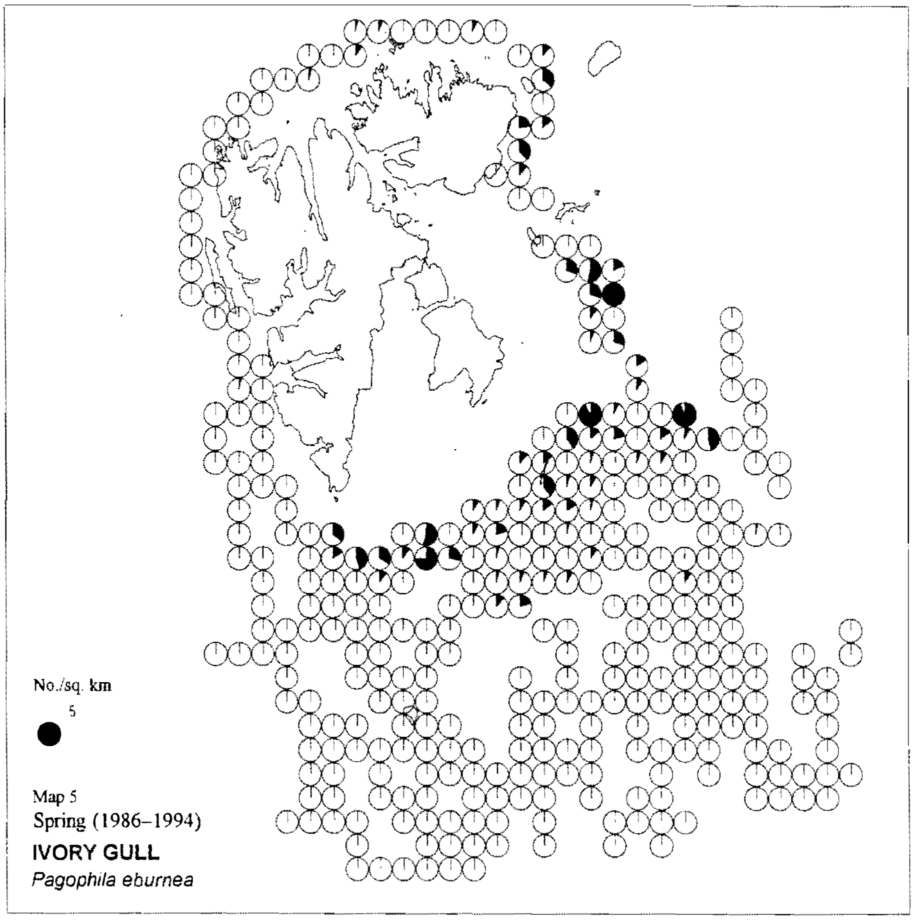
Map 2
Spring (1986–1994)
FULMAR
Fulmarus glacialis

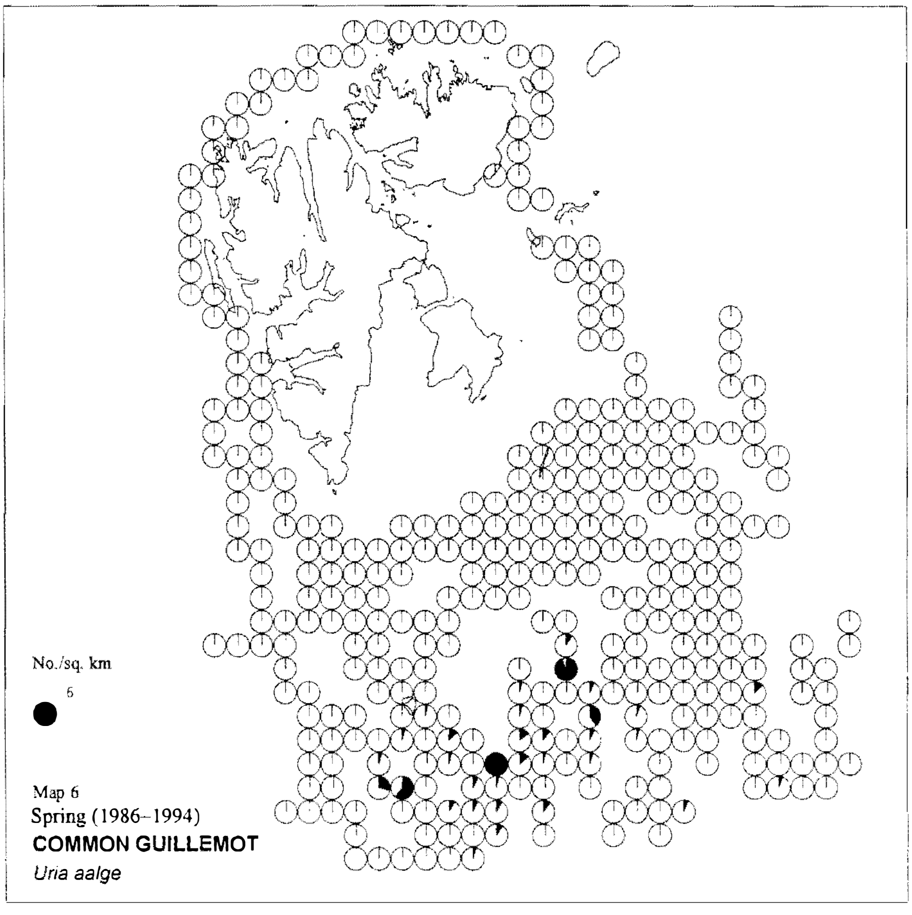


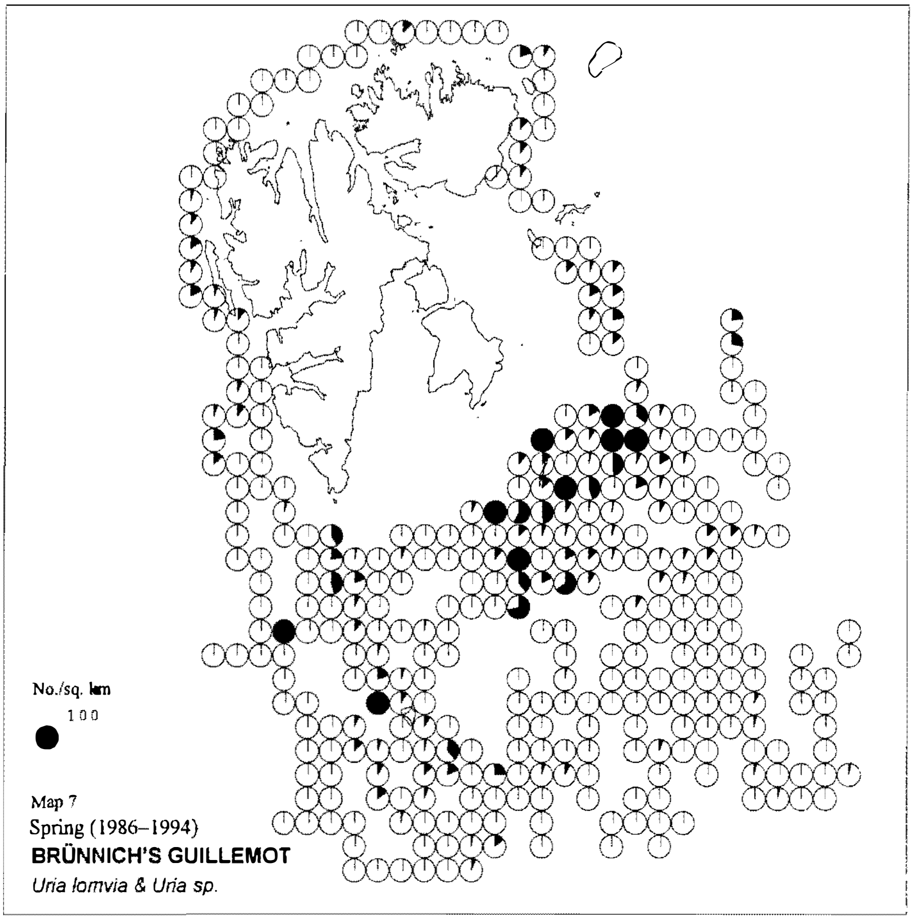
Map 3
Spring (1986–1994)
GLAUCOUS GULL
Larus hyperboreus



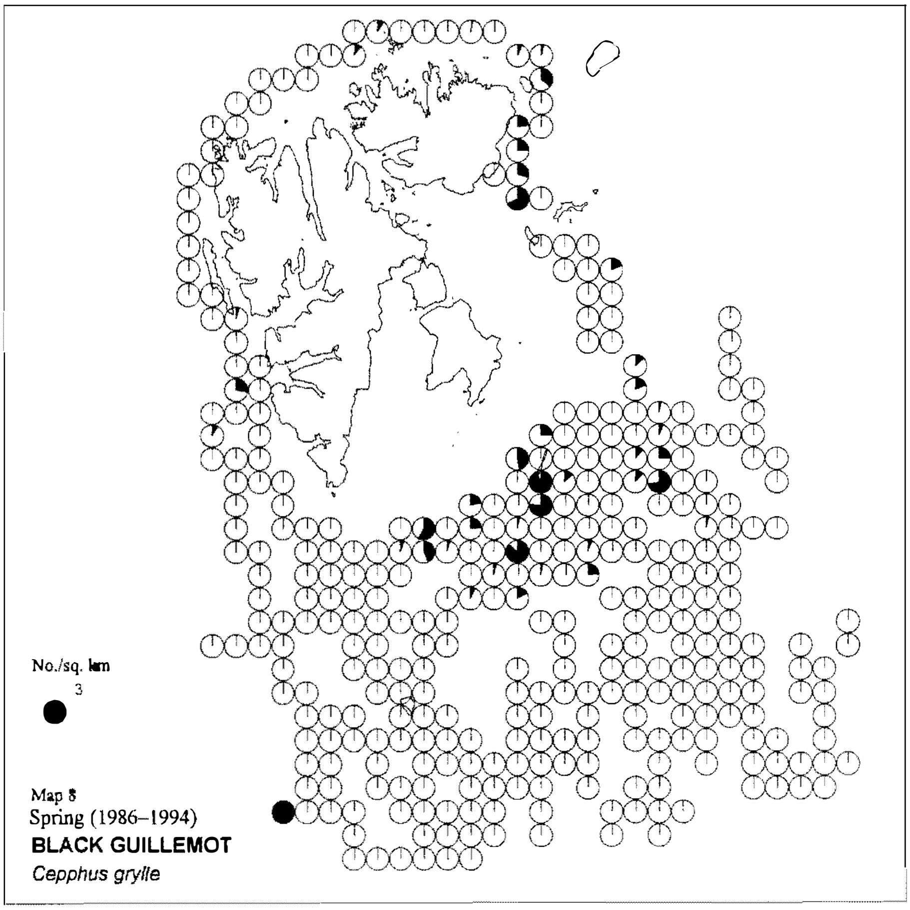
Map 4
Spring (1986–1994)
KITTIWAKE
Rissa tridactyla


No./sq. km
5
●
Map 5
Spring (1986–1994)
IVORY GULL
Pagophila eburnea

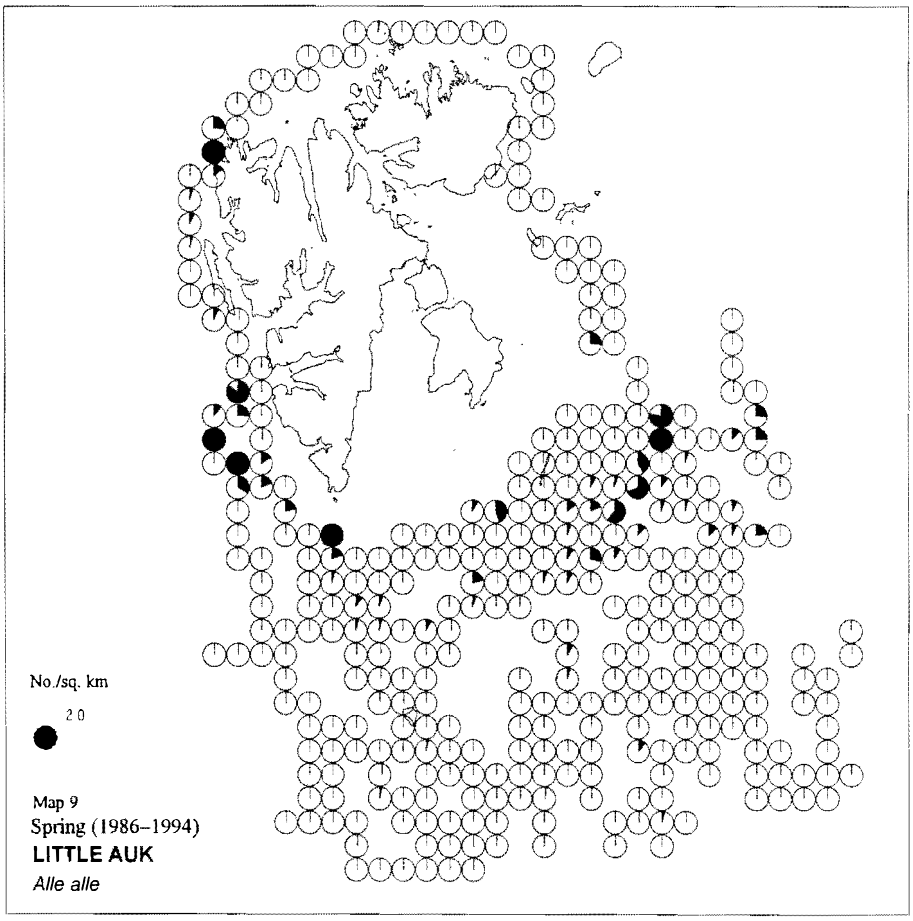

No./sq. km
6
●
Map 6
Spring (1986–1994)
COMMON GUILLEMOT
Uria aalge



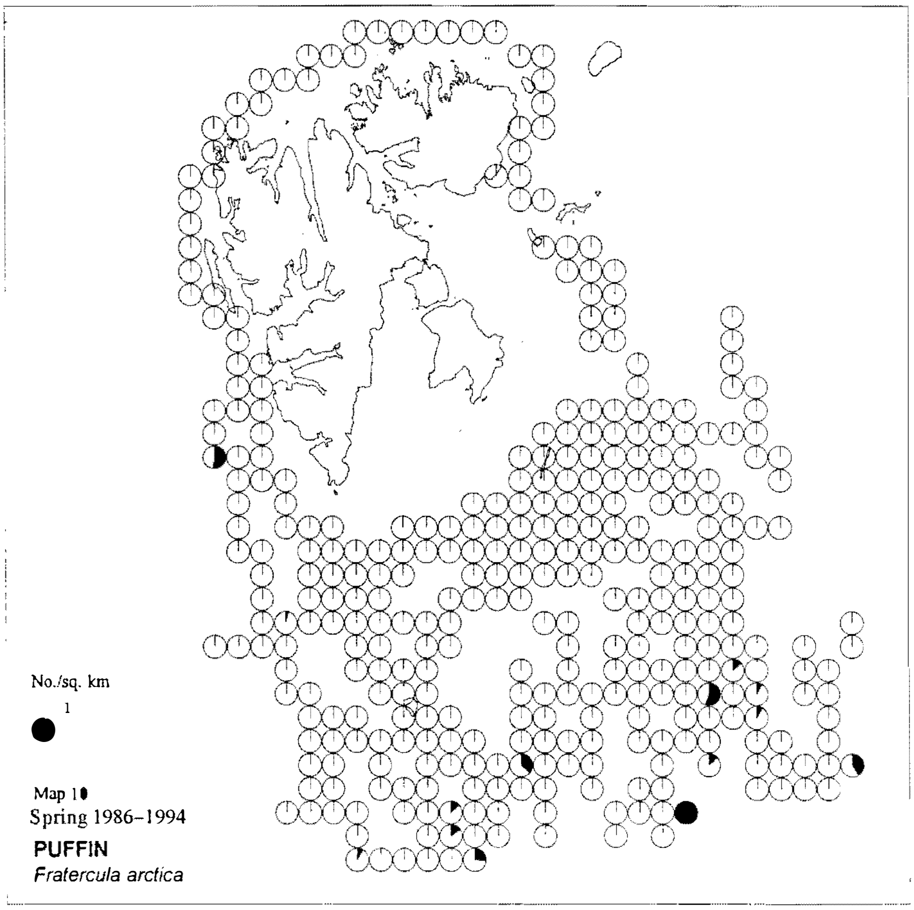
Map 7
Spring (1986–1994)
BRÜNNICH'S GUILLEMOT
Uria lomvia & Uria sp.



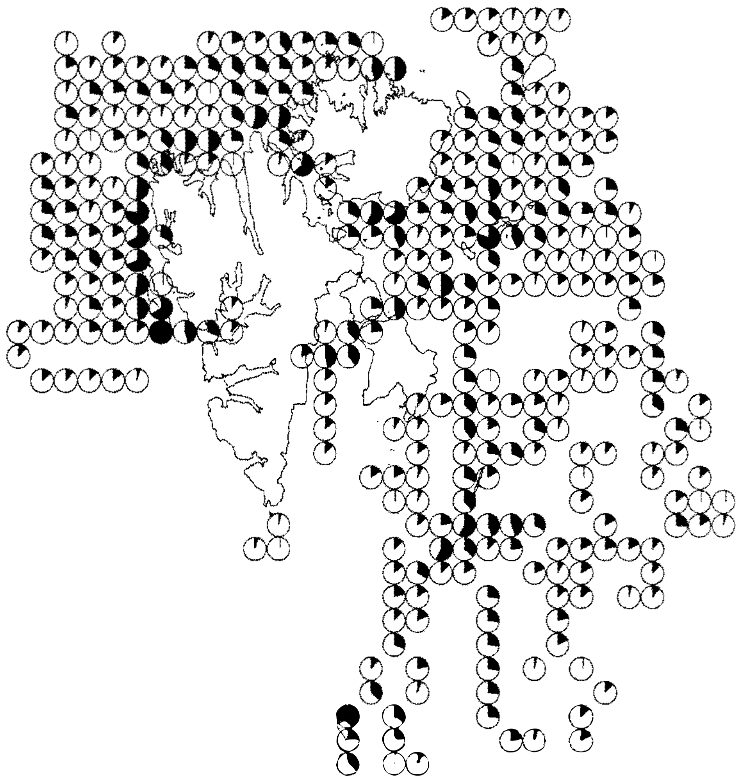
Map 8
Spring (1986–1994)
BLACK GUILLEMOT
Cepphus grylle



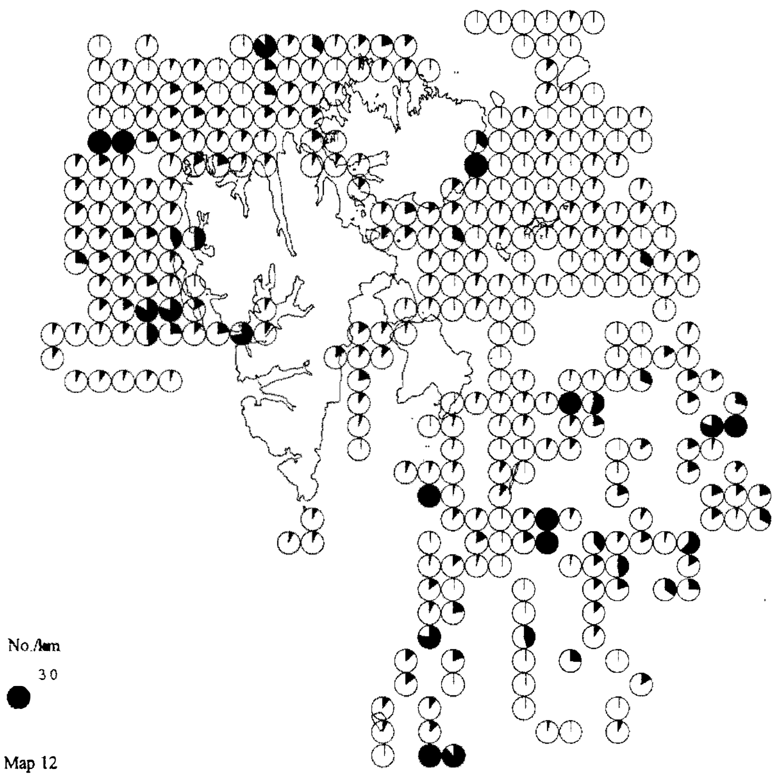
Map 9
Spring (1986–1994)
LITTLE AUK
Alle alle



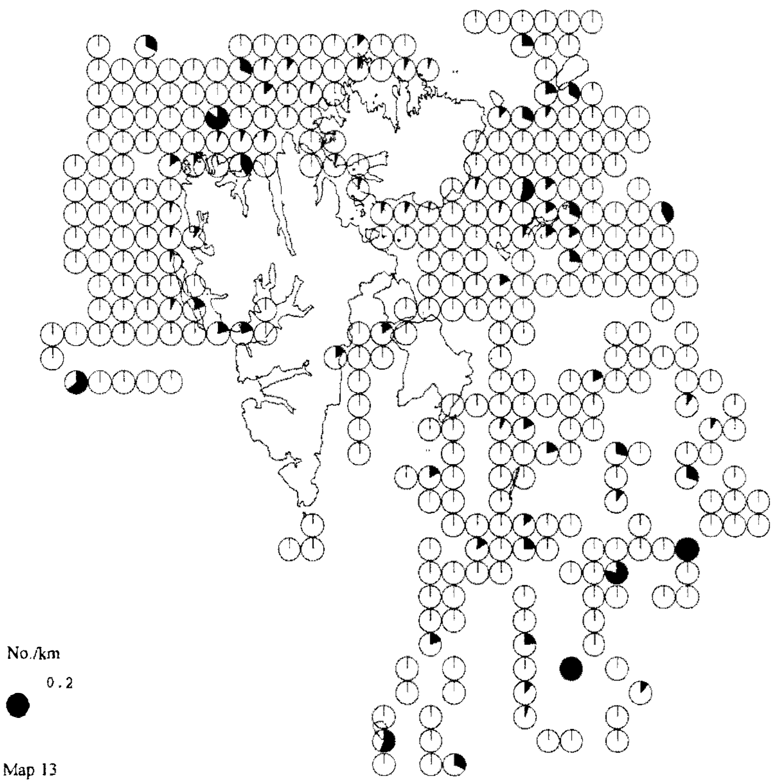
Map 10
Spring 1986–1994
PUFFIN
Fratercula arctica



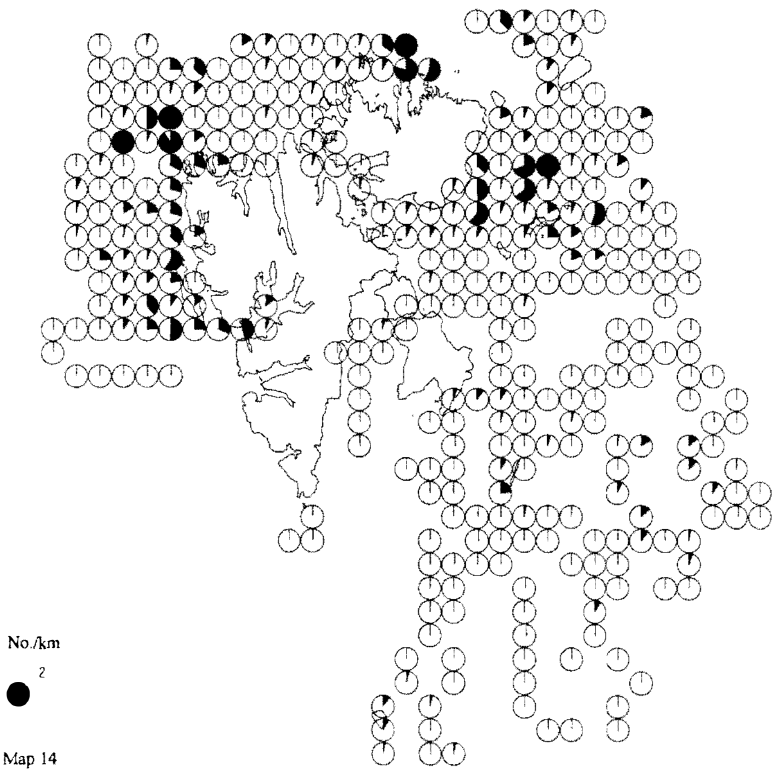
Map 11
Effort summer 1980–1984



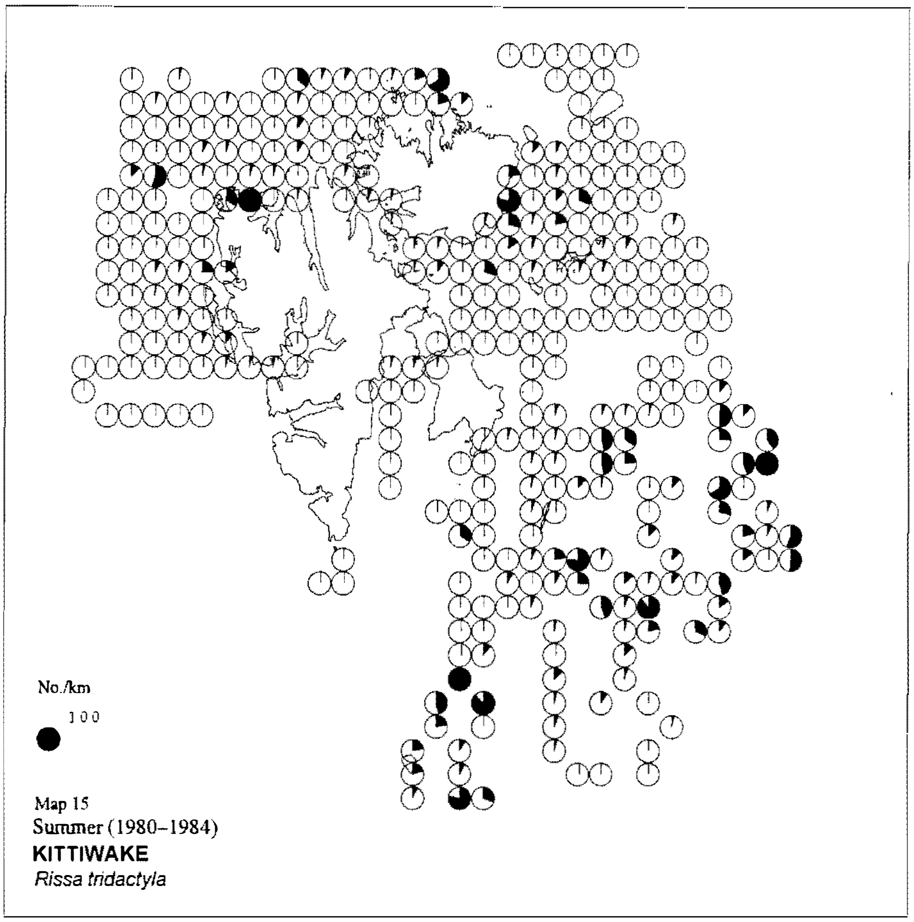
Map 12
Summer (1980–1984)
FULMAR
Fulmarus glacialis



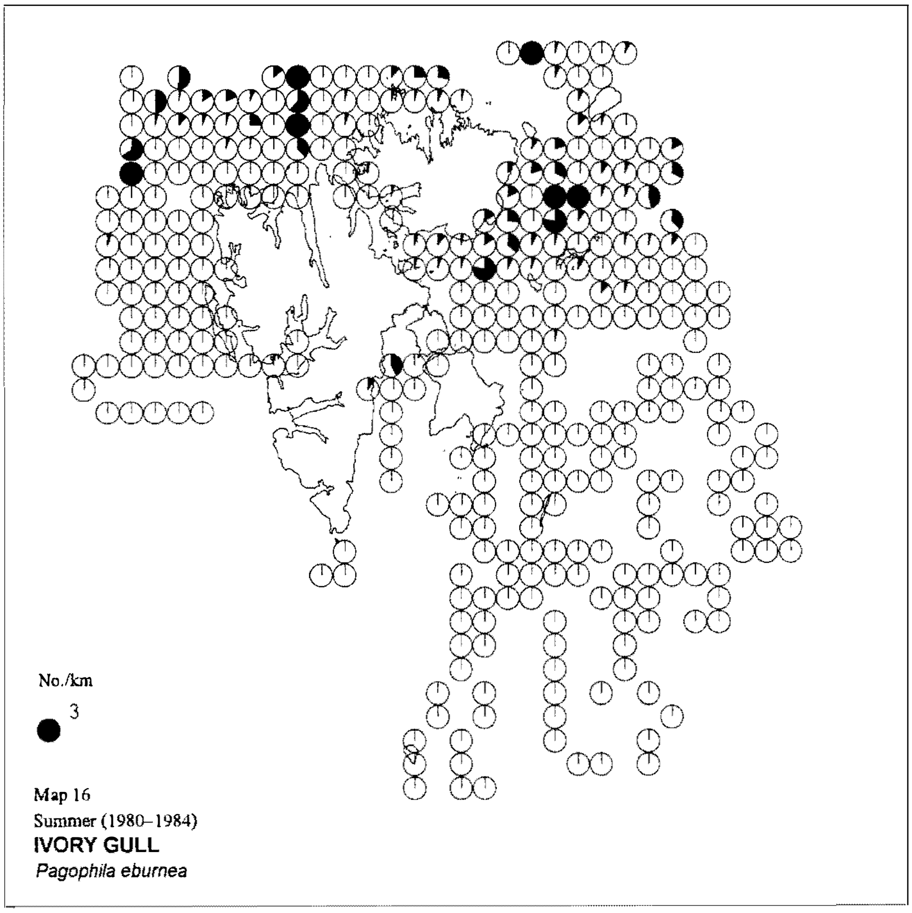
Map 13
Summer (1980–1984)
ARCTIC SKUA
Stercorarius parasiticus



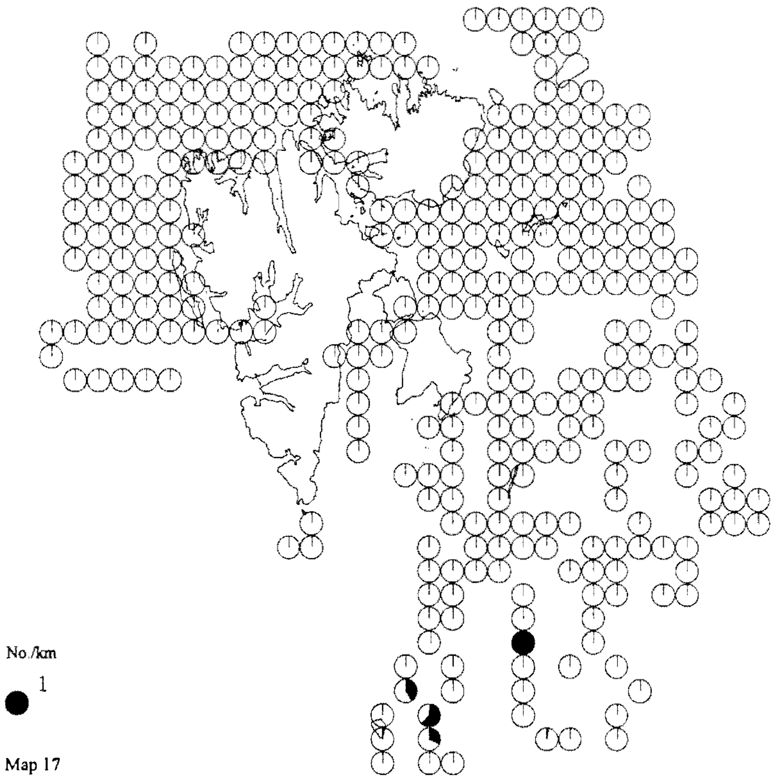
Map 14
Summer (1980–1984)
GLAUCOUS GULL
Larus hyperboreus



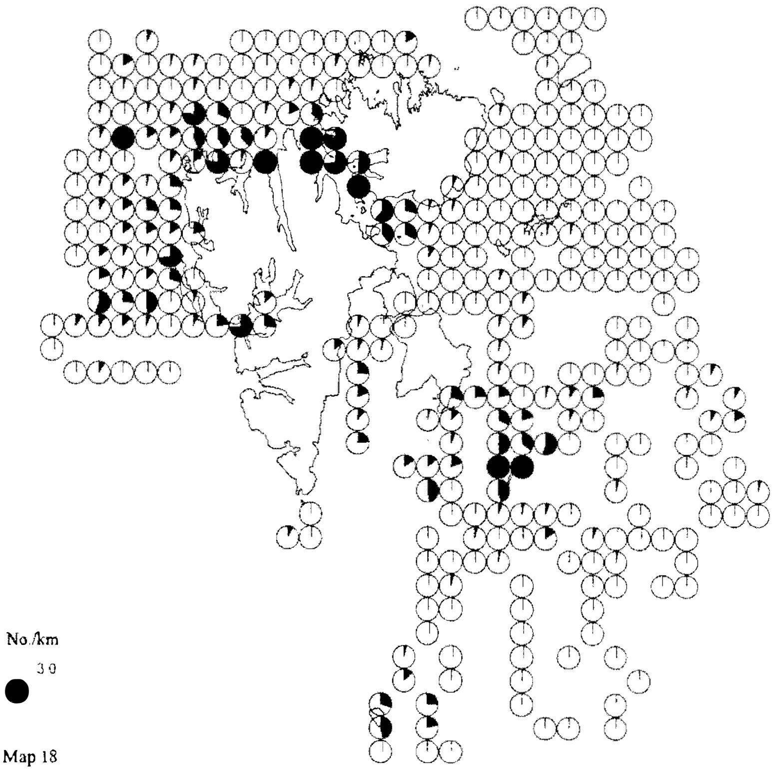
Map 15
Summer (1980–1984)
KITTIWAKE
Rissa tridactyla



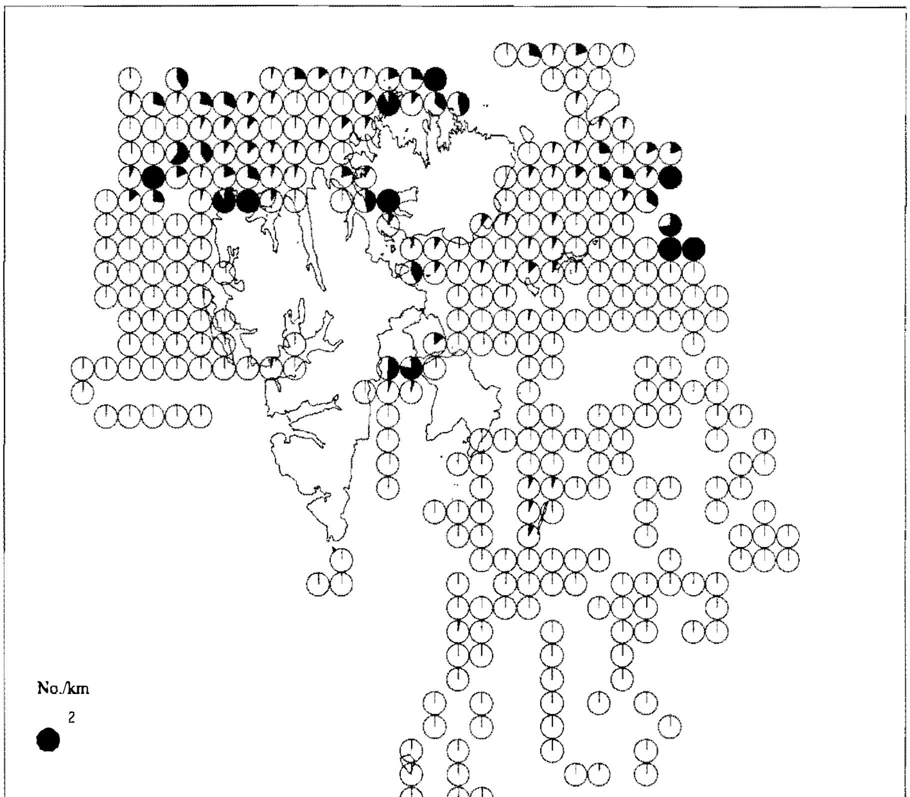
Map 16
Summer (1980–1984)
IVORY GULL
Pagophila eburnea



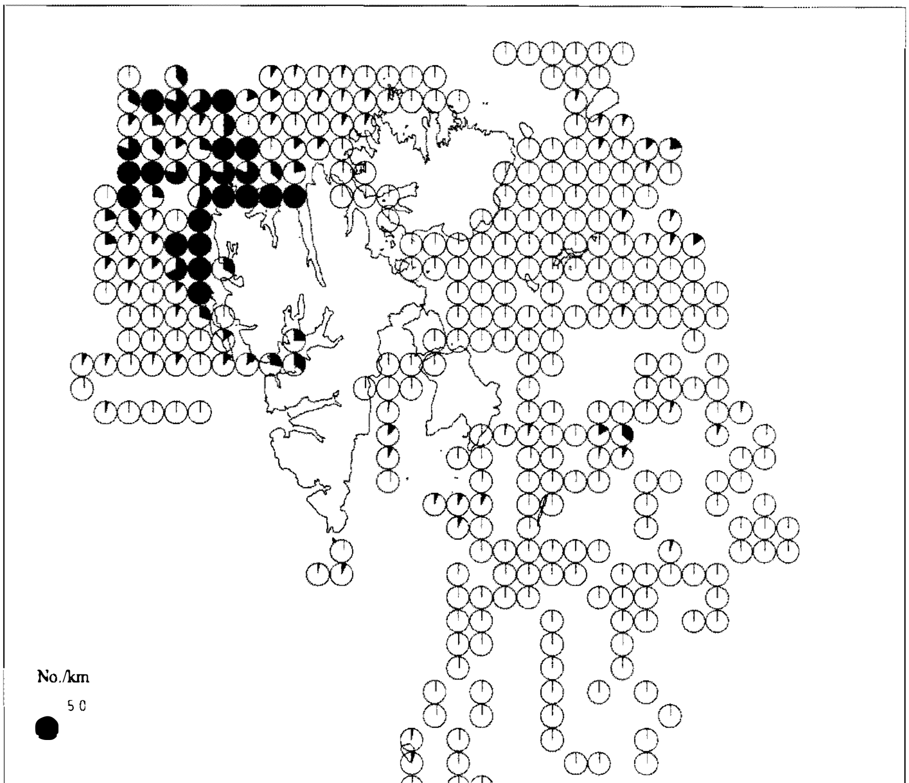
Map 17
Summer (1980–1984)
COMMON GUILLEMOT
Uria aalge



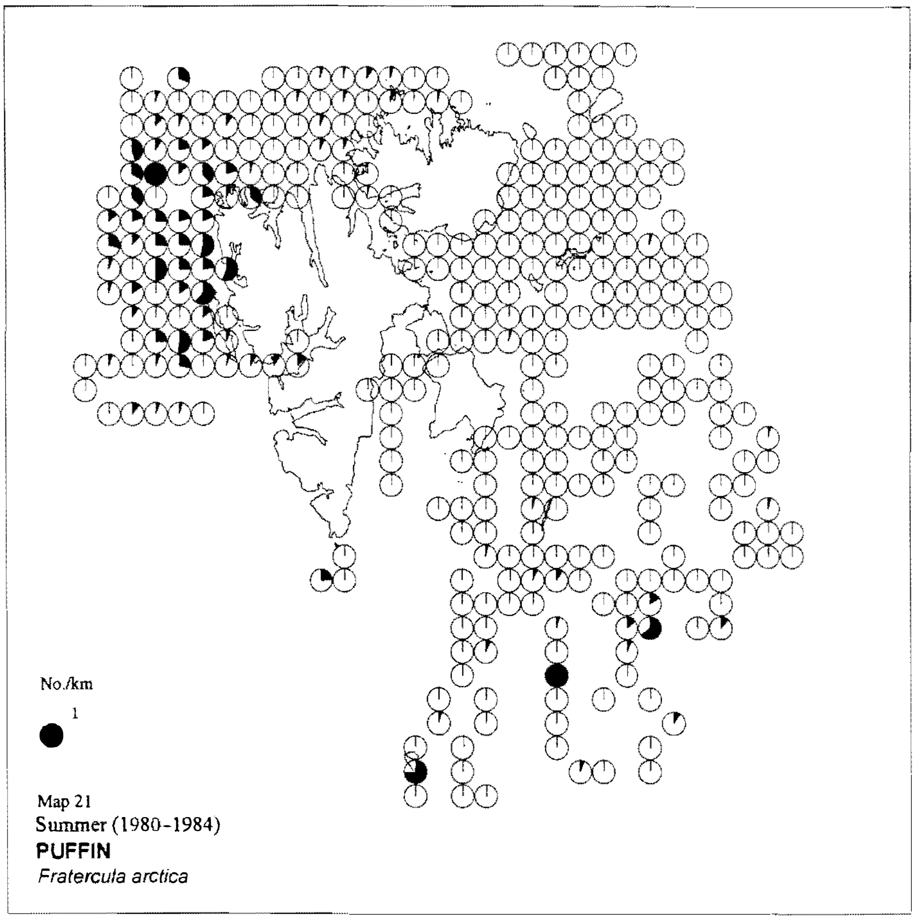
Map 18
Summer (1980–1984)
BRÜNNICH'S GUILLEMOT
Uria lomvia



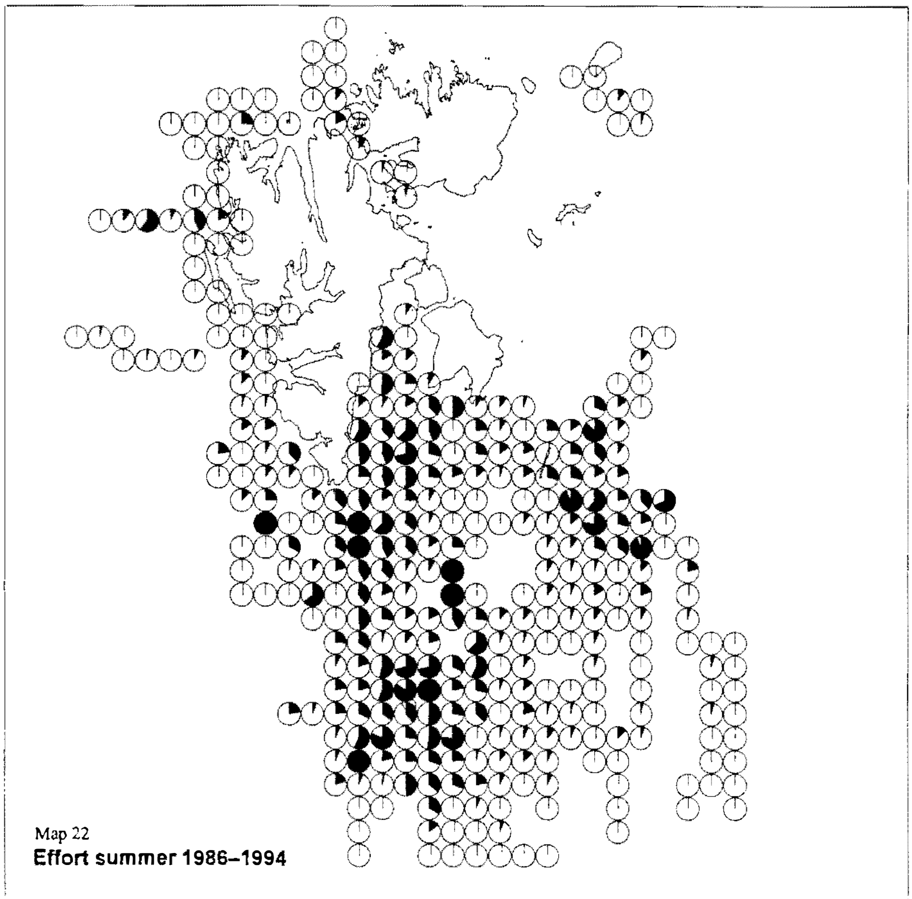
Map 19
Summer (1980–1984)
BLACK GUILLEMOT
Cepphus grylle



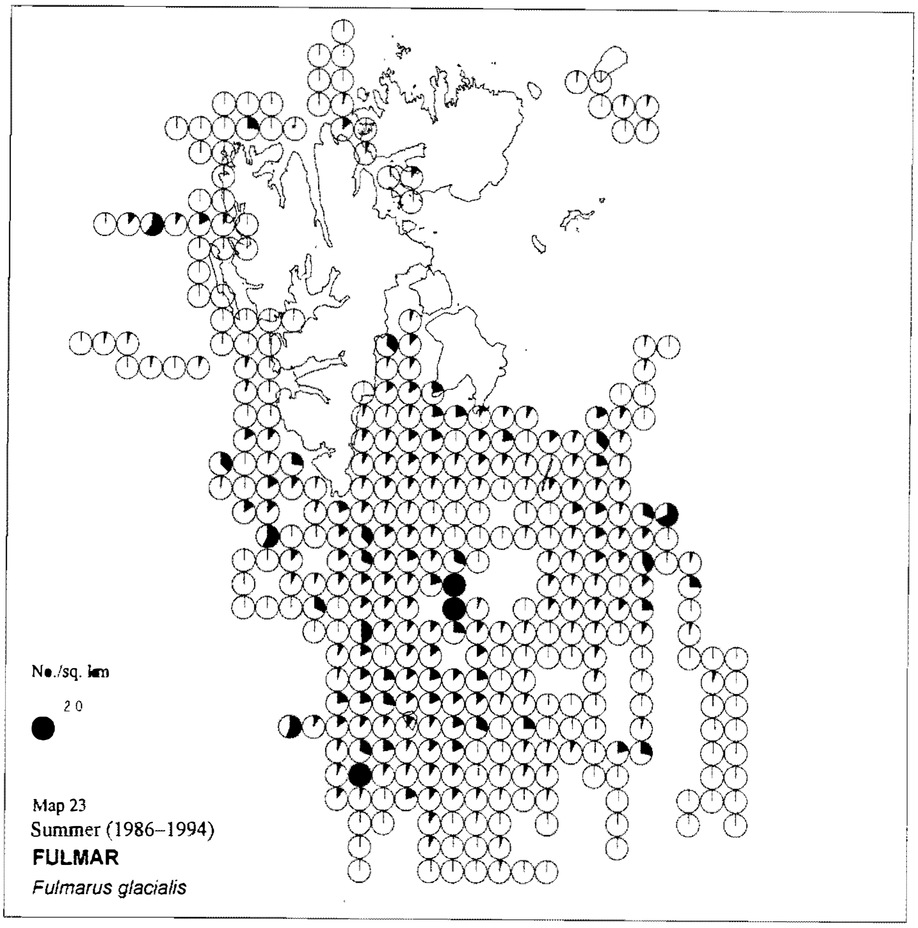
Map 20
Summer (1980–1984)
LITTLE AUK
Alle alle



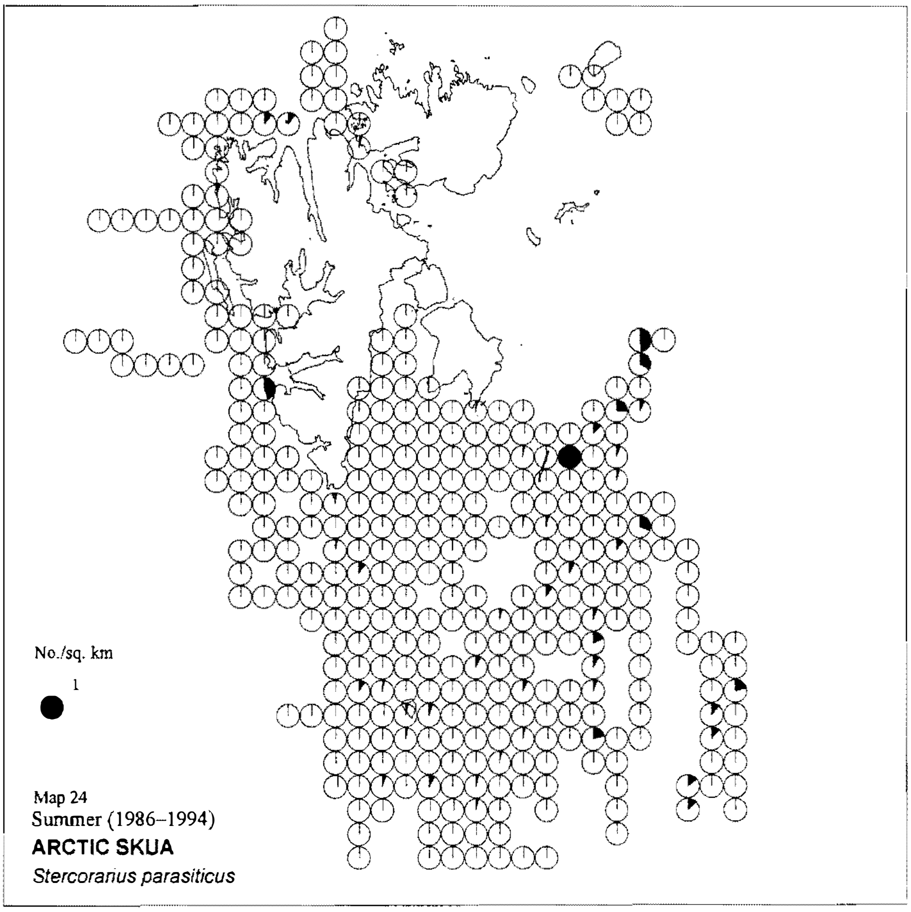
Map 21
Summer (1980-1984)
PUFFIN
Fratercula arctica



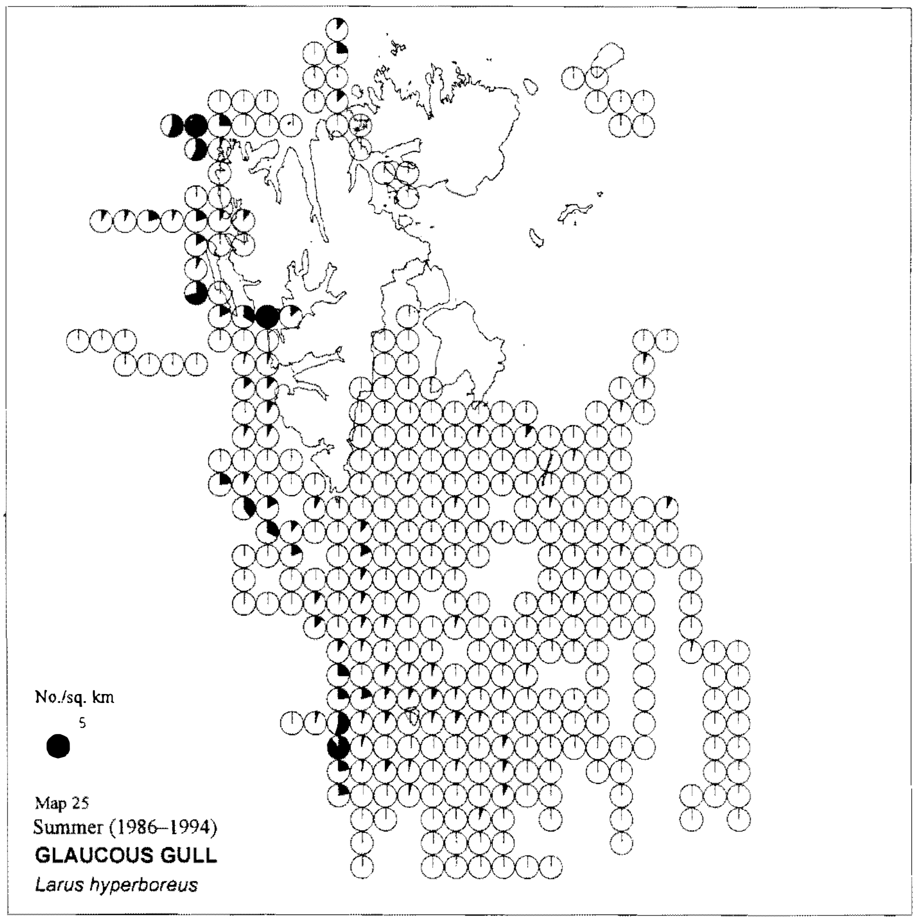
Map 22
Effort summer 1986-1994



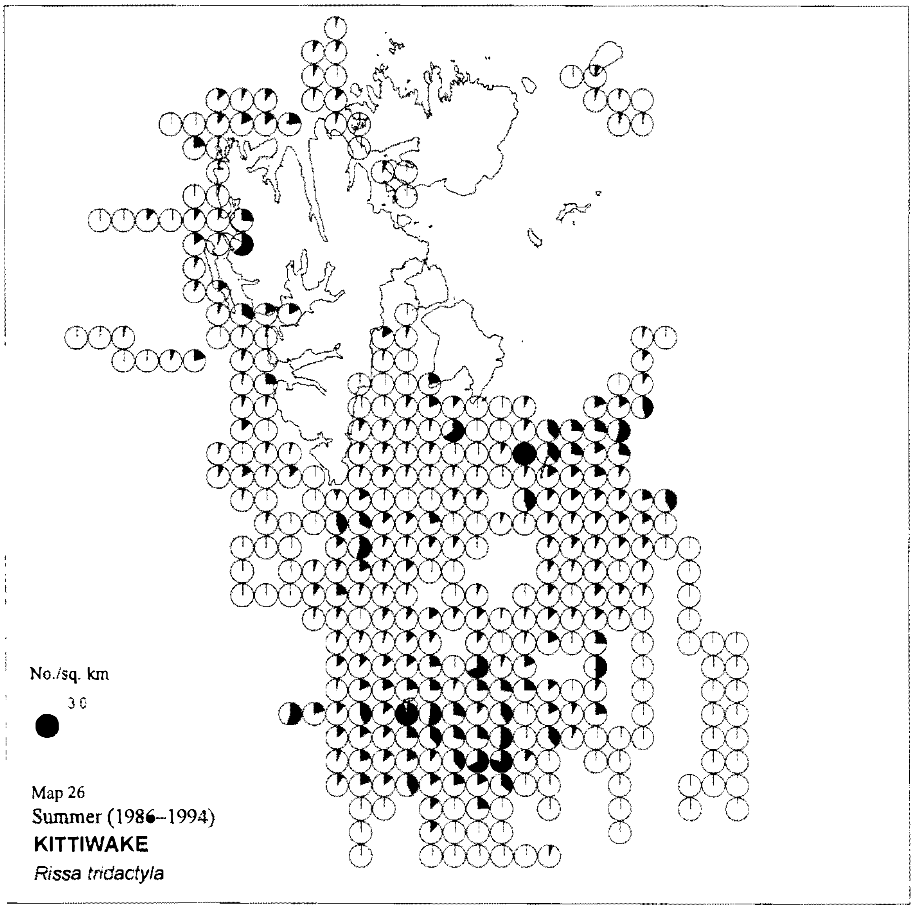
Map 23
Summer (1986–1994)
FULMAR
Fulmarus glacialis



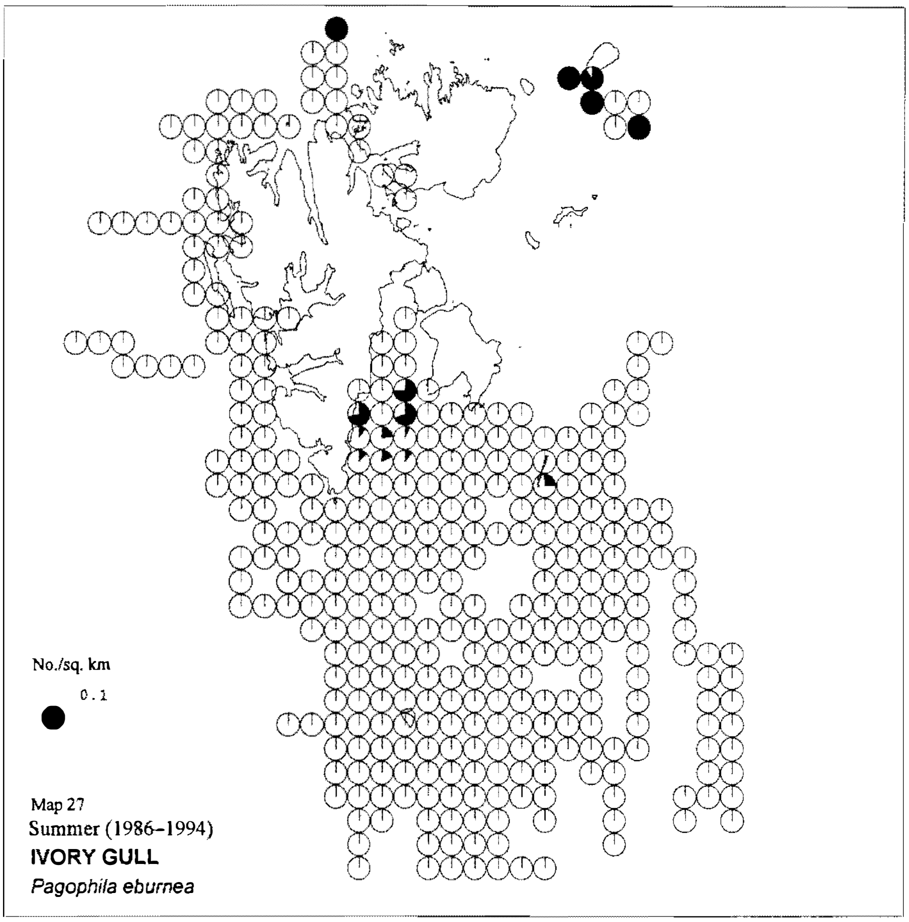
Map 24
Summer (1986–1994)
ARCTIC SKUA
Stercorarius parasiticus



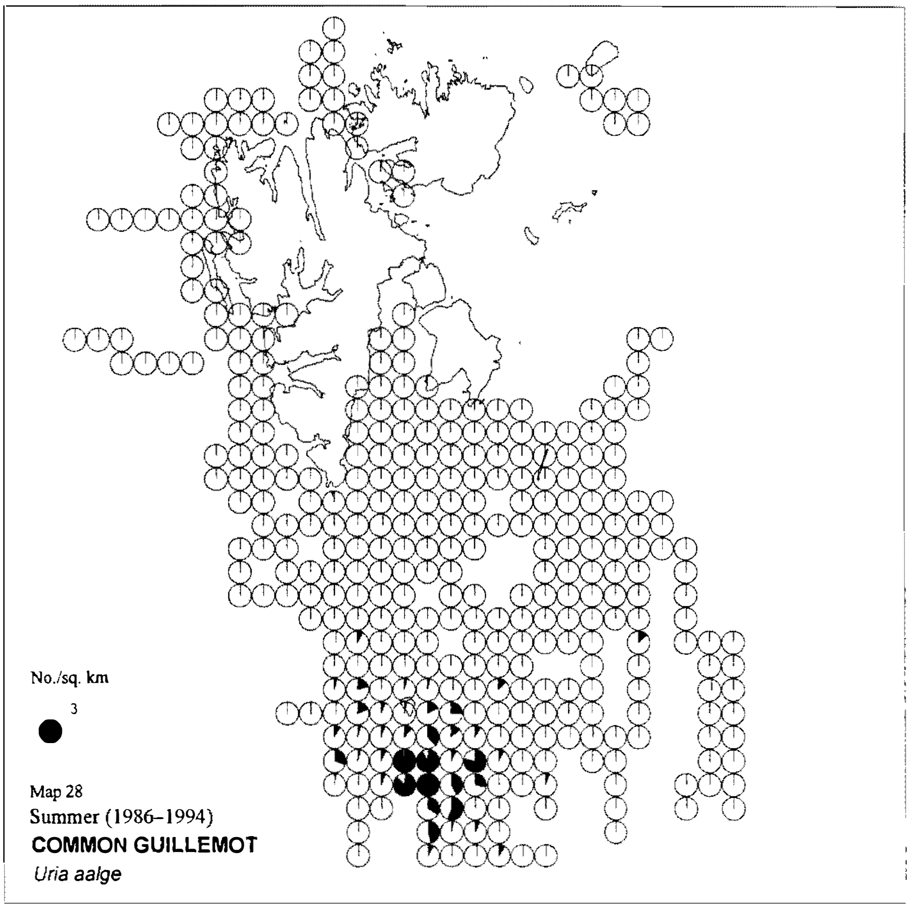
Map 25
Summer (1986–1994)
GLAUCOUS GULL
Larus hyperboreus



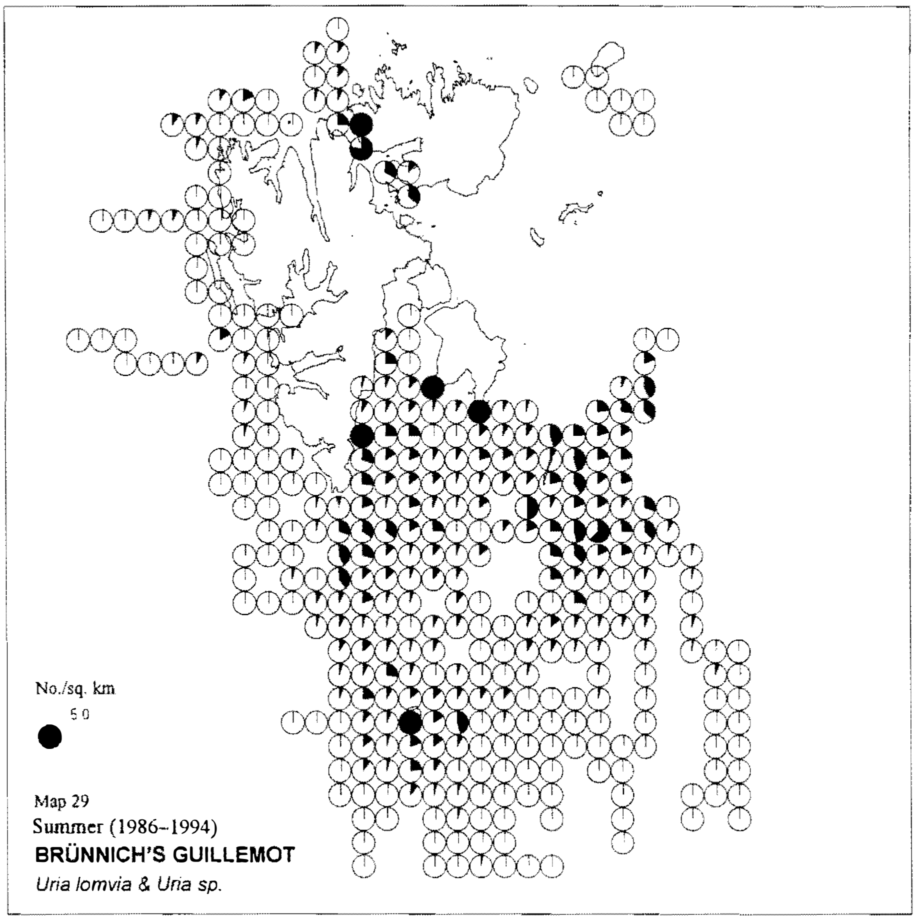
Map 26
Summer (1986–1994)
KITTIWAKE
Rissa tridactyla



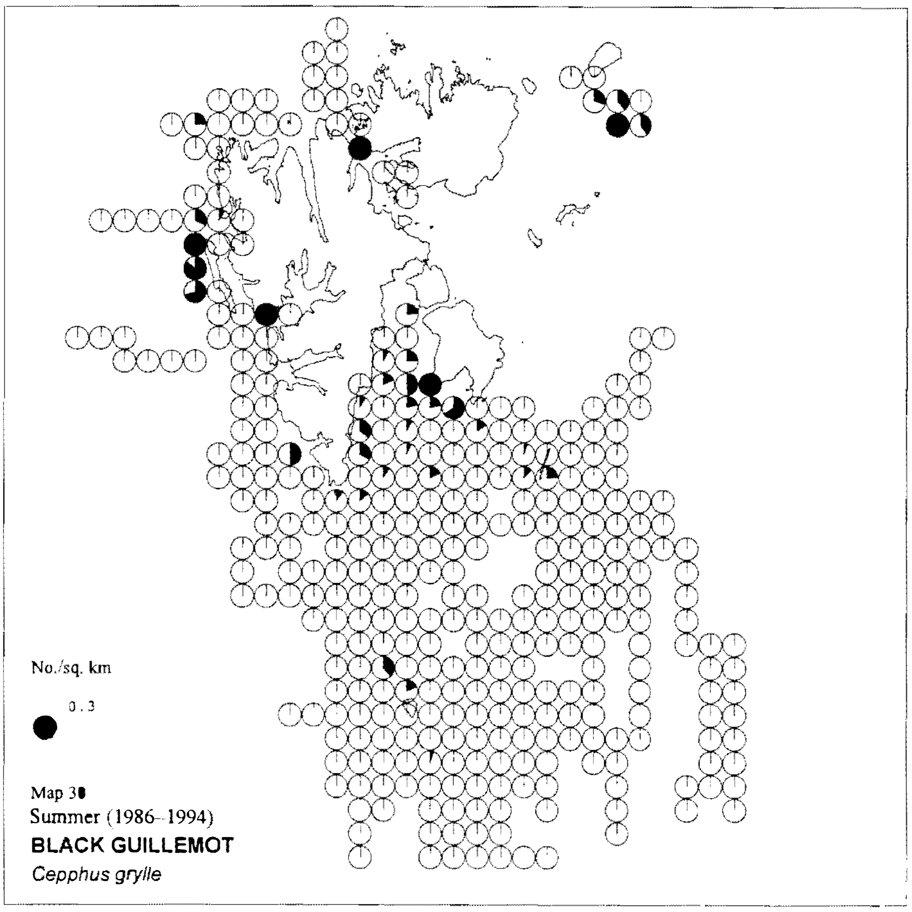
Map 27
Summer (1986–1994)
IVORY GULL
Pagophila eburnea



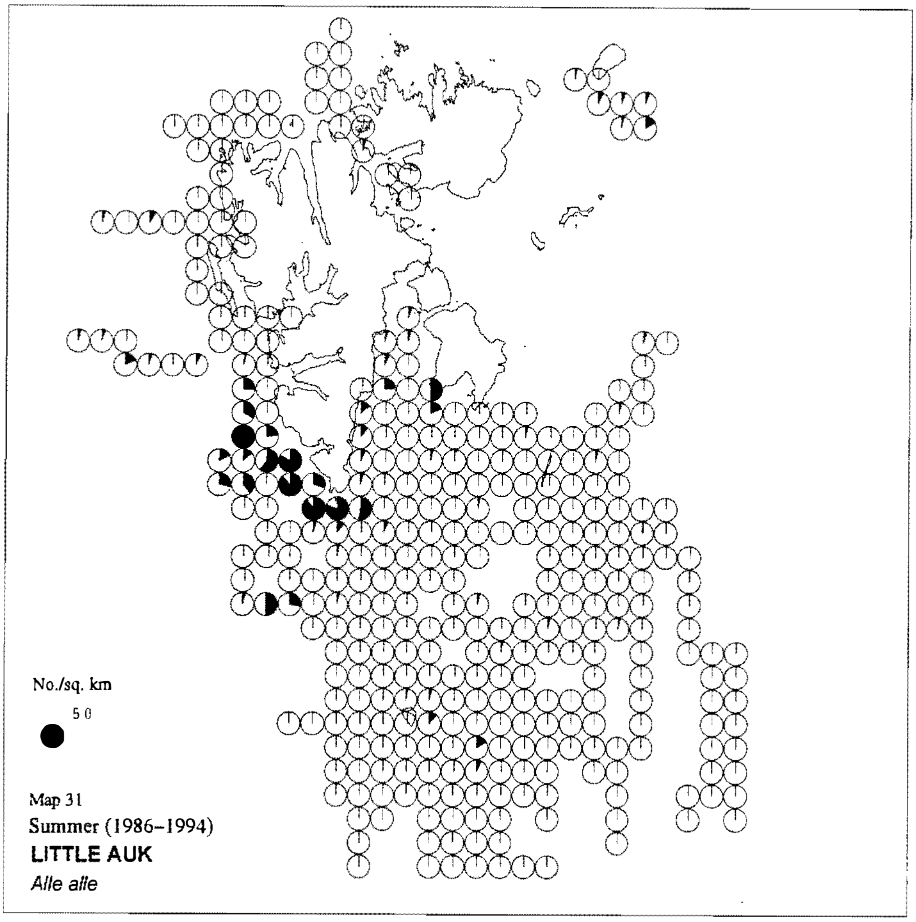
Map 28
Summer (1986–1994)
COMMON GUILLEMOT
Uria aalge



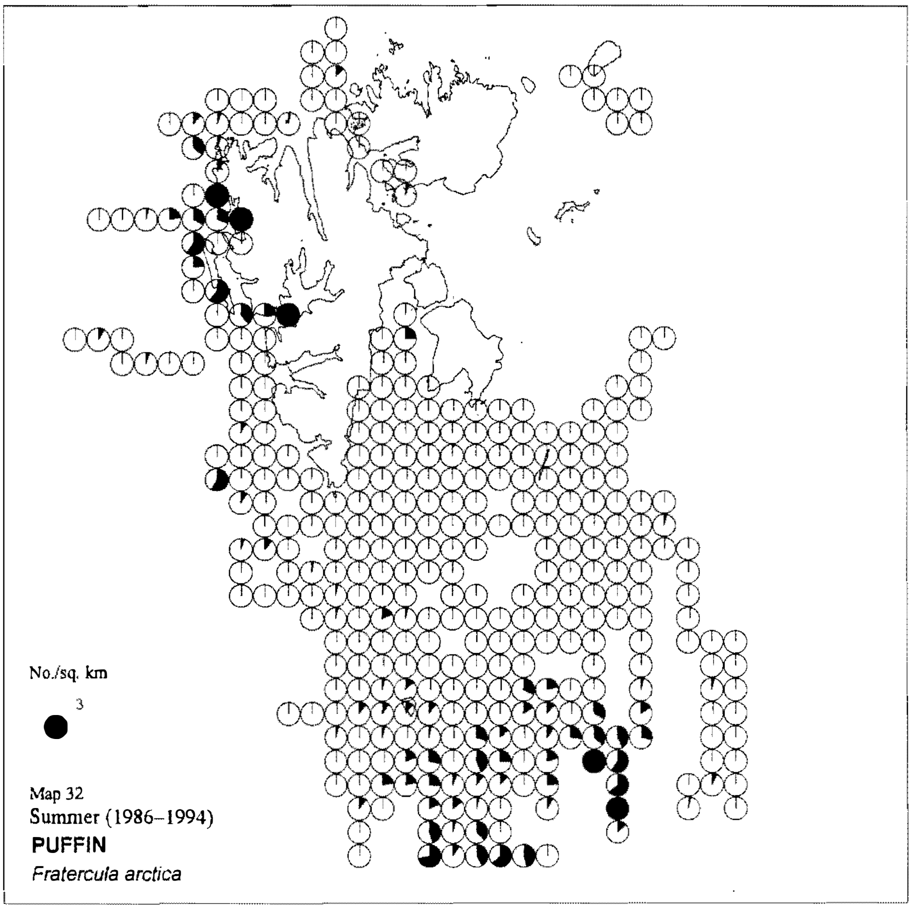
Map 29
Summer (1986–1994)
BRÜNNICH'S GUILLEMOT
Uria lomvia & Uria sp.



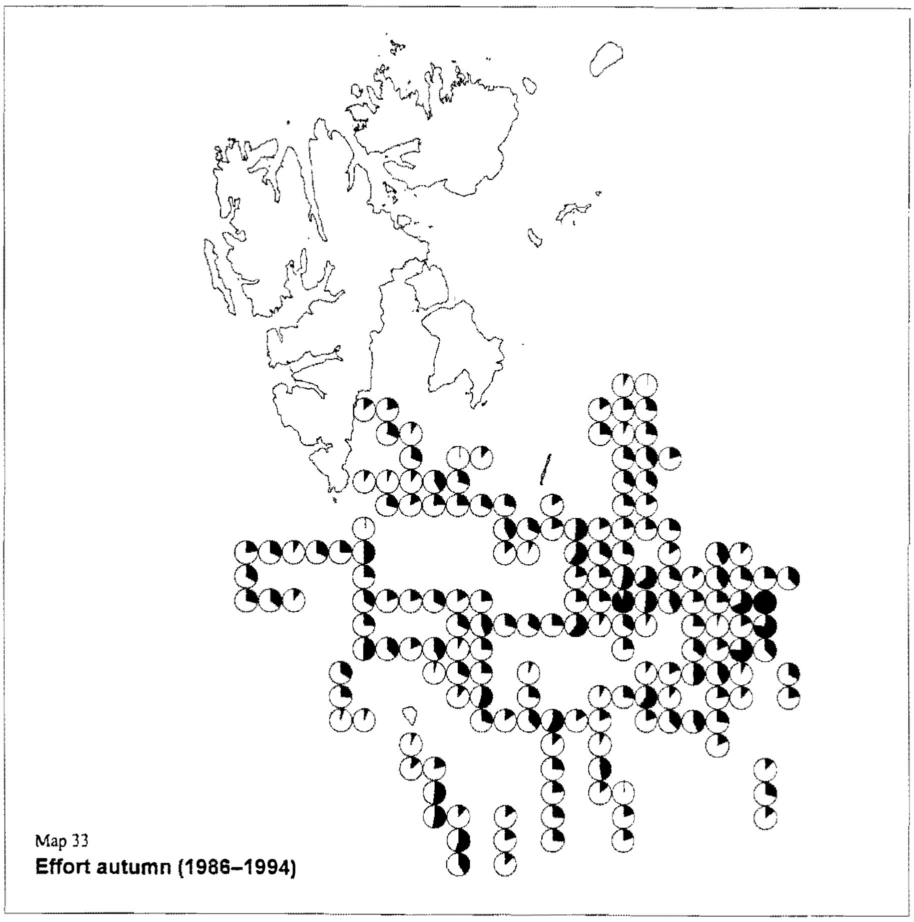
Map 30
Summer (1986–1994)
BLACK GUILLEMOT
Cepphus grylle



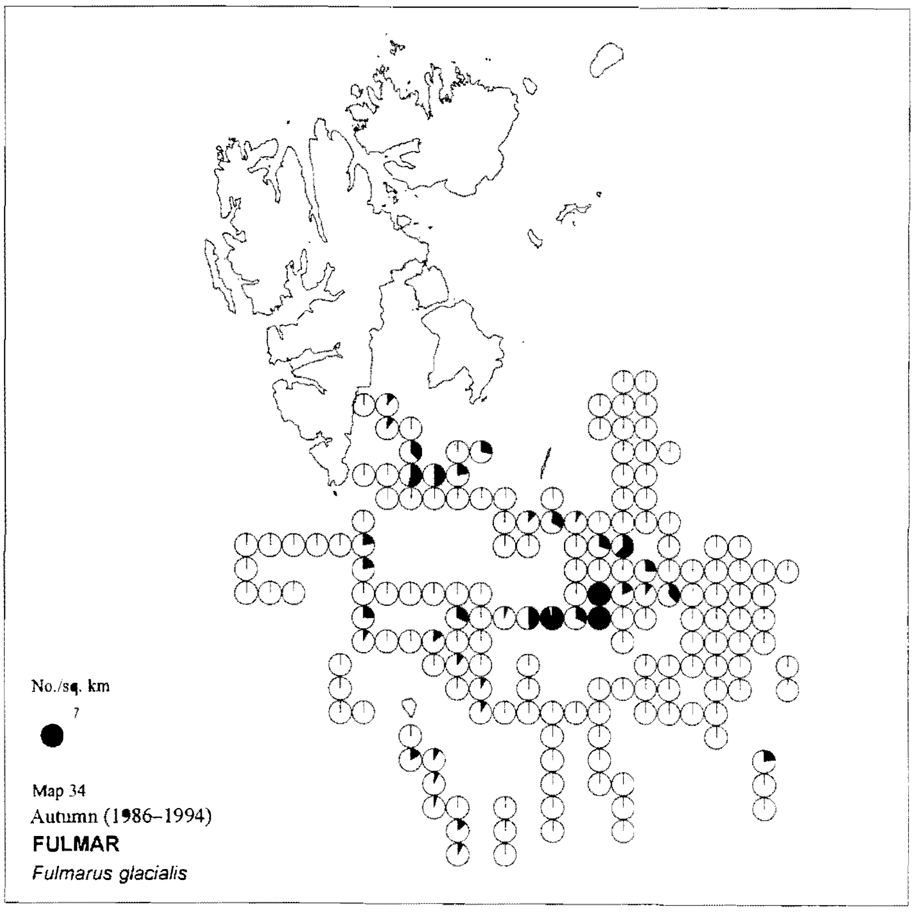
Map 31
Summer (1986–1994)
LITTLE AUK
Alle alle



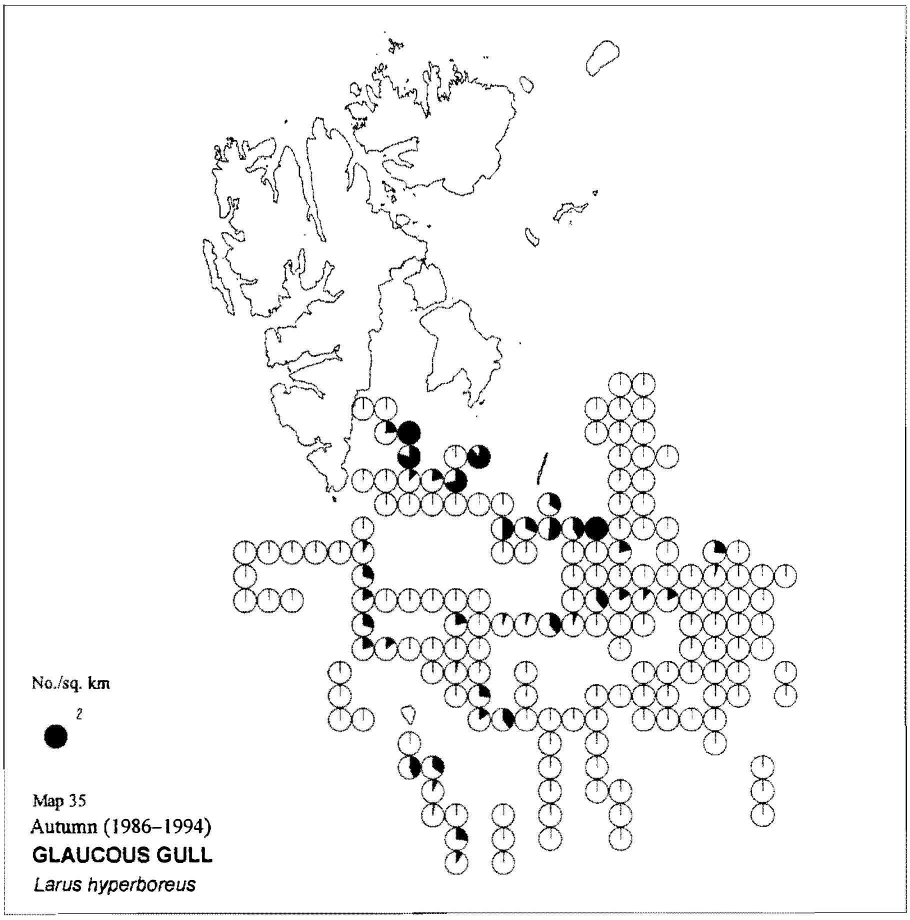
Map 32
Summer (1986–1994)
PUFFIN
Fratercula arctica



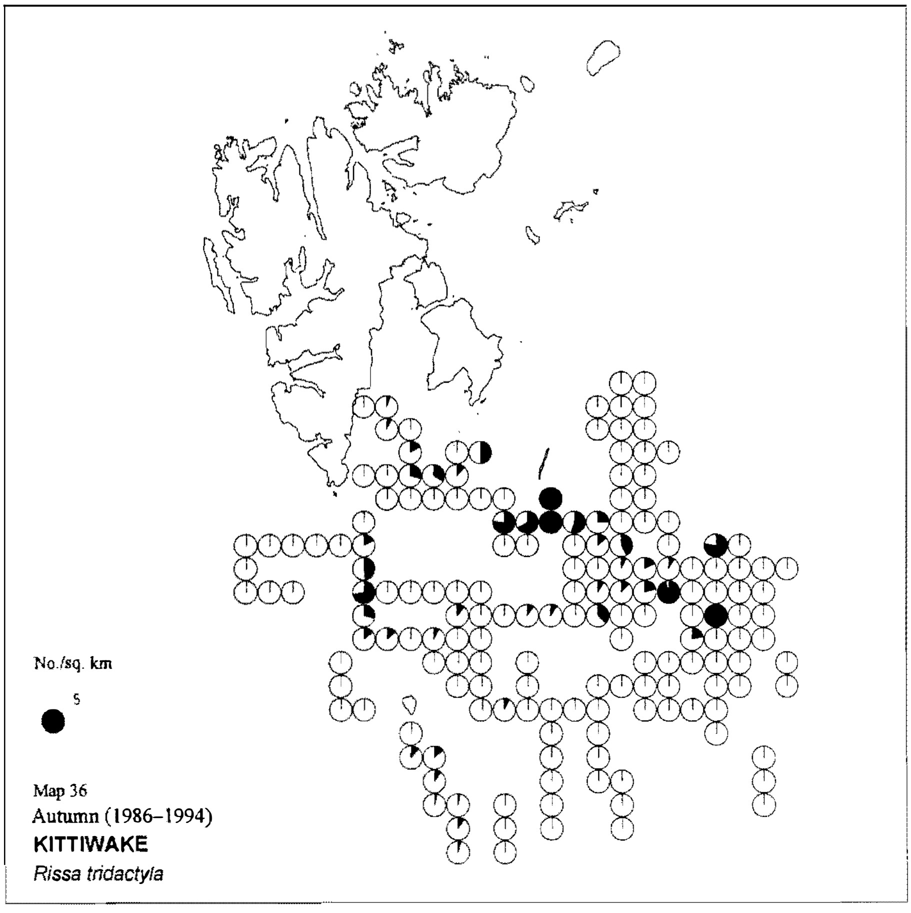
Map 33
Effort autumn (1986–1994)



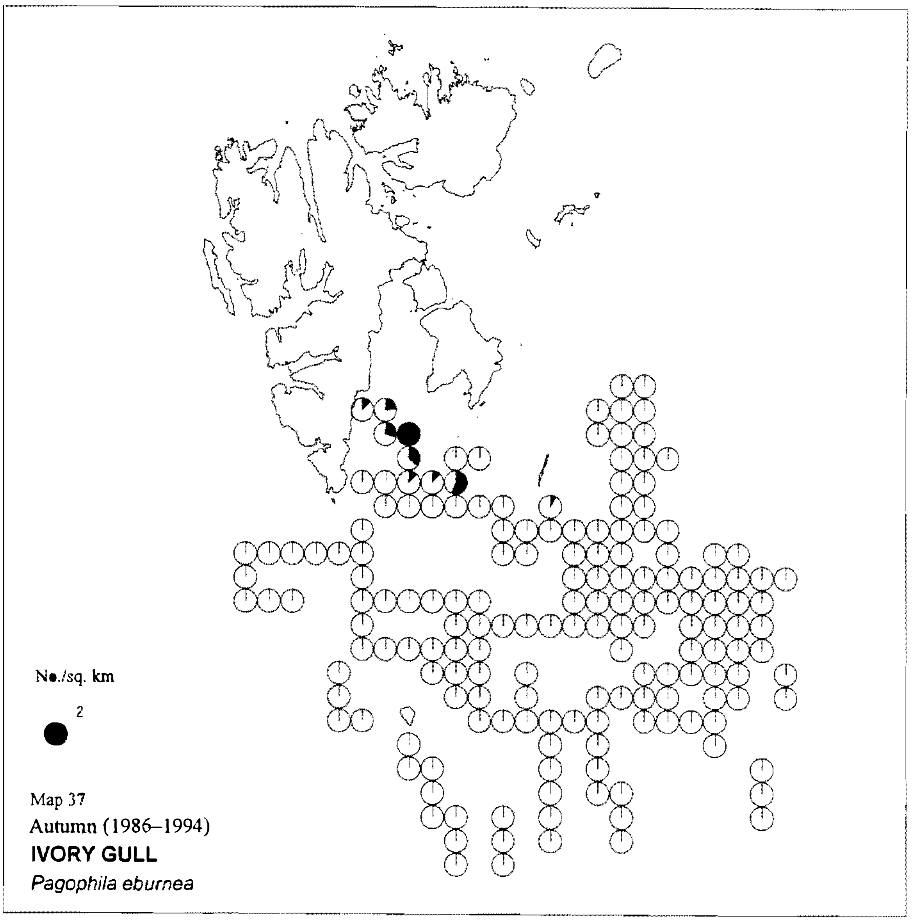
Map 34
Autumn (1986–1994)
FULMAR
Fulmarus glacialis



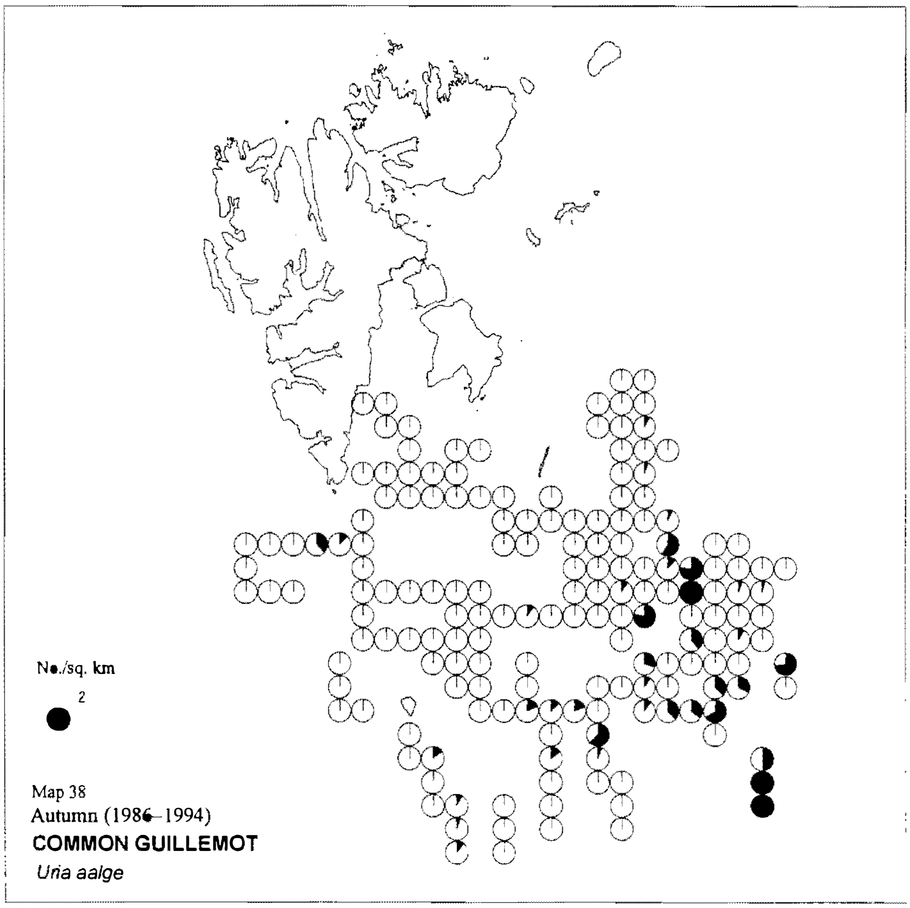
Map 35
Autumn (1986–1994)
GLAUCOUS GULL
Larus hyperboreus



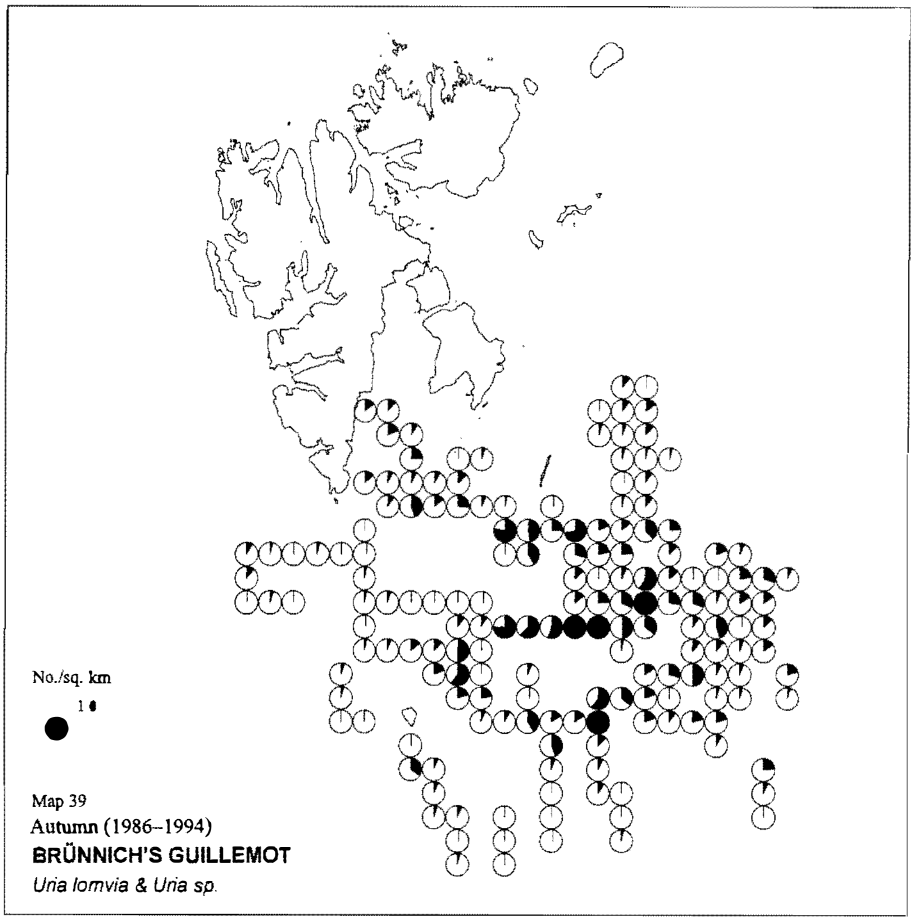
Map 36
Autumn (1986–1994)
KITTIWAKE
Rissa tridactyla



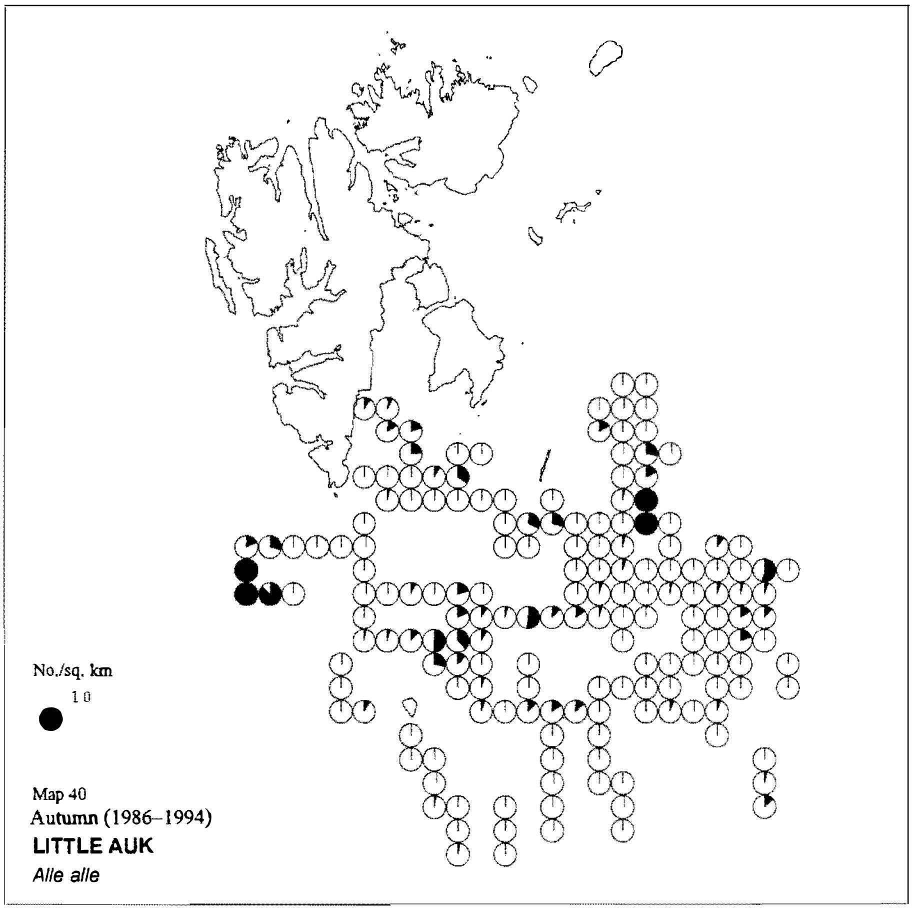
Map 37
Autumn (1986–1994)
IVORY GULL
Pagophila eburnea



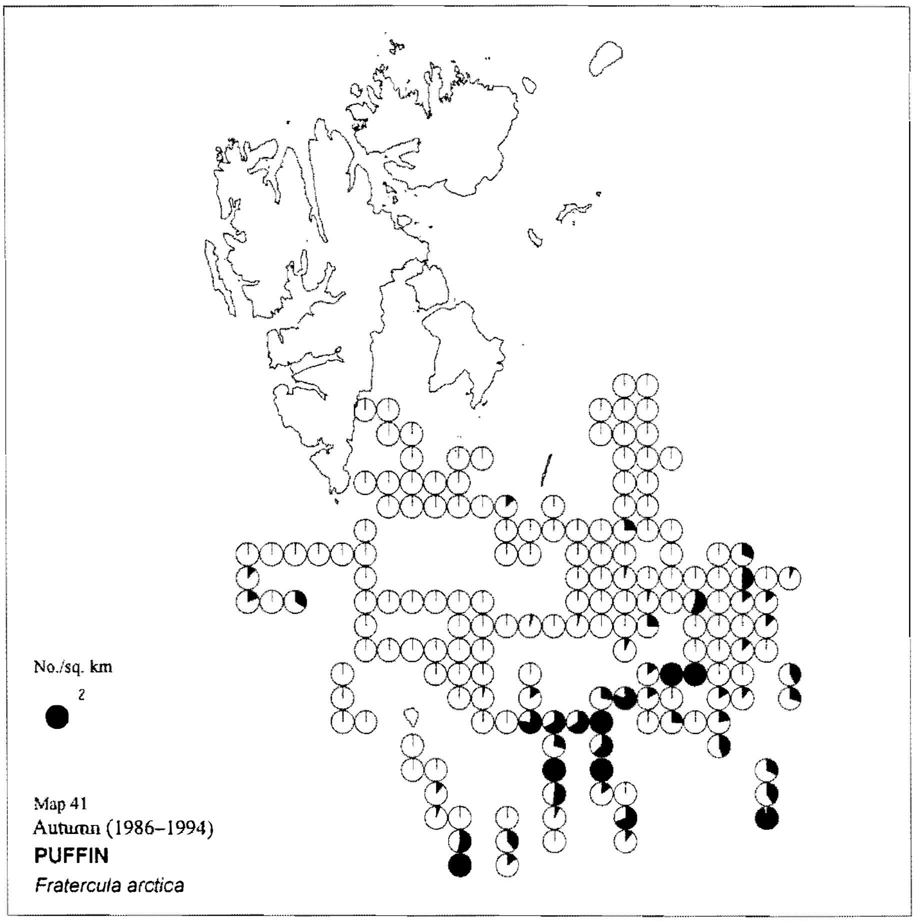
Map 38
Autumn (1986–1994)
COMMON GUILLEMOT
Uria aalge



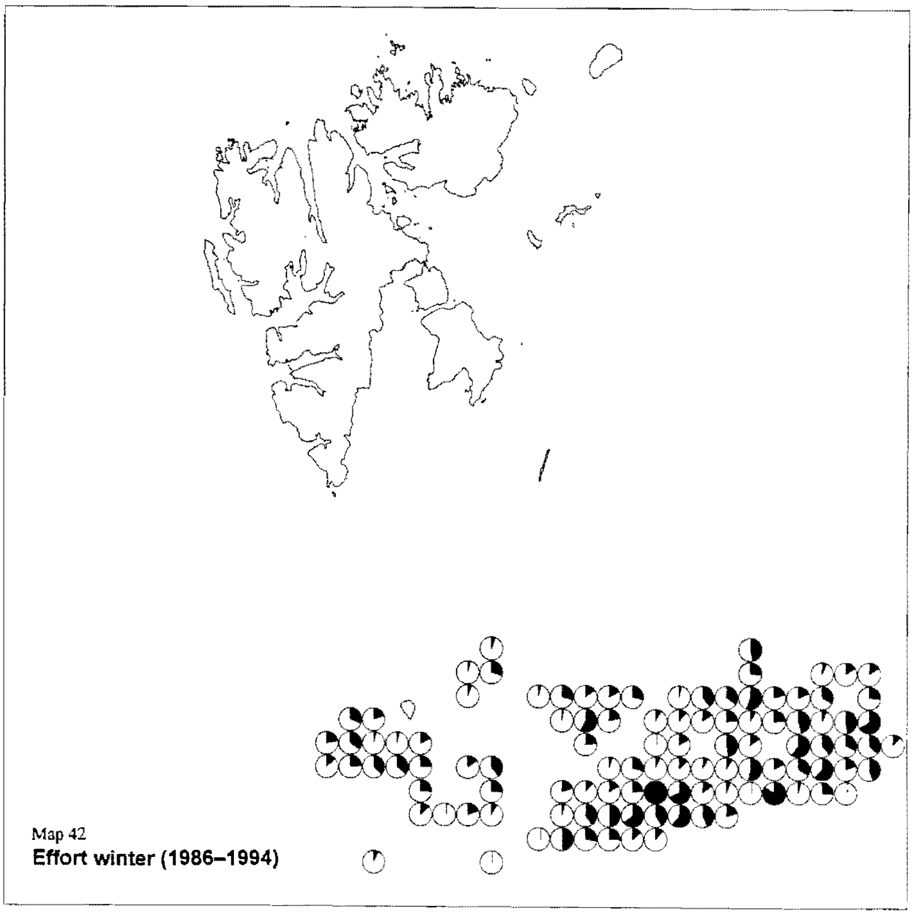
Map 39
Autumn (1986–1994)
BRÜNNICH'S GUILLEMOT
Uria lomvia & Uria sp.



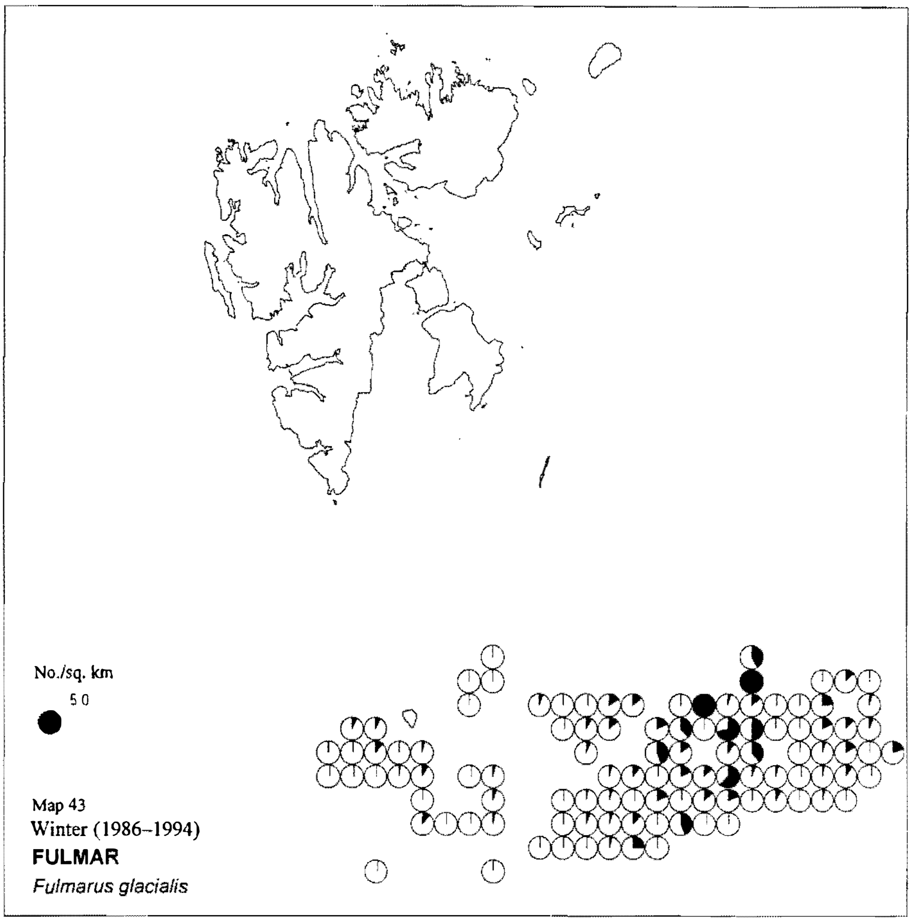
Map 40
Autumn (1986–1994)
LITTLE AUK
Alle alle



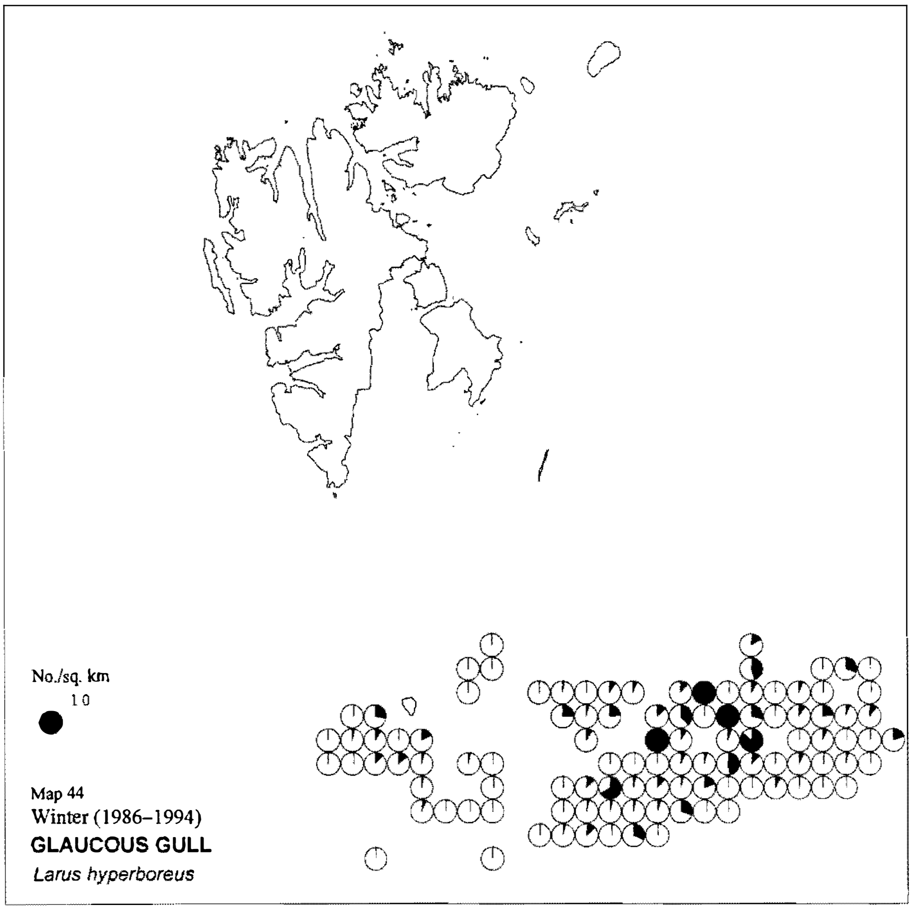
Map 41
Autumn (1986–1994)
PUFFIN
Fratercula arctica



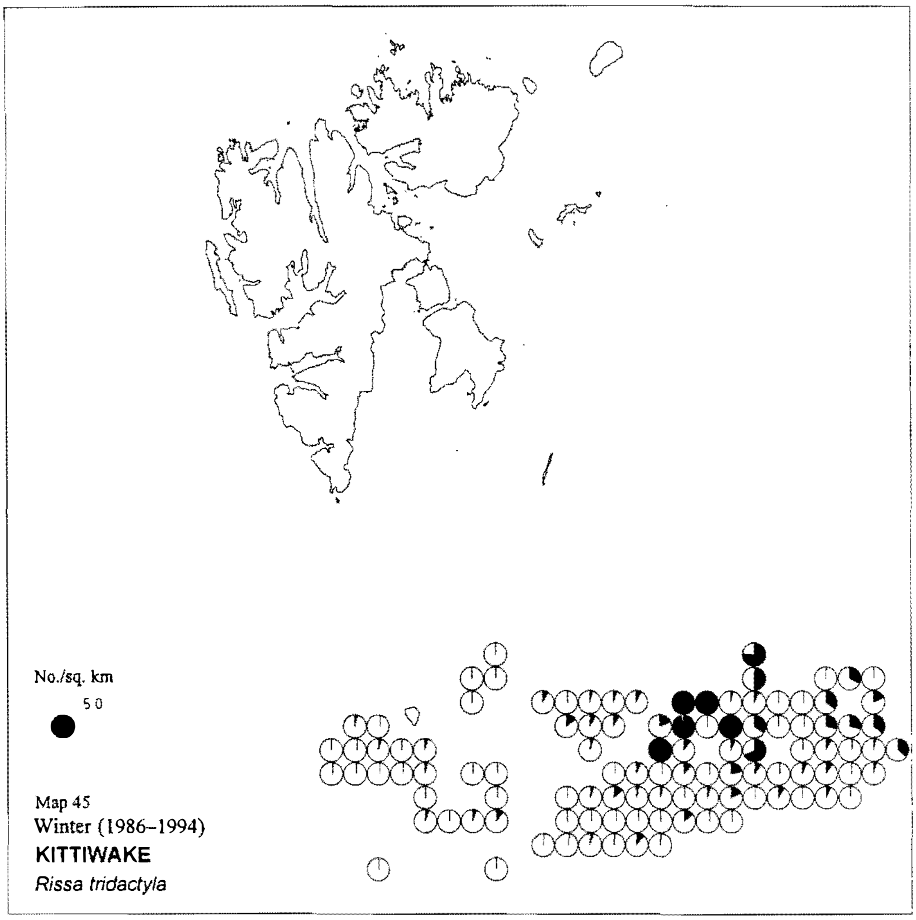
Map 42
Effort winter (1986–1994)



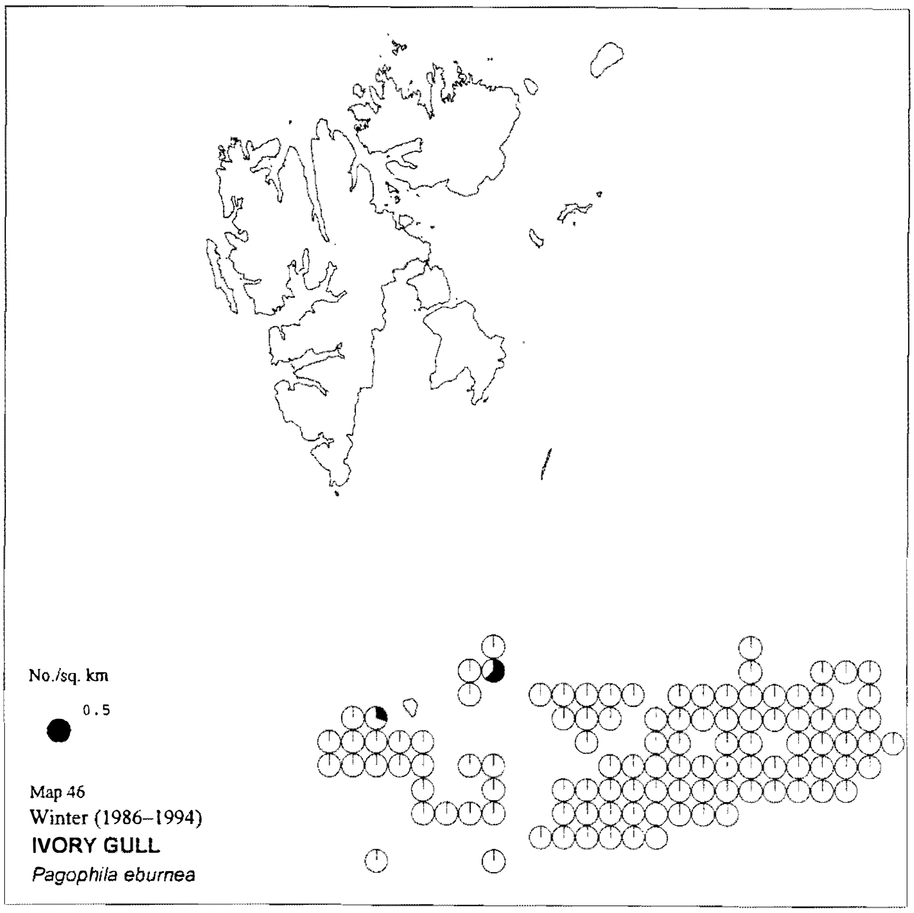
Map 43
Winter (1986–1994)
FULMAR
Fulmarus glacialis



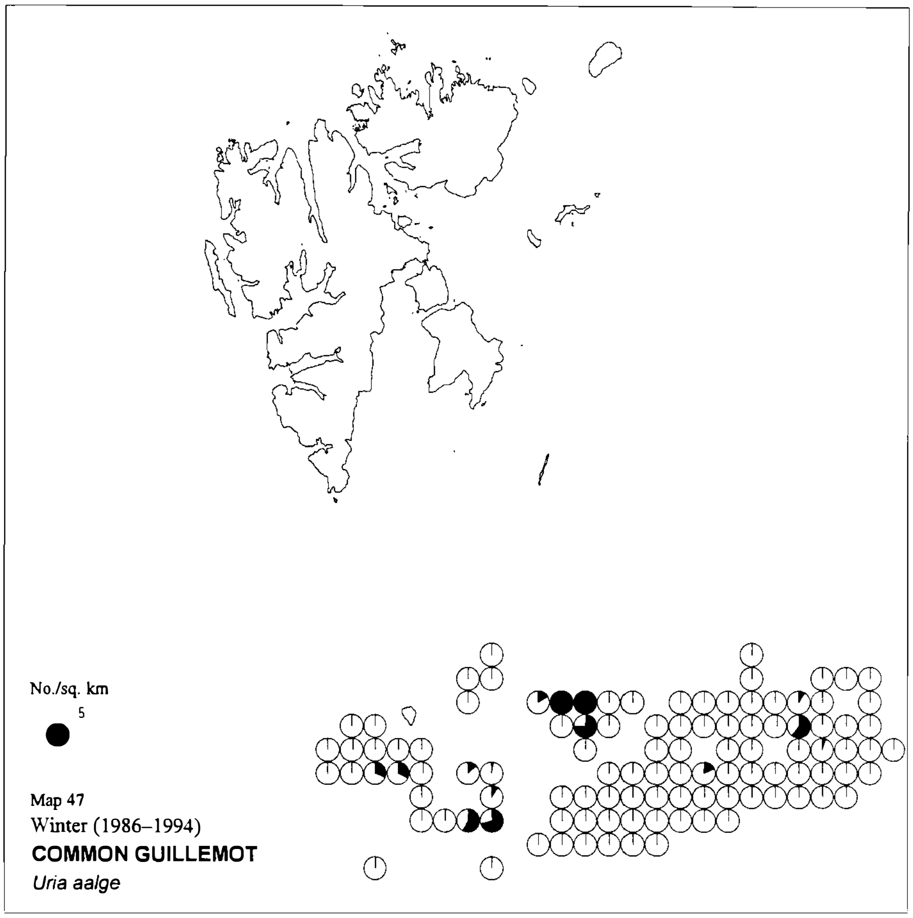
Map 44
Winter (1986–1994)
GLAUCOUS GULL
Larus hyperboreus



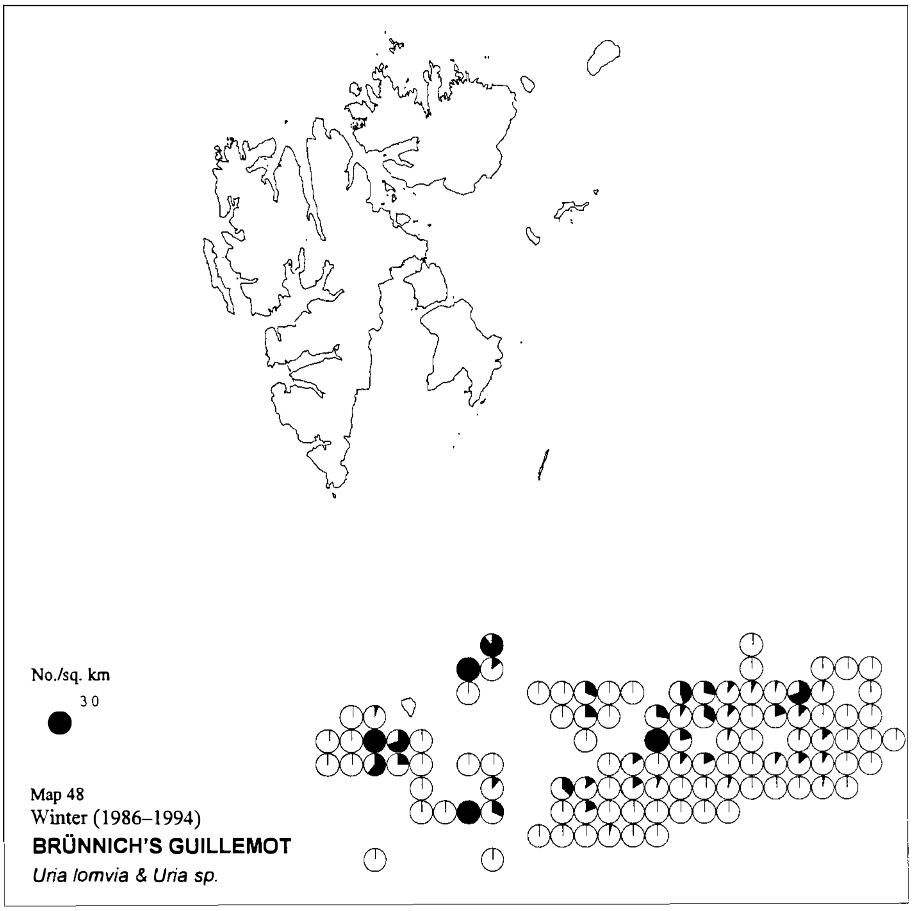
Map 45
Winter (1986–1994)
KITTIWAKE
Rissa tridactyla



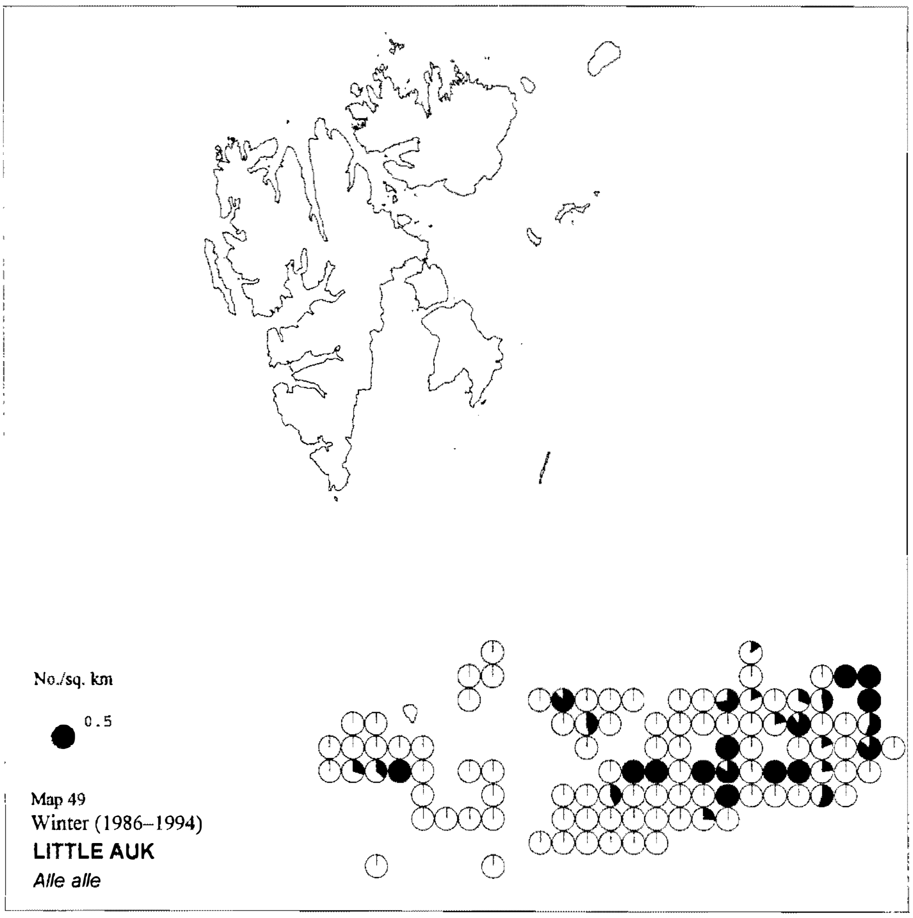
Map 46
Winter (1986–1994)
IVORY GULL
Pagophila eburnea



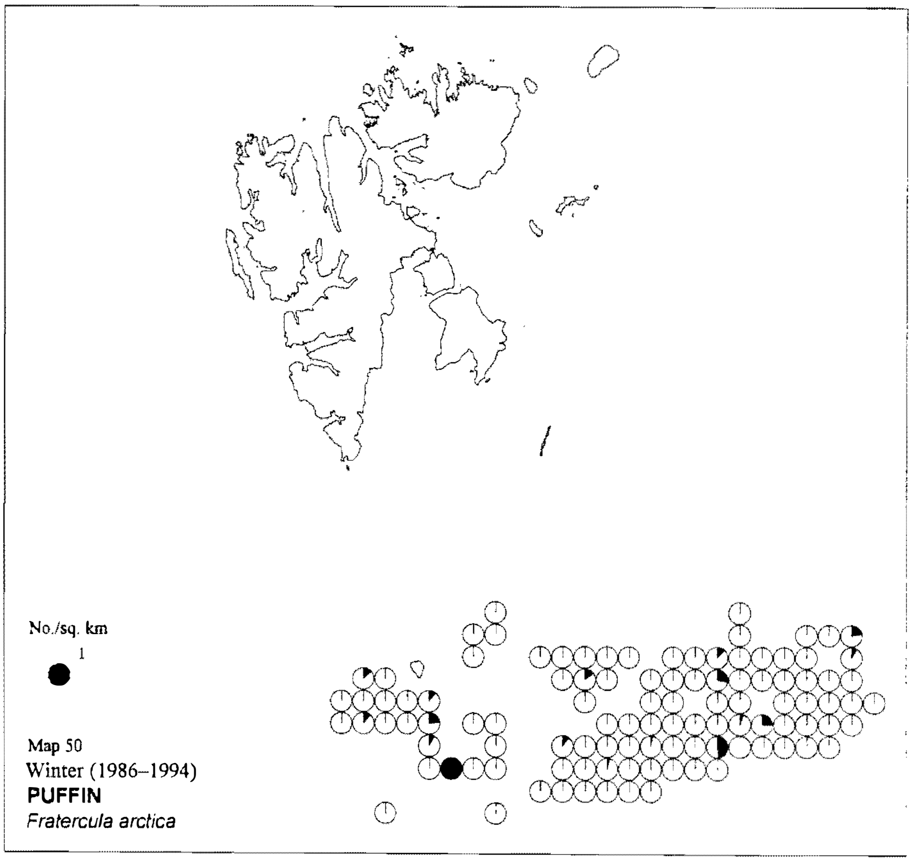
Map 47
Winter (1986–1994)
COMMON GUILLEMOT
Uria aalge



Map 48
Winter (1986–1994)
BRÜNNICH'S GUILLEMOT
Uria lomvia & Uria sp.



Map 49
Winter (1986–1994)
LITTLE AUK
Alle alle



Map 50
Winter (1986–1994)
PUFFIN
Fratercula arctica

THE PREDICTABILITY OF THE SPATIAL DISTRIBUTION OF GUILLEMOTS (*Uria* spp.) IN THE BARENTS SEA

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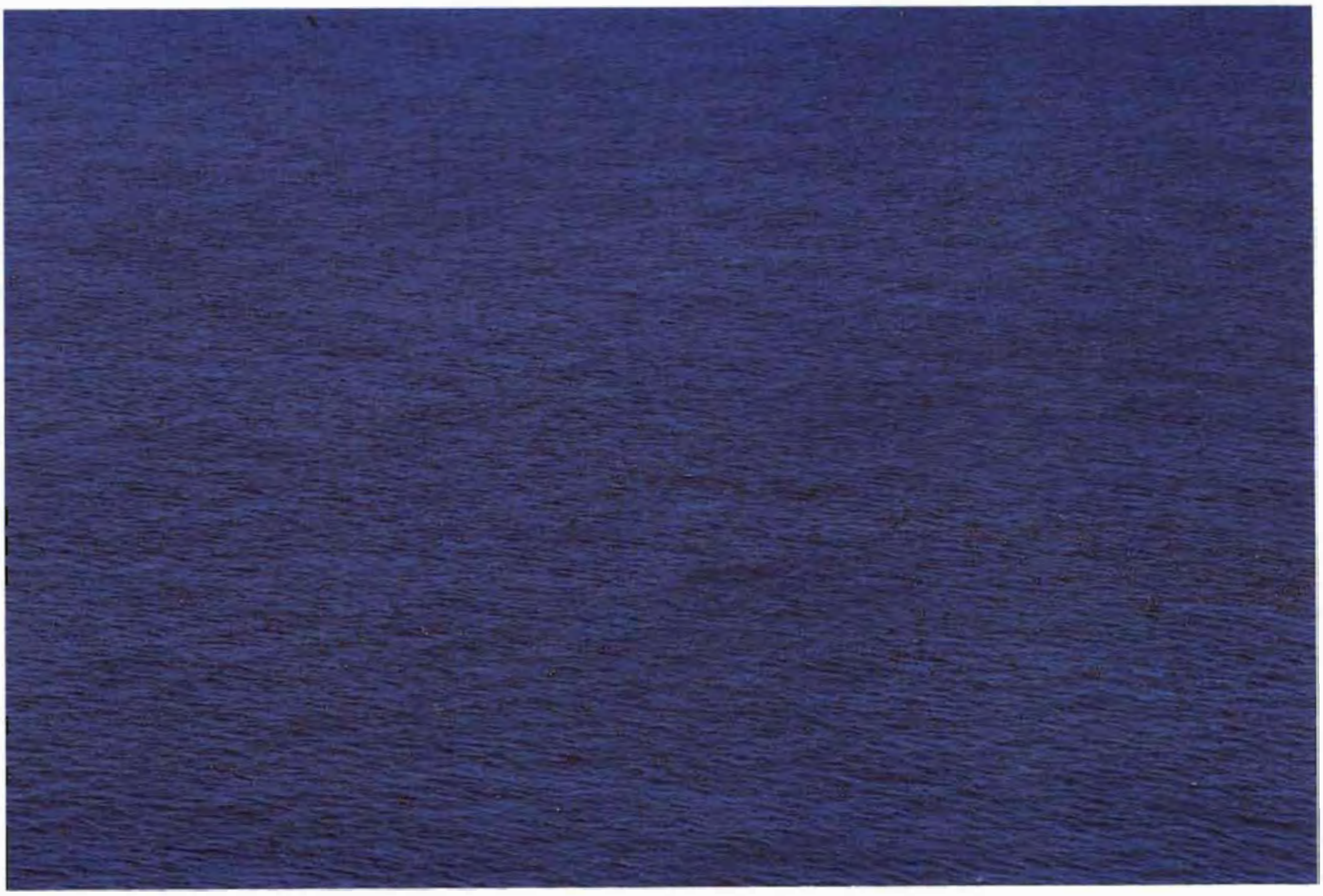

Large concentration of guillemots (*Uria* spp.) at sea. Photo by Vidar Bakken.

Abstract – Seabirds generally have a patchy distribution, and the vulnerability of a seabird population to an oil spill is therefore highly dependent on the time and location of the spill. In assessments of the effects of oil exploration on seabirds at sea, one central issue has been to predict where to find seabird aggregations in a given season. Such predictions have been calculated from datasets comprising counts of seabirds for only one or a few years. The value of such spatial predictions are highly dependent on the general spatial predictability of seabirds between years. In this study we investigate the spatial predictability of wintering guillemots (*Uria* spp.) in the Barents Sea from a nine-year period spanning from 1986 to 1994. The predictabilities were calculated from a simple Spearman rank correlation model, and the effects of scale and number of years included in the model were investigated. Even for large scales, and data from eight years of survey, only low spatial predictabilities of guillemots were found. Thus, this study does not support the assumption of a stable distribution of seabirds between years. It is suggested that the low spatial distribution of guillemots probably is due to variation in the general distributional pattern of their prime food, Capelin (*Mallotus villosus*).

INTRODUCTION

When assessing the effects on seabirds of oil exploration at sea, a common assumption is that seabirds have a stable spatial distribution for a given season between years. Despite the fact that this assumption has never been verified, most assessments have been made by using distributional data from a single year (e.g. Anker-Nilssen et al. 1988; Lorentsen et al. 1993; Strann et al. 1993).

At sea, seabirds have a highly patchy distribution. For example, Erikstad et al. (1990) found 50–60% of the guillemots (*Uria* spp.) counted along a 1050 km^2 transect in the Barents Sea in only 5% of the total area covered. At a given time, most of the guillemot population is therefore located only in a small fraction of the Barents Sea, and guillemots are more or less absent over vast areas. Accordingly, the vulnerability of guillemots to an oil spill is highly dependent on the location of the spill. In this context, the validity of earlier assessments depends heavily on the assumption of a stable seabird distribution. In general, seabirds track their prey over large areas and a low spatial predictability should be expected. On the other hand, prey are often aggregated at rather stable places, such as the continental edge, or at oceanographic fronts. Thus, the probability of finding seabird aggregations at such places should be rather high (reviewed by Hunt & Schneider 1987).

In this report we investigate the predictability of the spatial distribution of guillemots between years in the Barents Sea. The species investigated are the most abundant seabird species wintering in the Barents Sea: Common Guillemot (*Uria aalge*) and Brünnich's Guillemot (*Uria lomvia*) (Erikstad et al. 1990). Furthermore, these two species are among the most vulnerable species with relation to oil exploration in Norwegian waters (Anker-Nilssen et al. 1988; Strann et al. 1993). The dataset used in the present analyses comprises counts of seabirds in the same area and from the same period of the year (January–March) during a nine year period spanning from 1986–1994.

Scale is an important parameter in ecological studies (Levin 1992). The spatial distribution of organisms depends on the scale of measurement (Rose & Leggett 1990). Consequently, the spatial predictability of seabirds also varies with scale. One way to deal with scale is to divide the area under investigation into frames, and estimate the predictability of seabirds for different frame sizes. Obviously when predictability is a factor in the system, predictability will increase with increasing scale; dividing the Barents Sea into large frames will give a high predictability, while dividing the Barents Sea into very small frames will give a low predictability. In this study we divided the Barents Sea into frames with sizes from 5x5 to 500x500 km, and estimated the density of birds in each frame covered in the surveys. The spatial predictability from year to year at a given scale can loosely be defined as the association between densities of birds in each frame between years. That is, the tendency of high densities to occur in the same frame, and the tendency of low densities to occur in the same frame.

The main objective of this study was to determine the scale (frame size) at which there was a significant spatial predictability of guillemot distribution between years. Secondly, we evaluate how this predictability increases with the increasing number of years included. That is, how many years of investigation are necessary to give a maximum predictability of the spatial distribution of guillemots between years. Finally we present an estimate of the distribution of guillemots in the Barents sea in the period from January to March in relation to the estimate of the predictability.

MATERIALS AND METHODS

Counts of seabirds

Counts of seabirds were made by attending The Norwegian Institute of Marine Research's regular winter surveys in the Barents Sea. These surveys cover all ice-free parts of the Barents Sea. Due to short periods of daylight, the counts could not be carried out continuously. Furthermore, the surveys attended differ from year to year. Accordingly, the areas covered do not completely overlap between years (see Appendix 1). Because of the difficulties in discriminating between Common and Brünnich's Guillemots during the winter, the two species are treated together.

Birds were counted from the top of the vessel's bridge (10 m above sea level) in 300 m transects and 10 min blocks on one side of the ship. The speed of the ship was about 10 knots, such that counts covered an area of about 0.92 km^2 in 10 min.

Data analyses

For geographical interpretation, the dataset was divided into UTM-zones, and the density of *Uria* spp. were estimated for each zone. Frame size was varied from 5x5 to 500x500 km.

Only non-parametric statistical tests were applied in the analyses since the distribution of guillemots in open sea is highly aggregated.

To test for spatial predictability of bird distribution, we first used Kruskal-Wallis H statistics. Kruskal-Wallis test is a non-parametric rank test for comparison of groups. In our case each group represents a geographical frame with respect to year. Kruskal-Wallis H gives a measure of heterogeneity between frames, and thus gives a measure of the tendency of high ranks to occur in the same frame, and the tendency of low ranks to occur in the same frame (Eq. 1).

$$H = \frac{12}{n(n+1)} \sum_{i=1}^{k} n_i \left(\overline{R_i} - \overline{R}\right)^2 \text{, where}$$

n = total number of ranks

k = total number of frames (Eq. 1)

$\overline{R_i}$ = mean rank in frame i

$\overline{R}$ = mean of all ranks

In this analysis we used randomisation to test for significance. We randomised the dataset 10,000 times and counted the number of times the randomised H were equal to or larger than the measured H.

However, Kruskal-Wallis H does not give any quantitative measure of predictability between years. Accordingly, the test does not provide the opportunity to compare the predictability between different scales or between different numbers of years included. We therefore used Spearman rank correlation coefficient (R_S). R_S gives, in our case, a measure of how much of the spatial variation in ranks in one year that can be explained by the spatial variation in ranks in one or several other years. Thus, R_S gives a measure of predictability between years.

To estimate the general predictability between one year and one or several other years, we applied the following model: The year to be explained (dependent variable) was selected from the dataset of nine years. One other year (independent variable) were selected from the remaining eight years. When including more than one year in the independent variable, all the including years were selected from the dataset and mean density in each frame was calculated before ranking. Spearman rank correlations were then calculated for all possible combinations of dependent and independent variables for different numbers of years in the independent variable. Thus, the model includes additional years stepwise into the independent variable. Mean R_S, standard error of R_S and number of significant rejections ($p<0.05$) of independence between the two variables were calculated from all sets of combinations. This procedure was applied to different scales (different frame sizes).

RESULTS AND DISCUSSION

Guillemots and Capelin in the Barents Sea

Capelin (*Mallotus villosus*) is the main food item for guillemots in the Barents Sea during the winter (Belopol'skii 1957; Furness & Barrett 1985; Erikstad & Vader 1989). There have been large fluctuations in the Capelin stock during the last decade (Fig. 1). In 1986, when the first survey was conducted, the Capelin stock was about to collapse. The collapse of the Capelin stock in 1986–87 was probably the main cause of mass mortality of Common Guillemots during the winter of 1986–87 when as many as 50% of the breeding population in some colonies in the Barents Sea died (Vader et al. 1990). The Capelin stock increased in the beginning of the nineties, and reached a maximum in the 1992 survey. Since then, the stock has declined and is today at very low densities (Anon. 1994).

Except for two years (1991 and 1992) there was a variable but significant spatial association between guillemots and Capelin (own data). The low association in 1991 and 1992 was probably due to predator saturation. That is, the number of Capelin patches was much larger than the number of patches the guillemots were able to exploit. These results suggest that the spatial distribution of guillemots is determined to a high degree by the spatial distribution of Capelin. In January, the start of each survey, the maturing Capelin ascend to the surface layers and start their spawning migration to the coasts of Kola and Finnmark (Ozhigin & Luka 1984). Large flocks of seabirds and cod (*Gadhus morhua*) normally track Capelin along this migration route (Erikstad & Vader 1989). Large scale changes in the water temperature have shown to generate displacements both in the wintering area and the main spawning grounds for maturing Capelin. Thus the migration route may change significantly from year to year (Ozhigin & Luka 1984).

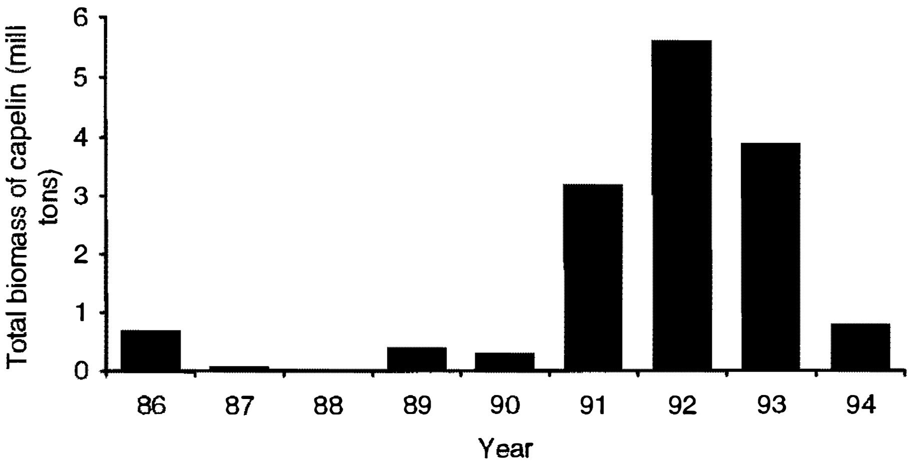

Fig. 1. Capelin stock biomass (> 2 years) in the Barents Sea estimated in autumn. Data from Anon. (1994).

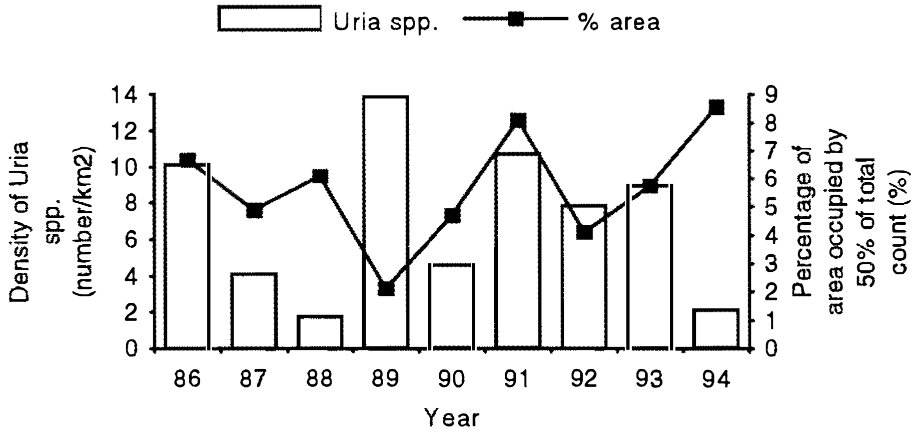

Fig. 2. Mean density of guillemots (*Uria* spp.) and minimum percentage of total area occupied by 50% of the total counts of guillemots in each survey. Scale 5x5 km.

The mean density of guillemots varied between years (Fig. 2). This probably not only reflects fluctuations in the population, but must in addition be an effect of changes in the main wintering areas. Such changes could be triggered by low prey densities in the Barents Sea. However, there seems to be no simple relationship between the size of the Capelin stock and the abundance of guillemots in the Barents Sea.

The distribution of guillemots was highly aggregated in all years. The percentage of the total area occupied by 50% of the counted guillemots varied between 2–9% (Fig. 2). There seems to be no association between this measure of aggregation and the mean density of birds, nor with the size of the Capelin stock.

Test of predictability

Despite the large variation in the environmental factors which may influence the spatial distribution of guillemots between years, we found a significant predictability of the guillemot distribution for all scales when applying the Kruskal-Wallis statistics (Table 1). We could therefore reject the null hypothesis that there is no heterogeneity between frames with respect to years. However, as mentioned above, the Kruskal-Wallis test gives no quantitative, comparable measure of predictability.

The Spearman rank correlation model

When applying the Spearman rank correlation model, we tested how the mean and standard error of correlation in ranks varied between one year and from one to several other year(s). Generally, mean R_s were positive, and increased with both number of years included and scale (Fig. 3). However, the predictability was generally low. The maximum mean R_s were found for frame size 150x150 km and 8 number of years included (R_s=0.5, S.E.=0.16). Thus, in average only 25% of the variation in the spatial distribution of ranks in one year could be explained by the other 8 years at this scale.

Table 1. Results from the Kruskall-Wallis test (see text). P-value was found by 10,000 randomisations of the dataset.

Scale (km)	Number of ranks (n)	Number of frames (k)	Mean H random	Variance H random	Observed H	P-value $P(H_{rand} \geq H_{obs})$
5x5	602	287	251.1	226.9	276.7	0.046
10x10	695	314	298.5	318.5	349.0	0.003
15x15	701	308	298.3	320.4	354.2	0.001
20x20	701	295	287.5	317.5	351.5	0
30x30	624	241	236.8	282.7	319.2	0
40x40	549	195	192.3	242.9	251.0	0
60x60	411	117	115.3	155.6	176.8	0
80x80	321	81	79.5	113.3	145.0	0
100x100	256	57	55.8	83.2	98.7	0
150x150	166	33	32.0	48.0	80.7	0
200x200	127	23	22.0	33.7	52.7	0
250x250	98	18	16.9	26.2	48.6	0
300x300	83	15	14.0	21.7	37.0	0
350x350	67	11	10.0	15.3	32.1	0
400x400	65	13	12.0	18.1	33.6	0
500x500	46	10	9.0	12.9	23.9	0

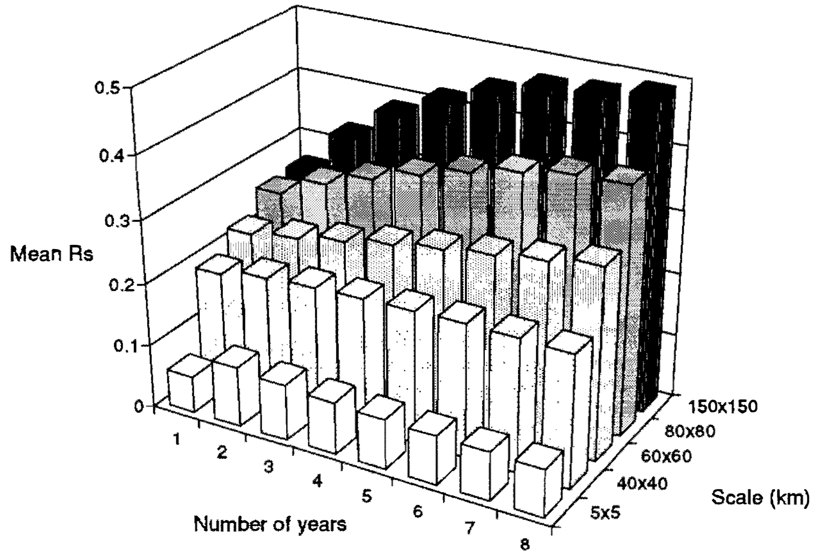

Fig. 3. Mean Spearman rank correlation (R_s) for all possible combinations of one year and 1–8 other year(s) for different scales.

When increasing the number of years included in the model, the mean predictability (R_s) at small scales did not increase (Fig. 3 and 4). In other words, including more years does not increase the possibility of predicting seabird aggregations at small scales. For larger scales, mean predictability (R_s) generally increased and levelled off at about 5–7 years (Fig. 4, Table

2). This effect is probably due to the effect of reducing non-predictable 'noise' in the main distributional pattern in the independent variable when including more years in the model. The percentage of significant correlations in the model, generally increased with increasing number of years included (Fig. 5). This is probably an effect of both reducing 'noise' and increasing mean sample size (Table 2). For instance, the scale 80x80 km has a higher percentage of significant correlations compared to scale 150x150 km, which presumably is an effect of reduced mean sample size as scale is increased (Table 2).

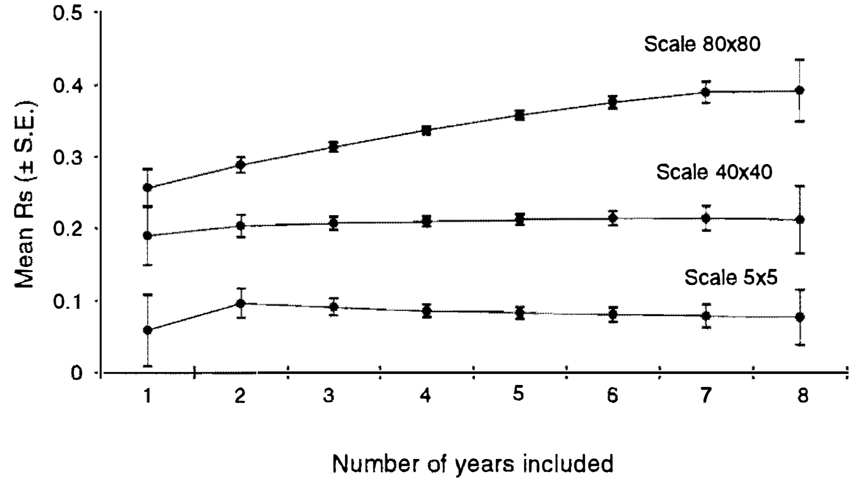

Fig. 4. Mean Spearman rank correlation coefficient (± 1 S.E.) for all possible combinations for one year and 1–8 other year(s) for scale 5x5 km, scale 40x40 km and scale 80x80 km.

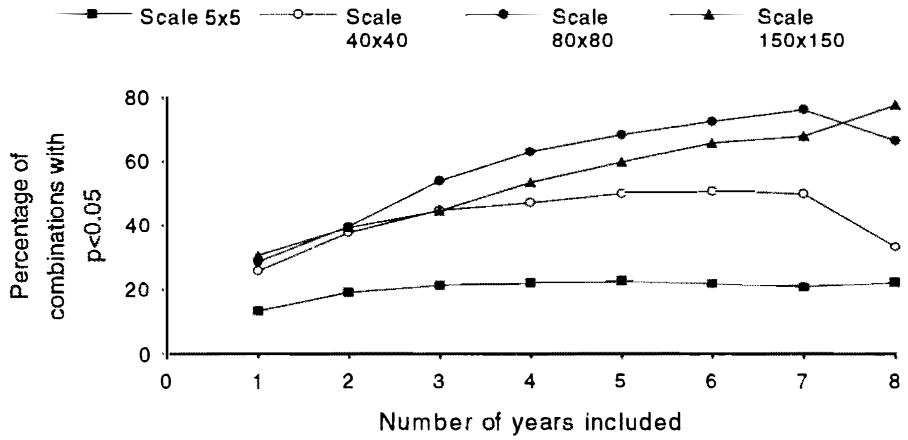

Fig. 5. Percentage of combinations with a significant ($p<0.05$) rejection of the null-hypothesis of independence between one year and 1–8 year(s) for different scales.

Table 2. Results from the Spearman rank correlation model (see text). Mean and standard error of sample size, mean and standard error of Spearman rank correlation coefficient, and percentage of combinations with a significant ($p<0.05$) correlation, are given for all possible combinations of years for different frame sizes and for different numbers of years included in the model.

Frame size (km)	No. of years included	No. of combinations	$\bar{n} \pm 1$ S.E.	$\bar{R}_s \pm 1$ S.E.	% $p<0.05$
5x5	1	60	11.07 ±0.83	0.06 ±0.05	13.33
	2	246	19.15 ±0.64	0.10 ±0.02	19.11
	3	503	27.65 ±0.58	0.09 ±0.01	21.27
	4	630	36.11 ±0.63	0.09 ±0.01	22.06
	5	504	44.29 ±0.82	0.08 ±0.01	22.62
	6	252	52.13 ±1.31	0.08 ±0.01	21.83
	7	72	59.67 ±2.76	0.08 ±0.02	20.83
	8	9	66.89 ±9.03	0.08 ±0.04	22.22
40x40	1	70	16.97 ±1.02	0.19 ±0.04	25.71
	2	252	28.79 ±0.73	0.20 ±0.02	37.70
	3	504	38.11 ±0.61	0.21 ±0.01	44.84
	4	630	45.28 ±0.62	0.21 ±0.01	47.14
	5	504	50.81 ±0.76	0.21 ±0.01	50.00
	6	252	55.10 ±1.16	0.21 ±0.01	50.79
	7	72	58.42 ±2.30	0.21 ±0.02	50.00
	8	9	61.00 ±7.14	0.21 ±0.05	33.33
60x60	1	70	17.51 ±0.85	0.22 ±0.04	34.29
	2	252	27.79 ±0.58	0.23 ±0.01	40.87
	3	504	34.58 ±0.47	0.25 ±0.01	43.45
	4	630	38.92 ±0.45	0.26 ±0.01	47.94
	5	504	41.71 ±0.54	0.27 ±0.01	53.97
	6	252	43.52 ±0.80	0.28 ±0.01	61.51
	7	72	44.75 ±1.55	0.29 ±0.01	65.28
	8	9	45.67 ±4.74	0.31 ±0.03	77.78
80x80	1	70	16.66 ±0.78	0.26 ±0.03	28.57
	2	252	24.65 ±0.51	0.29 ±0.01	39.68
	3	504	29.16 ±0.41	0.31 ±0.01	53.97
	4	630	31.71 ±0.40	0.34 ±0.01	63.17
	5	504	33.25 ±0.47	0.36 ±0.01	68.45
	6	252	34.29 ±0.70	0.38 ±0.01	72.62
	7	72	35.06 ±1.37	0.39 ±0.01	76.39
	8	9	35.67 ±4.19	0.39 ±0.04	66.67
150x150	1	72	11.94 ±0.46	0.26 ±0.03	30.56
	2	252	15.20 ±0.25	0.33 ±0.02	39.29
	3	504	16.49 ±0.19	0.38 ±0.01	44.64
	4	630	17.16 ±0.18	0.42 ±0.01	53.49
	5	504	17.60 ±0.21	0.45 ±0.01	59.92
	6	252	17.94 ±0.31	0.47 ±0.01	65.87
	7	72	18.22 ±0.60	0.48 ±0.02	68.06
	8	9	18.44 ±1.81	0.49 ±0.06	77.78

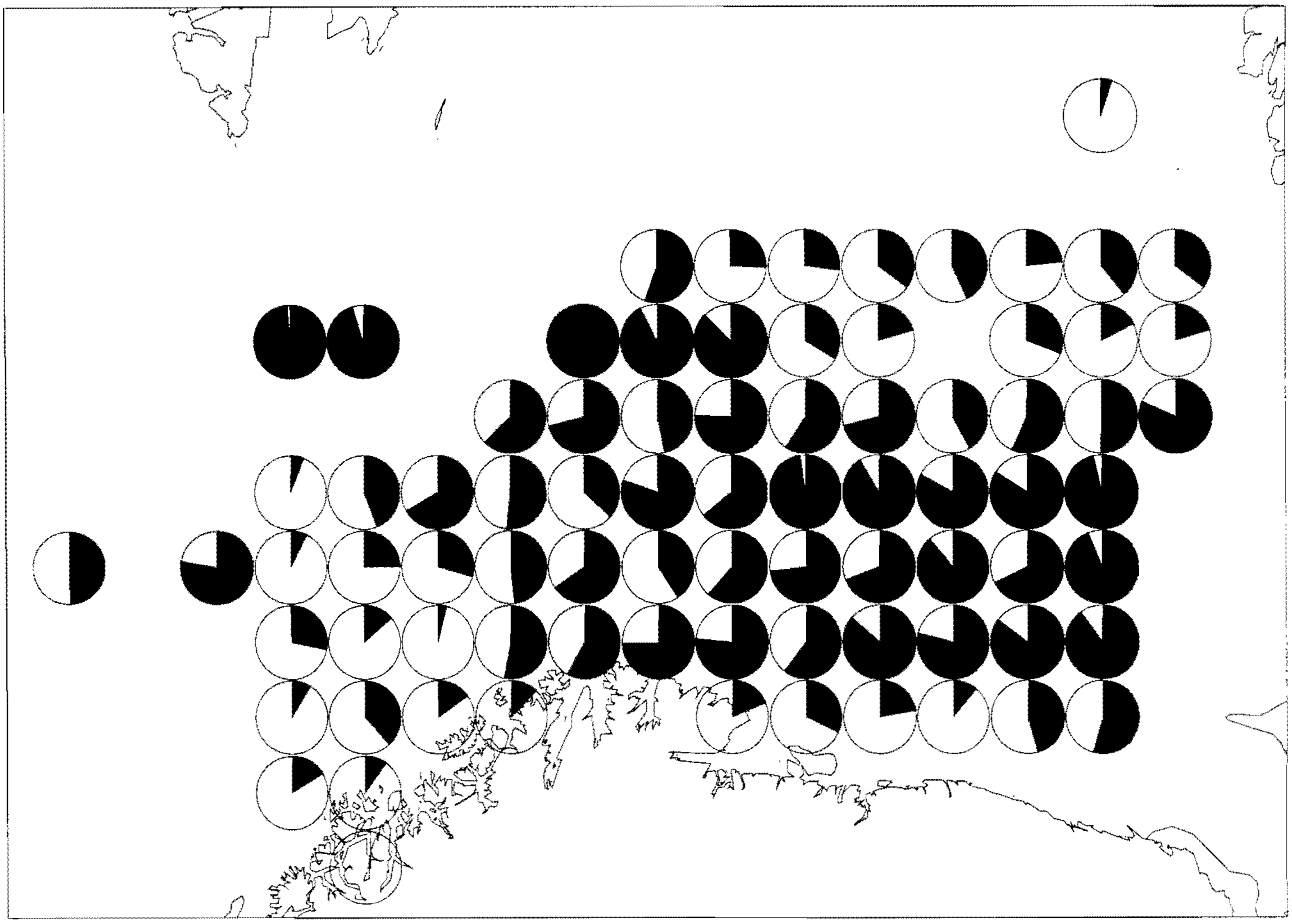

Fig. 6. Ranked mean densities of guillemots (*Uria* spp.) for nine years of survey in the Barents Sea. Frame size is 80x80 km. In at least 65% of all cases, there will be a significant ($p<0.05$) correlation between this spatial distribution of ranks and the spatial distribution of ranks in any other year. The variation of ranks in this distribution will on average explain at least 16% ± 0.2% (S.E.) of the variation in ranks in any other year.

The general distributional pattern of guillemots in the Barents Sea

In Fig. 6 the spatial geographical distribution of ranks of the mean density of guillemots in each frame for all nine years is presented (scale 80x80 km). According to the analyses, the correlation between this distribution and any other year will be significant in at least 65% of the cases. Furthermore, on average 16% ± 0.2% (S.E.) of the variation in ranks in any year can be explained by this distribution.

According to Fig. 6, the probability of detecting aggregations of guillemots seems to be high in an area from the Central Bank to the western part of the North Kanin Bank. In addition there is apparently a large aggregation of birds near Bjørnøya. This distributional pattern corresponds fairly well with the distribution of the wintering areas for maturing Capelin (Fig. 7).

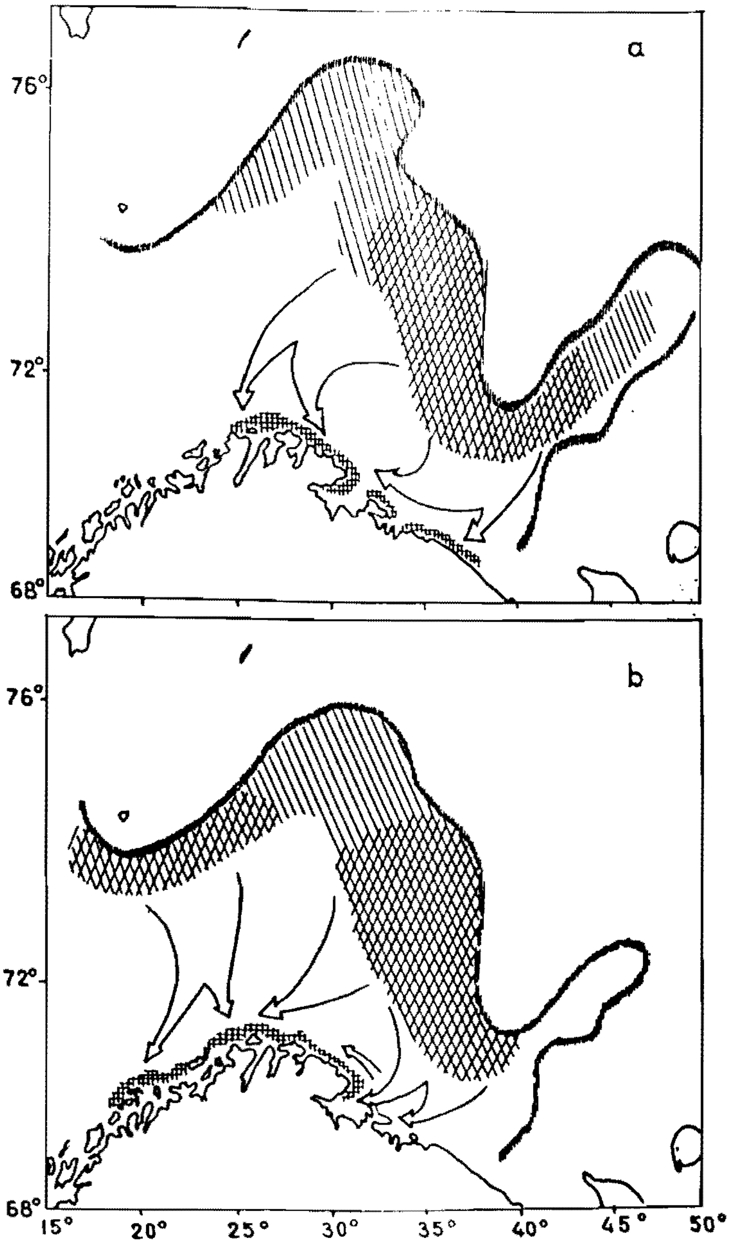

Fig. 7. Mature Capelin concentrations (intersected shading) and main routes of Capelin spawning migrations to the coast in January in warm (a) and cold (b) years. Areas of immature Capelin concentrations are shown by oblique shading; areas of main spawning are indicated by fine rectangular shading. The Polar Front is shown by fine vertical shading. From Ozhigin & Luka (1984).

CONCLUSION

There is a significant spatial predictability of guillemots between years in the Barents Sea. However, the strength of this predictability is very low. That is, only on average 7% of the variation in distributional pattern in any year could be explained by the distributional pattern in a single year at a rather large scale (80x80 km). This implies that no firm conclusions on the general distributional pattern of guillemots in the winter can be made from datasets including only a single year. Including more years will increase the predictability. The predictability seems however to level off when including more than 5–7 years, and on average only 16% of the variation in distributional pattern could be explained by 8 years of survey (scale 80x80 km). The assumption of a stable distribution of seabirds in a given season between years cannot therefore be supported by this study. It must be emphasised that this conclusion applies to the non-breeding season only. The close relation to the colonies will probably give a much higher predictability in the breeding season.

This study does, however, indicate a close connection between the distribution of guillemots and their main prey, Capelin. This connection should be used in further analyses to possibly increase the predictability between years. Including oceanographic regimes together with the distribution of the prime food (Capelin) will also presumably further increase the spatial predictability of birds. Such analyses would be of great importance in future assessments of the effects of oil exploration on seabirds at sea.

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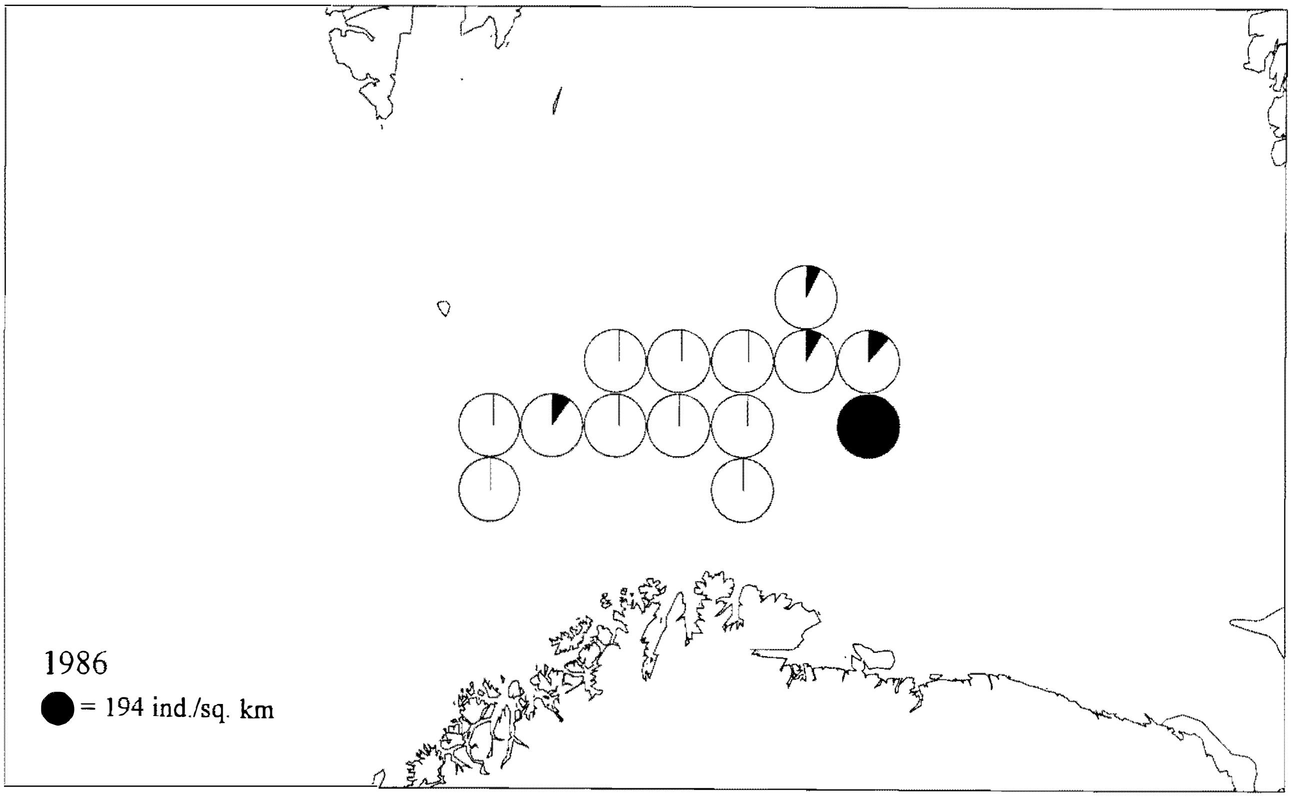
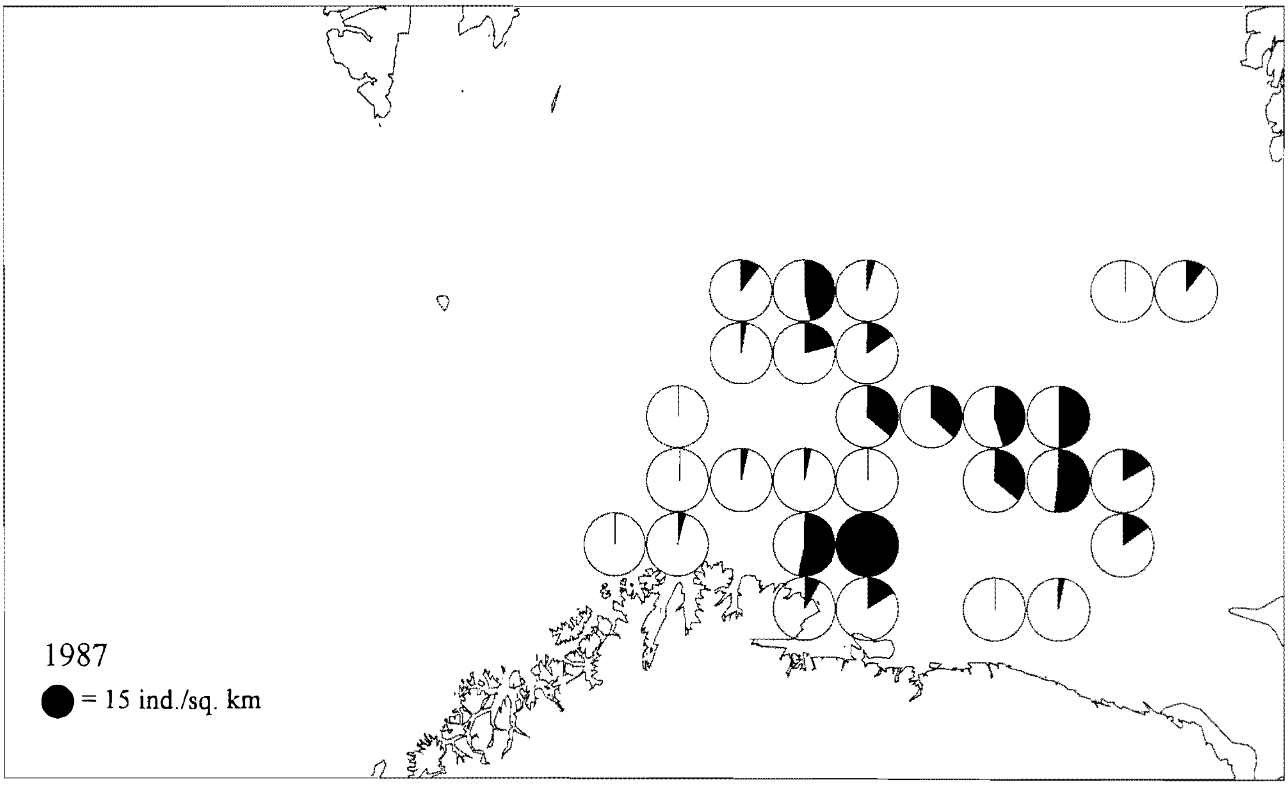
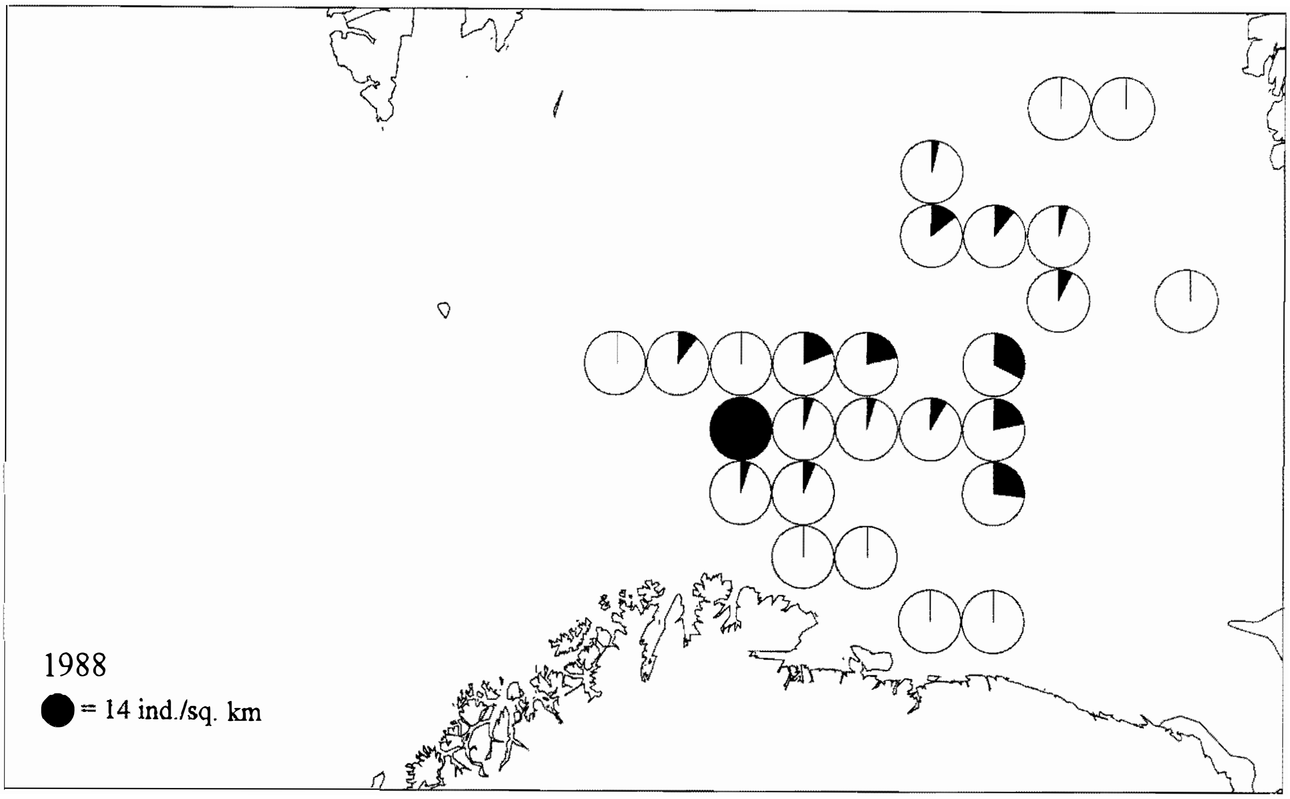
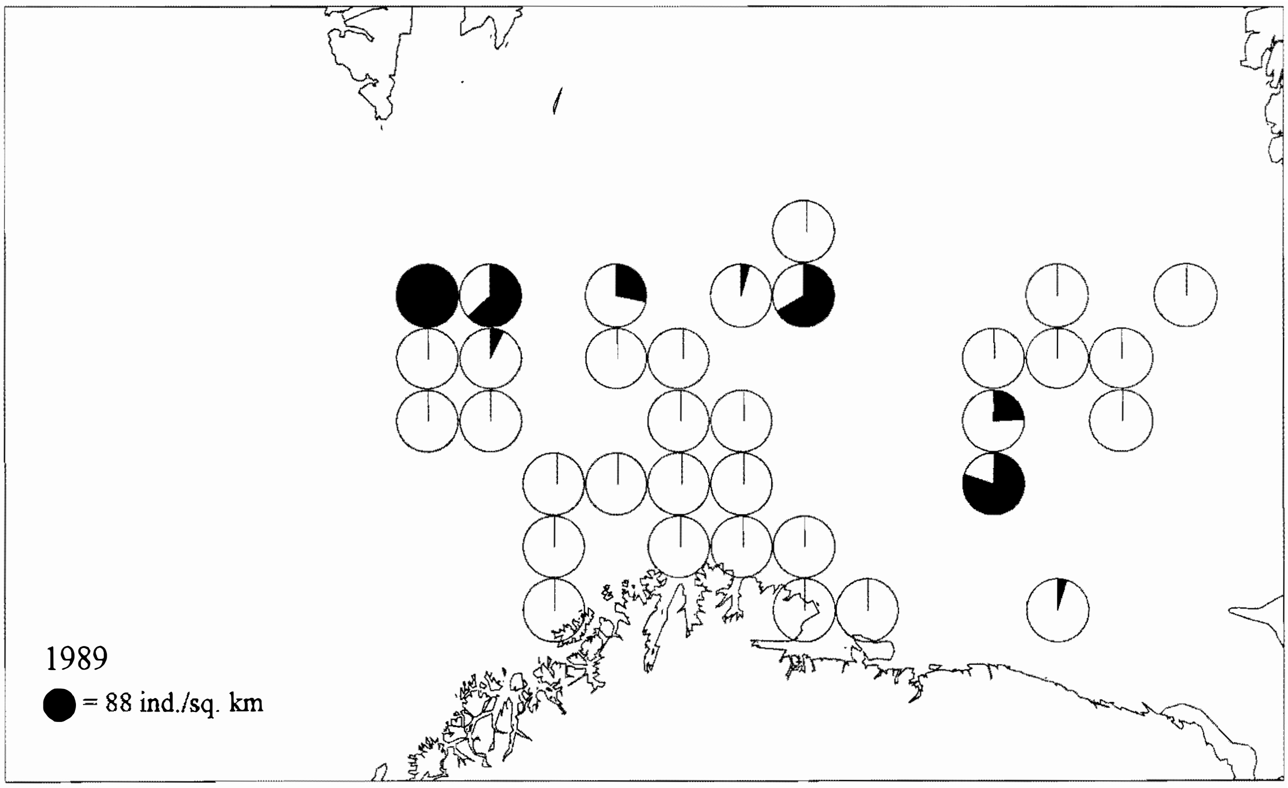
APPENDIX 1. Distribution of guillemots (*Uria* spp.) in the Barents Sea in the period January–March for 9 years of survey. The scale is 80x80 km.






1988
● = 14 ind./sq. km


1989
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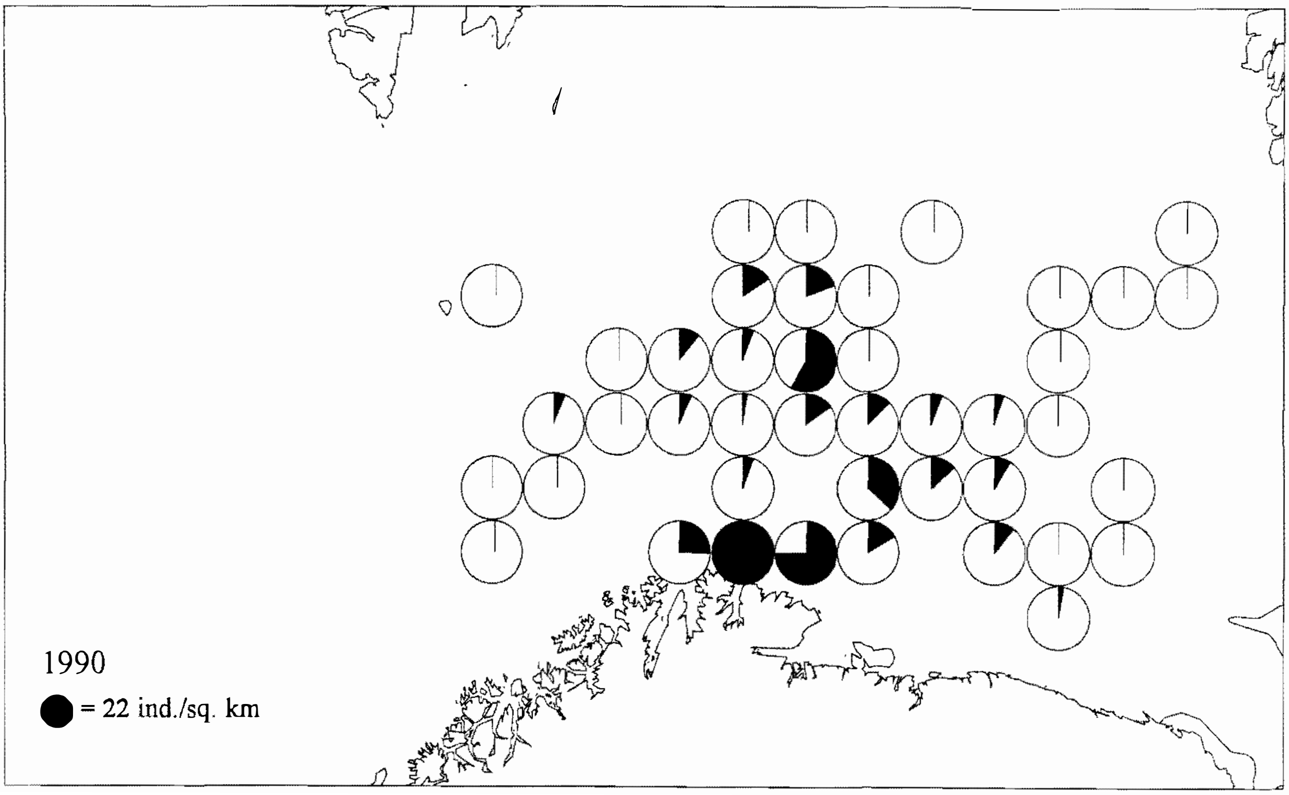
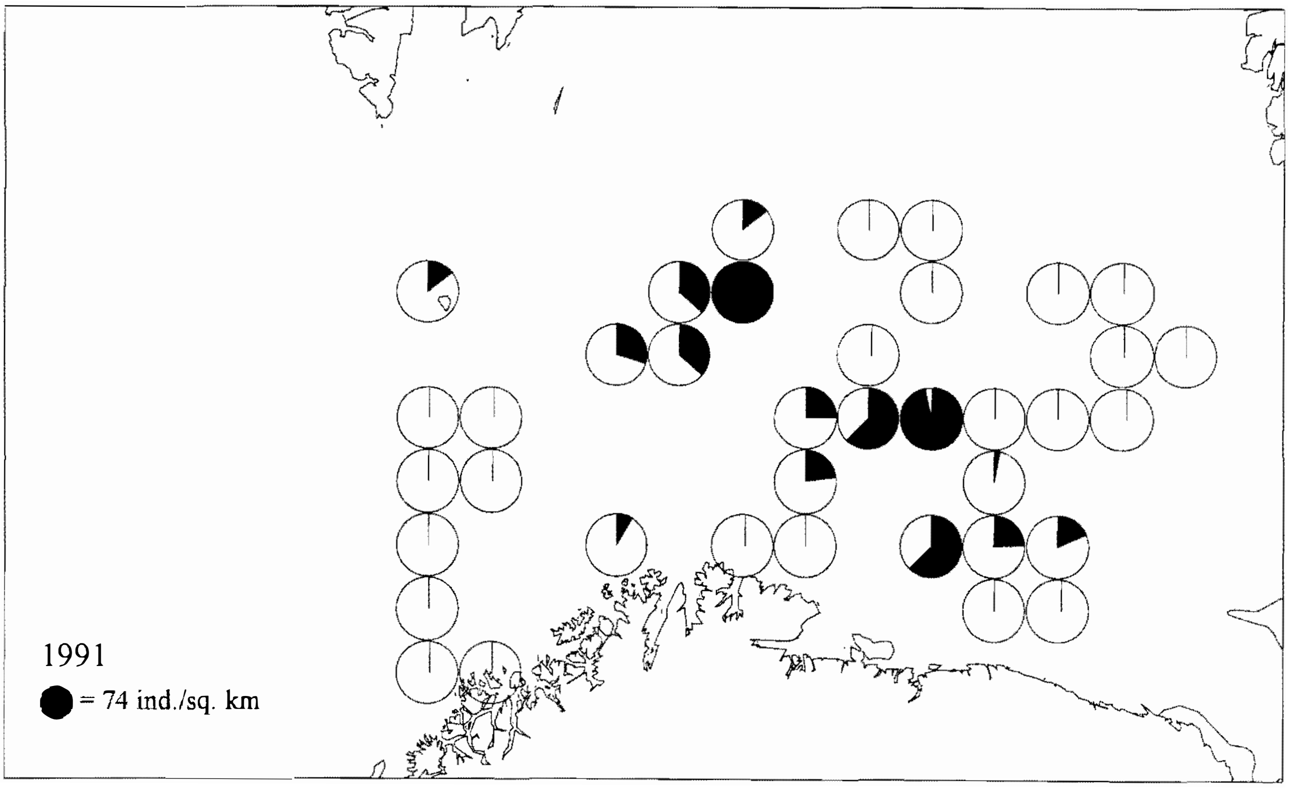

1990
● = 22 ind./sq. km


1991
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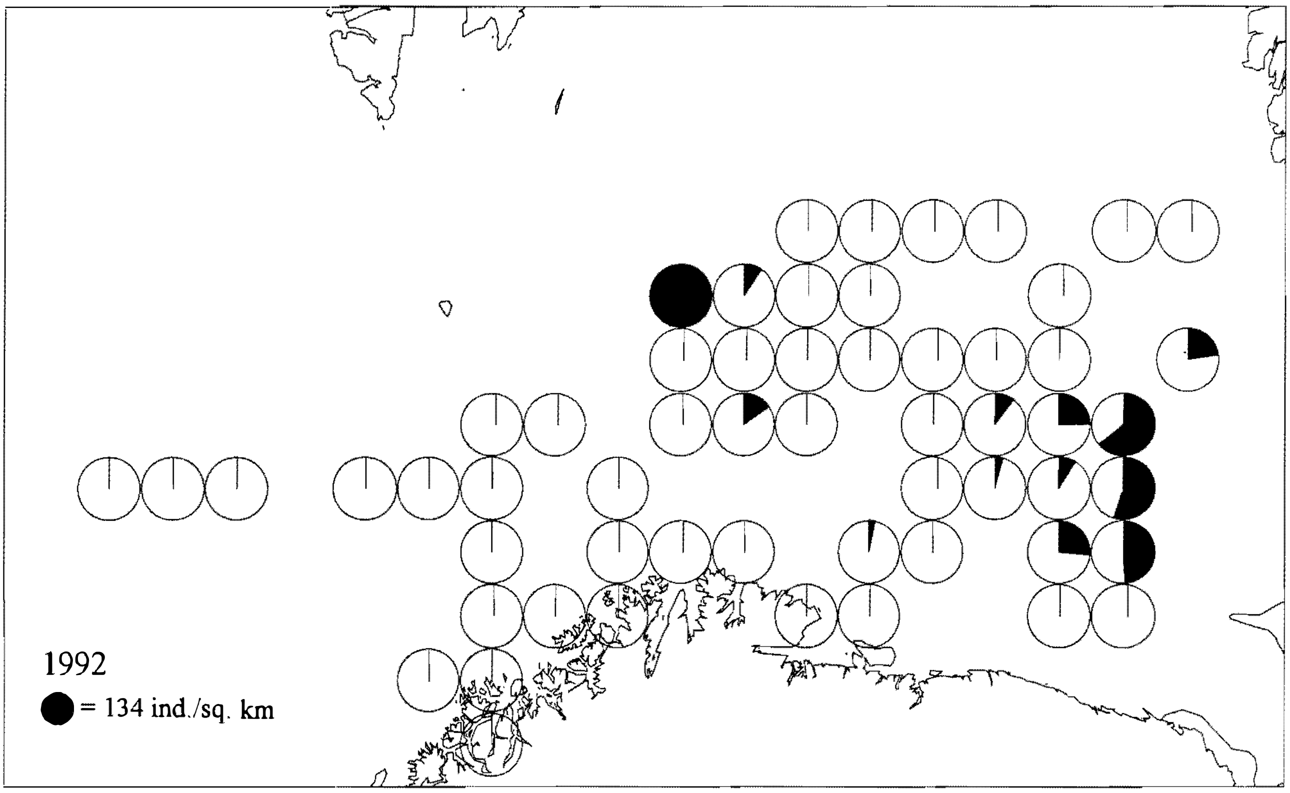
1992
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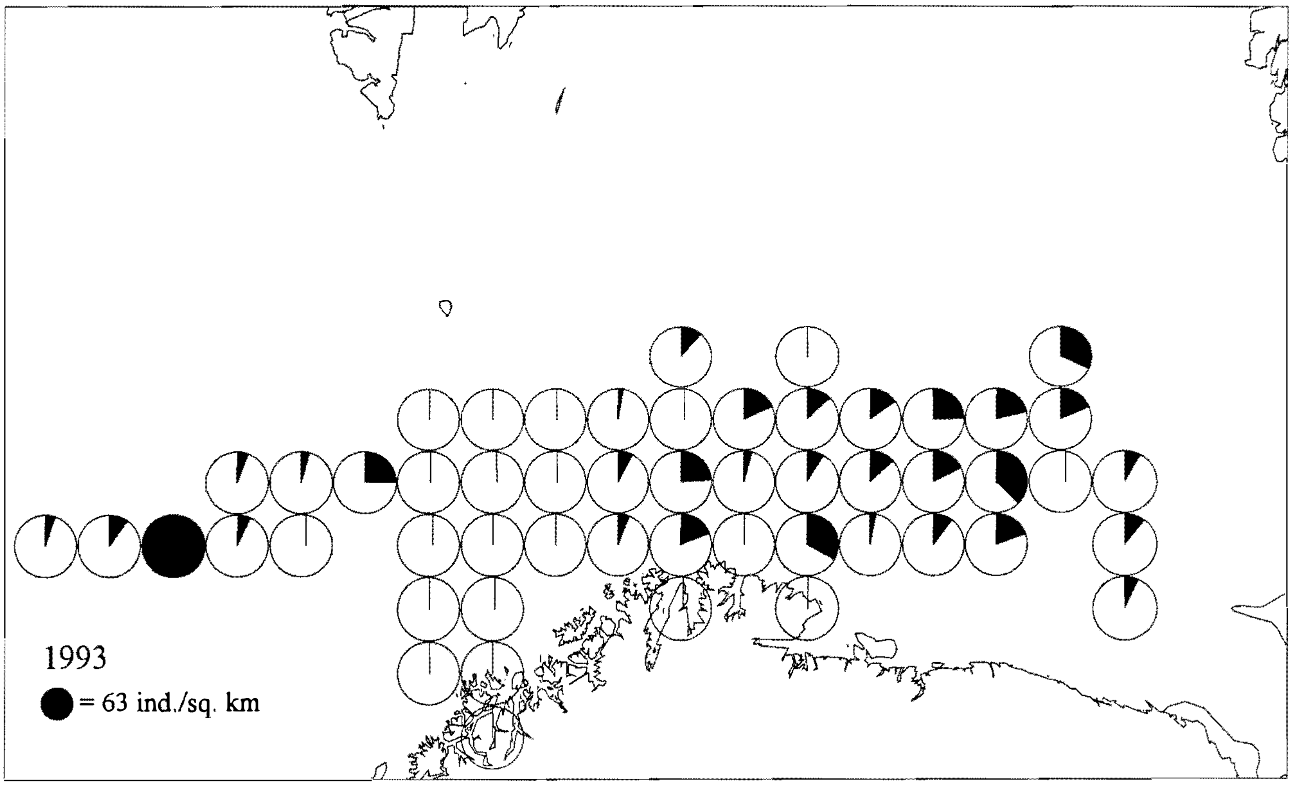
1993
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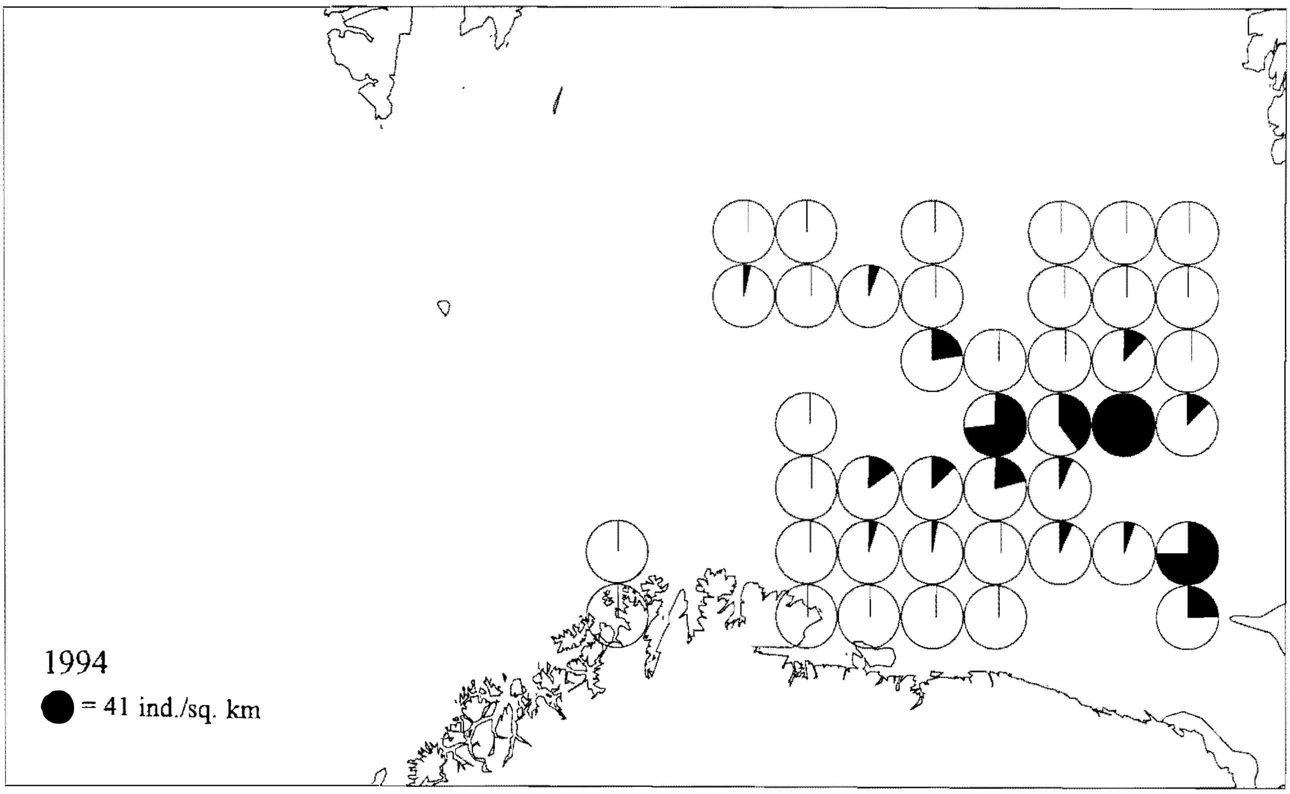
1994
● = 41 ind./sq. km

THE EFFECTS OF SEA ICE ON THE DISTRIBUTION OF SEABIRDS IN THE NORTHERN BARENTS SEA

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Kittiwakes (*Rissa tridactyla*) and Pomarine Skuas (*Stercorarius pomarinus*) in the sea ice. Photo by Fridtjof Mehlum.

Abstract – Large parts of the northern Barents Sea are covered by sea ice during most of the year. However, the extent of the sea-ice coverage varies seasonally and annually, which might have a significant effect on the pelagic distribution and ecology of the seabirds in the region. Some seabird species, such as the Ivory Gull, Ross's Gull, and the Black Guillemot, are more or less exclusively associated with sea ice in pelagic regions, and seldom recorded in areas of open water. On the other hand, several other species may occur both in ice-covered and in open water.

Seabirds have been shown to aggregate at ice edges where suitable prey is abundant and easily available. The melting of sea ice often creates a relatively stable stratification of the water masses, with a ca. 20–30 m layer of relatively fresh water lying on top of more saline water. Planktonic prey and fishes congregate in the transition zone between the water masses and are then accessible to diving seabirds. Wind-driven upwelling along ice edges may also cause concentration of planktonic prey and provide suitable foraging conditions for seabirds. Seabirds also exploit the fauna associated with the subsurface of the sea ice, especially gammarid amphipods and Polar Cod. Bird species known to be abundant at ice edges in the northern Barents Sea are Brünnich's and Black Guillemots, and Little Auks.

Leads far inside the ice edge may also be important foraging habitats for several species of arctic seabirds. In the northern Barents Sea the Brünnich's Guillemot is the predominant seabird species which uses suitable leads. During the spring thousands of Brünnich's Guillemots may be encountered in such leads. Leads close to the ice edge are usually small because the ice floes are greatly disturbed and broken into smaller pieces by wave action. Such areas are less favourable foraging sites for seabirds than large leads between large ice floes some kilometres inside the ice edge. Important areas with recurrent large leads and with observations of large numbers of foraging Brünnich's Guillemots are Spitsbergenbanken and northeast of Hopen between Spitsbergenbanken and Storbanken.

INTRODUCTION

Sea ice covers large parts of the northern Barents Sea, and as in other high-latitude waters may be a major factor in determining the distribution and ecology of high-latitude seabirds (Divoky 1979). Within regions where the sea is covered with sea ice, characteristic assemblages of seabirds have been identified both in the Antarctic (Cline et al. 1969; Ainley et al. 1983; Ribic & Ainley 1988/1989; Veit & Hunt 1991) and in the Arctic (Mehlum, unpubl.). High concentrations of foraging seabirds have also been recorded in association with ice edges or in marginal ice zones in Antarctic (Fraser & Ainley 1986) and Arctic waters (Irving et al. 1970; Bradstreet 1980; Renaud & McLaren 1982). These concentrations are not necessarily comprised of bird species belonging to a specific sea-ice assemblage, but might include species otherwise also abundant in open water. An example is the abundance of Brünnich's Guillemots *Uria lomvia*, which forage both in open and ice-covered waters (Mehlum unpubl.).

Ice edges may be suitable foraging locations for seabirds because of the occurrence of different phenomena in such areas which are increasing the availability of their prey. A high primary production is associated with the retreating outer ice edge during spring and summer.

This in turn is the basis for the growth of large populations of crustacean herbivore zooplankton, such as copepods and euphausiids. These crustaceans act as food for marine predators, such as several species of pelagic fishes and seabirds, while other seabirds might prey upon the fishes (Mehlum & Gabrielsen 1993). The melting of sea ice often creates a relatively stable stratification of the water with 20–30 m of relatively fresh surface water above more saline water. Plankton often congregates in the stratified area between these two water masses and is thus easily available to diving seabirds. Wind-driven upwelling along ice edges (Buckley et al. 1979) may also contribute to the concentration of planktonic prey for seabirds. The fauna associated with the bottom surface of the sea ice (the sympagic fauna) is also a potential source of concentrated prey for several species of seabirds (Bradstreet 1980; Mehlum & Gabrielsen 1993). The main sympagic prey species for seabirds include gammarid amphipods and the youngest year-classes of Polar Cod *Boreogadus saida*.

High numbers of seabirds have also been reported in open leads far inside the ice edge (Irving et al. 1970; Bakken 1990). In the Barents Sea area Brünnich's Guillemot is the main species found in such leads, where studies so far have concluded that they mainly prey upon the pelagic amphipod *Parathemisto libellula* and Polar Cod (Bakken 1990; Mehlum & Gabrielsen 1993).

In this chapter the status of the knowledge about seabirds and sea ice in the Barents Sea region is reviewed. This review is based on the results of studies made by the Norwegian Polar Institute in the period 1980–1994. Some of these studies have been parts of AKUP projects.

SEA-ICE CONDITIONS IN THE BARENTS SEA

In the Barents Sea the ice gradually extends southwards during the winter, but the extent of ice cover varies considerably from year to year. Also the position of the southern ice edge during spring and summer is quite variable (Vinje 1985; Mehlum 1989). This reflects the high variability both in meteorological and oceanographic conditions in the area.

Depending upon winds and currents, the ice edge might be a well-defined line or a more or less diffuse zone. In late spring and summer the sea ice generally melts and disintegrates, but during cold spells new ice might be formed between ice floes. At the ice edge the ice fields are exposed to the effects of waves and wind, and thus are usually broken into small floes, mostly less than 20 m across (Vinje 1985). Further into the ice, floes are larger, often 100–500 m across, or even larger. Between such floes leads are formed, which are more stable than open water between smaller floes closer to the ice edge.

THE SUMMER SITUATION

During the years 1980–1984 ship-based seabird censuses were performed during multidisciplinary cruises to the west, north, and east of Svalbard (Mehlum 1989; Isaksen

1995). These censuses comprised more than 2000 observation hours. Most of the data collected was from August, but some of the cruises also covered parts of July and September. In the Barents Sea the distribution of three seabird species, Ivory Gull *Pagophila eburnea*, Ross's Gull *Rhodostethia rosea*, and Black Guillemot *Cepphus grylle*, was found to be dependent on the presence of sea ice. These species were seldom seen in open water (Mehlum 1989, 1990, unpubl.). Another species, the Little Auk *Alle alle*, was observed more often than expected by random in ice-covered waters during only one of the years. Other species were also seen in ice-covered waters, but they were observed less often than expected by chance in ice-covered areas, or there was no difference between the actual distribution in ice-covered and open water compared to a random distribution (Mehlum unpubl.)

The Little Auk feeds mainly on copepods and young specimens of the pelagic amphipod *Parathemisto* spp. (Mehlum & Gabrielsen 1993). According to Sakshaug and Skjoldal's (1989) model of abundance of the copepod *Calanus glacialis* along the ice edge in the northern Barents Sea, the largest (oldest) age-stages of this copepod should be found in the outer part of the ice zone, grazing on the phytoplankton bloom in the stratified water. It was in these areas with low ice cover that the highest densities of Little Auks were also recorded (Mehlum 1989).

THE LATE WINTER AND SPRING SITUATION

The sea ice has its largest extent in the Barents Sea during spring (Vinje 1985). During the period 1986–1994 the Norwegian Polar Institute conducted a series of seabird studies in the ice-covered waters for increasing the knowledge of the distributional pattern of seabirds in this region. Studies have been made using both aerial and ship-based censuses (see Isaksen 1995 for ship-based censuses). The most abundant seabird species at this time of the year inhabiting the Marginal Ice Zone and open leads within the ice is the Brünnich's Guillemot.

A summary of all aerial survey results for guillemots is presented in Fig. 1. This figure comprises data from the following cruises: 'R/V Lance' May–June 1986, 'K/V Nordkapp' February–March 1987, 'R/V Lance' March 1988, 'K/V Andenes' May 1988, 'R/V Polarstern' April–May 1989, and 'R/V Lance' April–May 1994. Because it is difficult to discriminate between the Brünnich's and Common Guillemots in the field, and especially during aerial censuses, unidentified guillemots *Uria* spp. are also included in the figure. However, in the Svalbard region the Common Guillemot only breeds in large numbers on Bjørnøya, and it is unlikely that this species comprises a significant part of the birds observed except in the vicinity of this island.

It can be seen from Fig. 1 that major concentrations of guillemots were encountered on Spitsbergenbanken (between the islands Bjørnøya and Hopen), areas north and northwest of Hopen, and further away to the northeast of Hopen. The results from 20 February to 8 March 1987 and 20–31 May 1988 have been worked out separately by Hunt et al. (1995). They concluded, on the basis of both helicopter and ship surveys, that the densities of Brünnich's

Guillemots were higher in the pack ice than in open water. The guillemots also showed preference for larger leads, based on the result that large leads were more likely to be occupied and to have larger numbers of birds present. This result is similar to what was found on the 1986-cruise (Bakken & Mehlum 1988) northeast of Hopen, and also similar to the results of a cruise conducted in the same area during early June 1983 (Mehlum unpubl.). These large leads are found at some distance from the ice edge, and guillemots were seldom seen in leads near the ice edge. Leads near the ice edge may be less favourable foraging sites because there the ice is generally small and greatly disturbed and broken in smaller pieces by wave action, thereby disturbing or making less available prey associated with the sympagic (under-ice) prey community. The under-use of small leads near the ice edge may also be partly due to the guillemots' need for sufficient areas of open water between the ice floes to take off into the air.

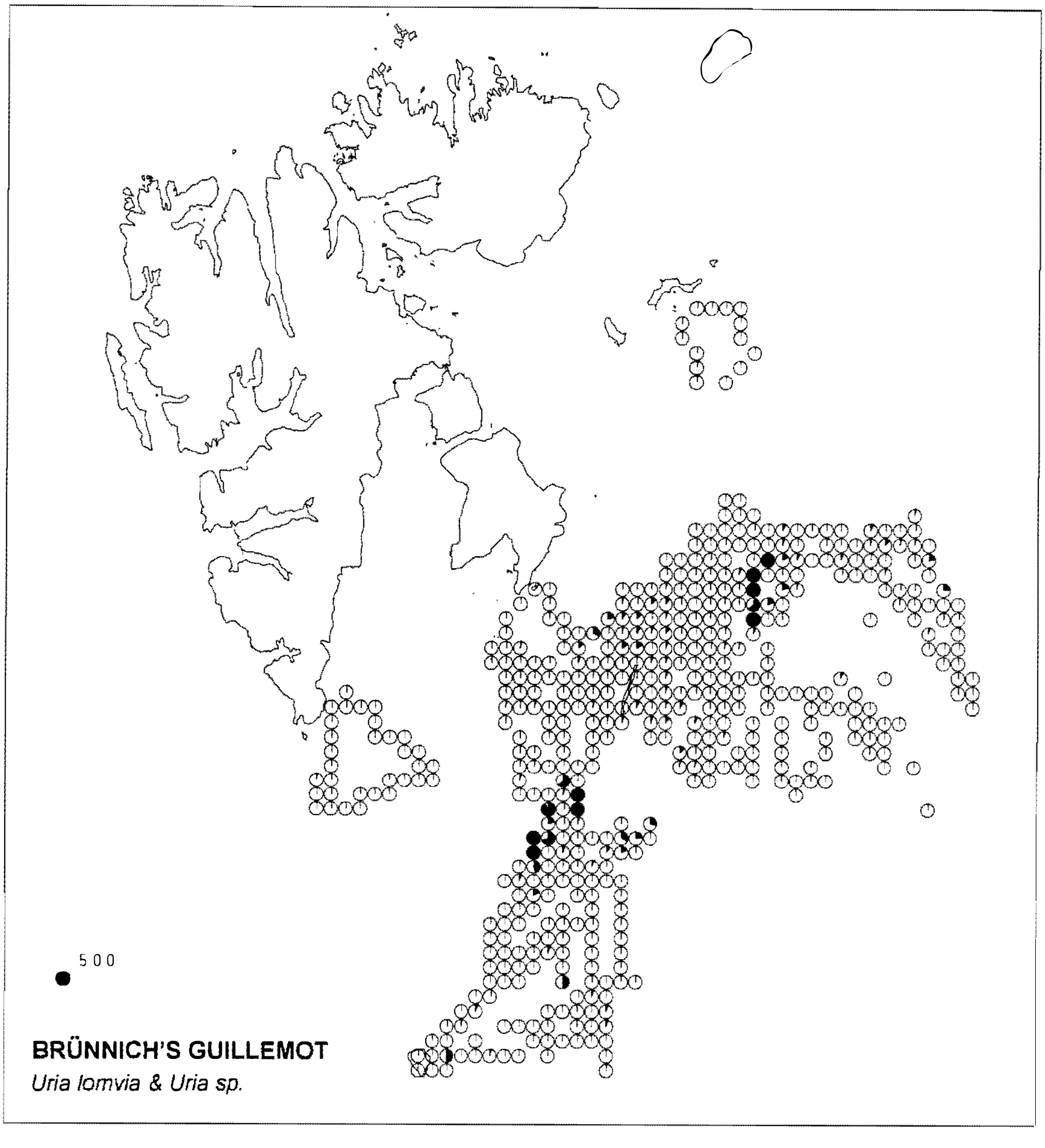


Fig. 1. Summary of aerial survey results for guillemots during the period 1986–1994. The observations are represented as density of birds per sq. km in each of 10x10 km squares (totally filled circle ≥500 birds/sq. km).

Analysis of prey caught by the Brünnich's Guillemots foraging within large leads in the northern Barents Sea has shown that their main prey consists of Polar Cod and the pelagic amphipod *Parathemisto libellula* (Mehlum & Gabrielsen 1993).

The areas which were rich in large leads were characterised by several physical features. One of these was Spitsbergenbanken, which is a shallow bank with water depths of as little as 17 metres. In this area the tidal effects on the ice fields may be considerable. Vinje and Kvambekk (1991) showed that the periodic divergence and convergence of the ice fields over Spitsbergenbanken may cause ice floes to move in circles with diameters of about 15 km.

The area with large leads to the northeast of Hopen, where large concentrations of Brünnich's Guillemots were observed, has been identified during all our seabird censuses in that region. The area (ca. 77°10'N, 30°00'E) is located at the submarine isthmus between Spitsbergenbanken and Storbanken. In this area the cold Arctic Water meets the warmer Atlantic Water in a Polar Front. This feature, and probably also tidal currents and clockwise currents on the two banks, may explain why the area seems to be characterised by the recurrent formation of large leads.

During some of the censuses the temperature was well below freezing, and new ice had formed in the leads which prevented them from being used by seabirds. Cold spells during the spring may result in a large scale migration of Brünnich's Guillemots from the freezing leads within the pack ice and out into open water. This was observed between Hopen and Kong Karls Land during the April–May 1989 cruise. A sudden drop in the ambient temperature from 0 °C to ÷10 °C and freezing of most of the leads coincided with a southward passage of thousands of Brünnich's Guillemots seen from the ship.

In winter time with little daylight and subzero ambient temperatures the Brünnich's Guillemots apparently leave the ice-covered areas in the evening and stay overnight in open water south of the ice edge (Bakken 1990). This type of diel movement has been observed south and west of Hopen in February/March 1987.

ICE EDGES

Seabird affinities to ice edges

During some of the cruises a well-defined ice edge was encountered, and surveys were made for comparing the densities of birds close to the ice edge compared to densities further offshore and on the inside of the ice edge. Some transects were also performed for describing the heterogeneity of birds *along* ice edges. The latter is an important aspect, because even if concentrations of seabirds have been reported from ice edges, there is only scarce information about the aggregative pattern of birds along the edges.

An example of seabird abundances on transects perpendicular to the ice edge is given by Hunt et al. (1995). On three helicopter crossings of the ice edge 5 n.m. apart, in May 1988, a distinct peak in numbers was recorded at the ice edge for the Brünnich's Guillemot in all three cases (Fig. 2), whereas the Little Auk showed a distinct peak in one of three crossings (Fig. 3). Other species, i.e. Fulmar *Fulmarus glacialis* and Kittiwake *Rissa tridactyla*, showed no peaks in numbers at the ice edge.

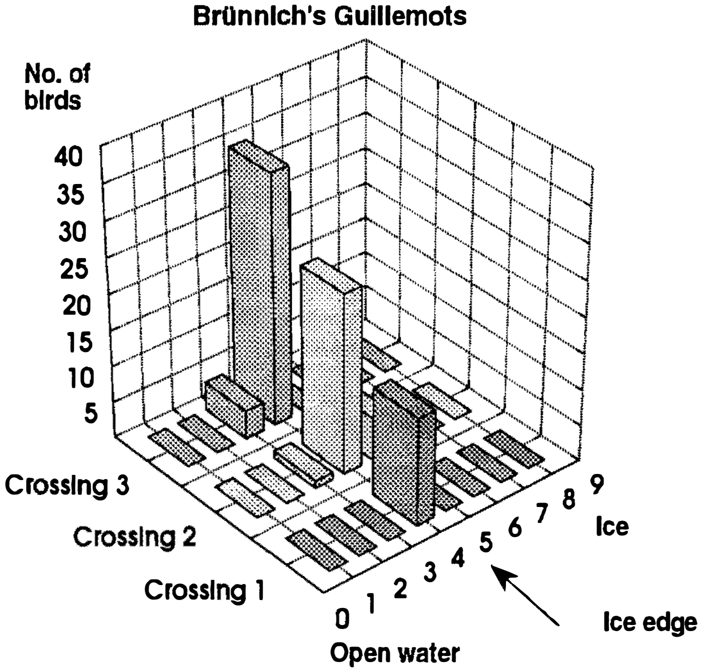


Fig. 2. Observations of Brünnich's Guillemots from helicopter transects crossing the ice edge. Each unit on the Z-axis represents 1.5 nautical mile. The transect width was 200 m.

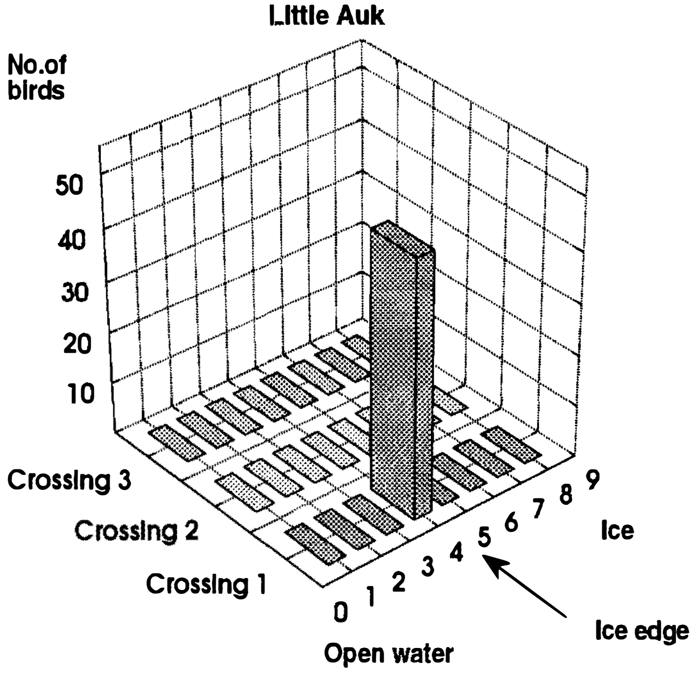


Fig. 3. Observations of Little Auks from helicopter transects crossing the ice edge. Each unit on the Z-axis represents 1.5 nautical mile. The transect width was 200 m.

Some examples of the spatial distribution of seabirds along ice edges are given below.

The first is from a distinct ice edge encountered during a cruise in April 1994 northeast of Hopen Island. A strong easterly gale was responsible for packing the ice to a well-defined edge. Based on analysis of synthetic aperture radar pictures obtained by a satellite passing the area during our census period, we could measure the speed of movement by the ice edge. It moved 28 km to the southwest in three days (or ca. 10 cm/s). This ice edge was censused three times, and the only seabird species present was the Brünnich's Guillemot. The total number of birds associated with the ice edge increased from the first to the third census, but the overall distribution pattern of birds along the edge was similar in all censuses. The results of the third census is shown in Fig. 4. A total of 8735 Brünnich's Guillemots were recorded along this transect, but the distribution was very clumped with up to 1100 birds seen during one nautical mile unit. The peak in bird numbers was located at 76°45'N, 28°23'E, about 100 km northeast of Hopen. Physical oceanographic measurements of the water column were taken during the second census, using a CTD probe. A strong stratification in temperature and density in the water was evident with the thermocline and pycnocline at ca. 40 m depth. The strongest stratification was found at a station which coincided with the highest density of birds. Net hauls showed that *Parathemisto libellula* was abundant in the water. The strong wind probably packed the ice from the ice edge and toward Hopen, which resulted in few open leads available for Brünnich's Guillemots attached to the breeding colonies on this island.

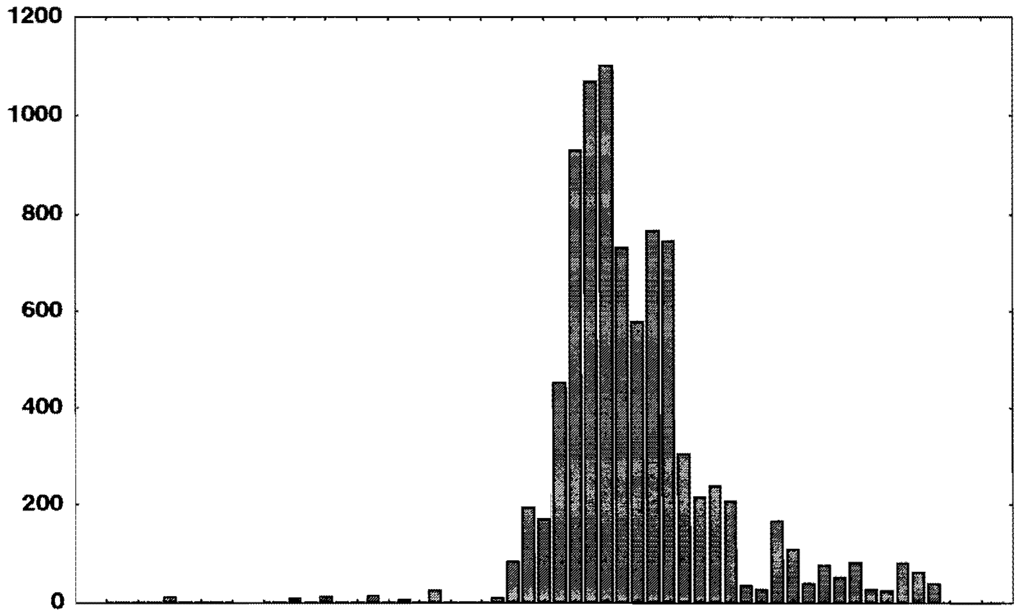
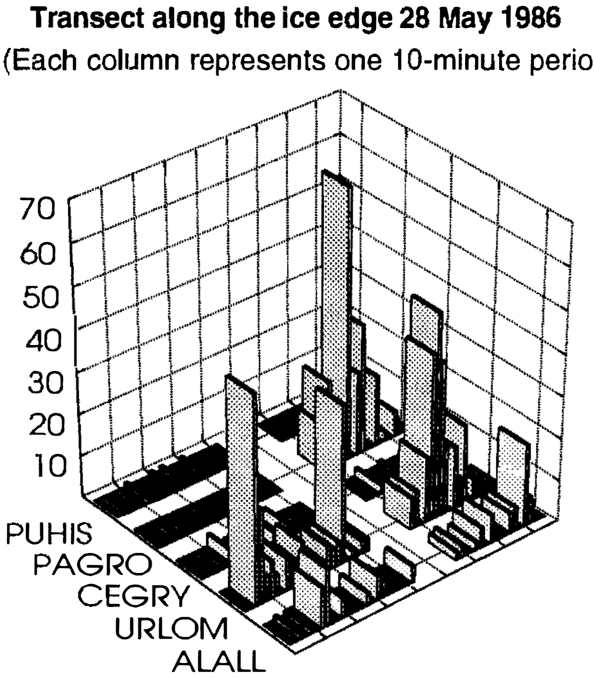


Fig. 4. Brünnich's Guillemots observed along the ice edge during a 80 km long transect (from 76° 54'N, 30°23'E to 76°30'N, 27°45'E). The Y-axis represents no. of birds per 6-minute transect period (1 nautical mile). The transect width was 300 m.

The second example is from a cruise along the ice edge east of Hopen on 28 May 1986. The transect had a total length of 166 km, including a 23 km long gap of observations. The distribution of the main species of seabirds and marine mammals observed during the transect is shown in Fig. 5. Brünnich's Guillemots and Harp Seals *Phoca groenlandica* were the two most abundant species observed. On the 10-minute interval scale the correlation between the occurrence of different species pairs was low. A Spearman rank order correlation analysis showed significant positive correlation only between Black Guillemots and Ringed Seals *Phoca hispida*, whereas a Pearson correlation analysis showed significant positive correlations only between Brünnich's Guillemots and Harp Seals and between Black Guillemots and Ringed Seals. The same results were obtained by increasing the bin size to 30-minute periods. One result of these analyses is that there was no correlation between the distribution of the two most abundant seabird species, Brünnich's Guillemot and Little Auk, along the transect. An explanation of the discrepancy between the distribution of the different species might be that they exploit different prey, which also may have different distribution along the transect. Brünnich's Guillemots and Harp Seals primarily feed on larger pelagic crustaceans and fishes, whereas Little Auks feed primarily on copepods.



Transect along the ice edge 28 May 1986
(Each column represents one 10-minute period)

Fig. 5. Seabird and marine mammal observations on the water on a transect along the ice edge with starting point 76°24'N, 28°20'E and end point 75°26'N, 33°03'E (PUHIS = Ringed Seal, PAGRO = Harp Seal, CEGRY = Black Guillemot, URLOM = Brünnich's Guillemot, and ALALL = Little Auk). The Y-axis represents the number of individuals observed per 10-minute (or 1.8 km).

Also along the ice edge in May 1988 there was considerable patchiness in the distribution of foraging Little Auks and Brünnich's Guillemots (Hunt et al. 1995). Multiple passages along the same section of the ice edge also showed a temporal variability in distribution. No correlation in abundance was found between two subsequent passages on a measurement scale of three nautical miles. Even on larger scales, significant correlations in distributions of species between pairs of surveys were rare.

We conclude from these studies that the location of seabird concentrations along ice edges in some cases show temporal stability on the scale of hours or longer, whereas in other cases the patches of seabirds are shorter in duration.

Swimming migration to ice edges

Chicks of Common and Brünnich's Guillemots (*Uria aalge* and *U. lomvia*) leave their breeding ledges at the age of approximately three weeks, long before they are able to fly. They swim, together with one of their parents (usually the male), away from the breeding colony out into the open sea. The swimming migration of these two alcid species in the northern Barents Sea region is described by Bakken and Mehlum (1988). Only the Brünnich's Guillemots may be associated with sea ice in the Barents Sea during the swimming migration. A study from 1987 on the swimming migration of Brünnich's Guillemots from the large breeding colonies at Hopen (Bakken & Mehlum 1988) showed that most adults with chicks were observed at the ice edge approximately ten nautical miles to the north of the island. This observation may indicate that Brünnich's Guillemots with chicks from the breeding colonies at Hopen concentrate along the ice edge (if present at reasonable distances from the island) and use it as a foraging area just after breeding.

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APPENDIX (Systematic list of seabirds)

Systematic list of seabird species treated in this report. The populations of these species in the Barents Sea have been found either to be vulnerable to oil spills (long-term effects) in one or more seasons (vulnerability category 2 and 3 in summer and spring, and category 3 at other seasons; SP=spring, SU=summer, MO=moulting male eiders, AU=autumn and WI=winter), or of special national (N) or international (I) conservation value (vulnerability and conservation value after Fjeld & Bakken (1993) and, for the Common Guillemot and the Puffin in winter and the Sabine's Gull, the introduction to this volume).

SPECIES NAMES			VULNERABILITY					CONSERVATION VALUE
NORWEGIAN	ENGLISH	SCIENTIFIC	SP	SU	MO	AU	WI	
Smålom	Red-throated Diver	*Gavia stellata*	2	3	–	2	–	N
Islom	Great Northern Diver	*Gavia immer*	2	2	–	2	–	N
Havhest	Fulmar	*Fulmarus glacialis*	3	3	–	3	3	I
Kortnebbgås	Pink-footed Goose	*Anser brachyrhynchus*	2	3	–	3	–	I
Hvitkinngås	Barnacle Goose	*Branta leucopsis*	2	3	–	3	–	I
Ringgås	Brent Goose	*Branta bernicla*	3	3	–	3	–	I
Ærfugl	Common Eider	*Somateria mollissima*	3	3	3	3	2	I
Praktærfugl	King Eider	*Somateria spectabilis*	3	3	3	3	–	I
Havelle	Long-tailed Duck	*Clangula hyemalis*	3	3	–	3	–	–
Polarsvømmesnipe	Grey Phalarope	*Phalaropus fulicarius*	1	1	–	1	–	N
Tyvjo	Arctic Skua	*Stercorarius parasiticus*	1	2	–	1	–	–
Storjo	Great Skua	*Stercorarius skua*	2	1	–	2	–	N
Sabinemåke	Sabine's Gull	*Larus sabini*	–	2	–	–	–	N
Polarmåke	Glaucous Gull	*Larus hyperboreus*	3	2	–	3	2	N
Svartbak	Great Black-backed Gull	*Larus marinus*	2	2	–	2	2	–
Krykkje	Kittiwake	*Rissa tridactyla*	3	3	–	3	3	I
Ismåke	Ivory Gull	*Pagophila eburnea*	2	1	–	2	3	I
Rødnebbterne	Arctic Tern	*Sterna paradisaea*	2	3	–	2	–	N
Lomvi	Common Guillemot	*Uria aalge*	3	3	–	3	3	I
Polarlomvi	Brünnich's Guillemot	*Uria lomvia*	3	3	–	3	3	I
Alke	Razorbill	*Alca torda*	3	2	–	3	–	–
Teist	Black Guillemot	*Cepphus grylle*	3	3	–	3	3	I
Alkekonge	Little Auk	*Alle alle*	3	3	–	3	3	I
Lunde	Puffin	*Fratercula arctica*	3	3	–	3	3	–