The Kongsfjorden colony of barnacle geese: Nest distribution and the use of breeding islands 1980–1997

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The Kongsfjorden colony of barnacle geese in Svalbard was established in the early 1980s. This paper presents a fifteen-year data set of nest distribution and individual use of different nest locations are presented for the geese breeding in this colony. Nest site fidelity, clutch sizes and a relation between numbers of goose nests and common eider nests are also investigated. The first nest of barnacle geese were observed in Kongsfjorden in 1980. Numbers have since increased on all nest locations (mainly islands). In 1997, 329 barnacle goose nests were recorded in Kongsfjorden, the largest concentrations of nests being found on Storholmen and on Juttaholmen. Two-thirds of the females had a high fidelity to their breeding island, whereas the rest showed a medium low fidelity to their nest site. Poor breeding conditions, a combination of sea ice around breeding islands and egg predation by arctic foxes were probably the main reasons for shifts in nest sites. Average clutch sizes were similar in most years and on most islands, although some variation has occurred within some islands (no directional trend). No relationship between clutch size and nest number on the different islands was found. A positive relationship between the number of goose nests and the number of common eider nests was found on four islands, which reflects the importance of sea-ice conditions and island availability for successful nesting. No increase in the percentage of goose nests relative to common eiders nests was recorded during the last five years. This indicates that no obvious competition for nest sites has existed between the two species. Even if sea ice conditions and the presence of foxes proximately influence breeding conditions on the different islands, nest site *per se* is presumably not the determining factor for clutch size and breeding success.

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Introduction

The population of barnacle geese *Branta leucopsis* breeding in Svalbard has increased considerably since the 1940s (Owen 1984; Black 1998, this volume). The current population estimate is approximately 23,000 geese (Madsen et al. 1998, this volume). The population winters in a restricted area in the Solway Firth in southwest Scotland and northwest England, but on the breeding grounds in Svalbard the geese breed in many colonies scattered mainly in the western parts of the archipelago (Mehlum 1998, this volume). The colonies in Svalbard have been established successively, giving significant differences in the age of the colonies (Prestrud et al. 1989; Black 1998, this volume). Originally, the barnacle geese in Svalbard nested on cliff faces and rocky slopes (Løvenskiold 1964), but at present most colonies are located on offshore islands and on a few inland cliffs (Prestrud et al. 1989; Mehlum 1998, this volume). Barnacle geese feed during the incubation period, and distance to food from the nest site may be an important parameter in nest site selection (Prop et al. 1984). The colony in Kongsfjorden in the vicinity of the Ny-Ålesund village (78°55′N, 12°00′E) was established in the early 1980s and consists today of almost 800 individuals (Loonen et al. 1998, this volume). The majority of the geese breed on islands in Kongsfjorden, but some geese also breed on the mainland near Ny-Ålesund village and on an adjacent bird cliff (Mehlum unpubl.; Tombre 1995; Loonen 1997).

This paper presents data on nest distribution and individual use of different nest locations in the Kongsfjorden colony of barnacle geese in Svalbard. The colonisation of the different islands from 1980, when the first nest was found, to the present, when more than 300 nests are distributed on several islands, is described. Nest site fidelity for individual females in the period 1992–1997 is examined, and differences in clutch sizes between islands and possible changes in clutch sizes over years within each island are evaluated. During 1993–1997, the total number of breeding geese has been relatively stable (Loonen 1997), though the numbers of breeders have varied among islands. The islands are also important breeding islands for common eiders *Somateria mollissima*, and in order to reveal a possible competition for nest sites between the two species, we compared the number of barnacle geese and common eider nests on islands where the number of goose nests have varied more than 50%.

Study area and methods

The study area, Kongsfjorden with the islands and the Ny-Ålesund village, is shown in Fig. 1. Islands without names on the map are islands rarely used by geese (or by common eiders) because the general late break-up of fjord ice around these islands exposes them to egg predation by arctic foxes *Alopex lagopus* breeding in the inner part of the fjord (Mehlum 1991a). The islands were censused each year from 1981 to 1997, except in

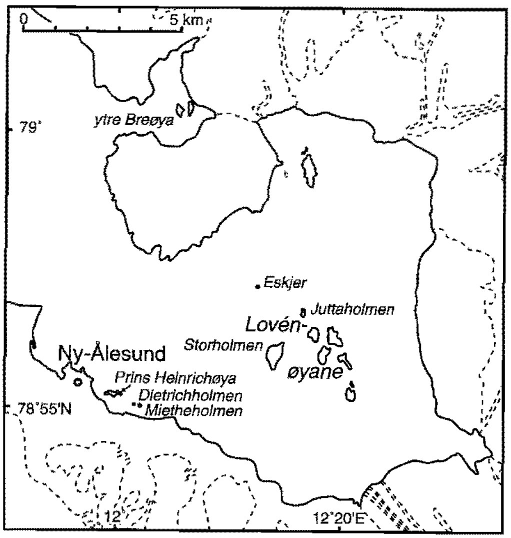

Fig. 1. Location of Ny-Ålesund and the islands in Kongsfjorden, Svalbard. Islands without names are rarely used by the barnacle geese.

1986 and 1988. In 1989, 1990 and 1992 censuses are available from only some nest locations. Nest locations censused were Prins Heinrichøya (3 ha), Dietrichholmen (0.15 ha), Mietheholmen (0.4 ha), Storholmen (30 ha), Juttaholmen (2 ha), Eskjer (1 ha), Ytre Breøya (3 ha) and the Ny-Ålesund village with adjacent areas (300+ ha) (Fig. 1). After hatching, families bring their young from the islands to the Ny-Ålesund area, which is the major brood rearing site (Loonen 1997). For further description of the colony and the study area see Tombre (1995) and Loonen (1997).

All islands were visited by boat and searched systematically for nests. Nests were counted once during the incubation period (last week of June–first week of July). In some years we also recorded the date when the fjord ice broke up around the different islands.

More than 70% of the adults in the Kongsfjorden colony are now individually marked with coded plastic leg bands and metal rings. The plastic rings can be read through telescope from more than 200 m (for details of the ringing procedures see Owen & Black 1989; Black & Owen 1995; Loonen et al. 1998, this volume).

In the period 1992–1997, rings were intensively recorded on nest locations in order to evaluate nest site fidelity between years for individual females. Only females which were seen in at least three different seasons or more were used in the analyses (females seen less than three seasons, n = 252, females seen more than three seasons, n = 166). Every year some females were observed with goslings later in the season but their nest sites were unknown. Females seen in three seasons with unknown nest site in two of the seasons were deleted from the nest site fidelity analyses. This was also true for females seen in four seasons with unknown nest sites in two or more seasons, for females seen in five seasons with unknown nest site in three or more seasons and for females seen in six seasons with unknown nest sites in three or more seasons. We allowed some unknown nest sites in the remaining sample (n = 112) and defined an unknown nest site as a 'new' nest site. An unknown nest site could therefore also have been the same nest site as in the previous year. Nest site fidelity was defined at three different levels: high, medium and low (Table 1).

With the exception of Dietrichholmen and Ny-Ålesund, clutch sizes were recorded on all nest locations in 1991–1993 and in 1995–1997. Clutches with one egg were assumed to be in-

Table 1. Definitions of nest site fidelity for barnacle geese breeding in Kongsfjorden, Svalbard.

Level of nest site fidelity	Percentage of fidelity (number of seasons nesting at the same site)
High	83% (5 of 6 seasons)
	80% (4 of 5 seasons)
	75% (3 of 4 seasons)
	67% (2 of 3 seasons and 4 of 6 seasons)
	60% (3 of 5 seasons)
Medium	50% (2 of 4 seasons and 3 of 6 seasons)
	40% (2 of 5 seasons)
Low	33% (1 of 3 seasons and 2 of 6 seasons)
	25% (1 of 4 seasons)
	20% (1 of 5 seasons)
	17% (1 of 6 seasons)

complete clutches and deleted from the analyses. Common eider nests were counted on Mietheholmen, Prins Heinrichøya, Storholmen and Juttaholmen in 1993 and in 1995–1997.

Results and discussion

Number of nests

Since the first nest in the Kongsfjorden area was found in 1980, there has been a general increase in nest numbers at all locations, except at Ny-Ålesund (Fig. 2, linear regressions, Ny-Ålesund: $R^2 = 0.08$, $n = 14$, $p = 0.31$, Prins Heinrichøya: $R^2 = 0.33$, $n = 13$, $p = 0.03$, Dietrichholmen: $R^2 = 0.52$, $n = 11$, $p = 0.01$, Mietheholmen: $R^2 = 0.30$, $n = 13$, $p = 0.05$, Storholmen: $R^2 = 0.50$, $n = 14$, $p = 0.001$, Juttaholmen: $R^2 = 0.61$, $n = 12$, $p = 0.003$, Eskjer: $R^2 = 0.71$, $n = 12$, $p = 0.001$, Ytre Breøya: $R^2 = 0.75$, $n = 12$, $p = 0.0003$). The first nest locations colonised were Ny-Ålesund and Dietrichholmen, and from 1983 nests were also found on Prins Heinrichøya, Mietheholmen and Juttaholmen. Today, the largest concentration of geese is on Storholmen (41.3% of the nests in 1997), although in recent years Juttaholmen has also become important (21.6% in 1997, Fig. 2).

Due to exposure to fox predation, the number of nests on each island is influenced every year by the general sea-ice conditions as well as the location of the nests in relation to the extent of sea ice. Regardless of the ice conditions in the fjord, the number of nests in the Ny-Ålesund village will depend on the presence of foxes. On the basis of their geographical position, nest locations were grouped in four categories: (1) Ny-Ålesund, (2) the Ny-Ålesund islands (Prins Heinrichøya, Dietrichholmen, Mietheholmen), (3) Lovénøyane (the inner-fjord islands Storholmen, Juttaholmen, Eskjer) and (4) Ytre Breøya (Fig. 1).

Ny-Ålesund

In general, since the first nest was found at Ny-Ålesund in 1980, the village has hosted few barnacle goose nests (Fig. 2). In 1987, 1990 and 1991, no foxes were seen at Ny-Ålesund and a few geese nested successfully (1987: $n = 10$, 1990: $n = 10$, 1991: $n = 22$). Some preferred nest sites disappeared in 1992 when a new dock was built at Ny-Ålesund. Seven nests were found in 1992, but because several foxes visited the village that year, nesting success was low for the geese attempting to breed there. There were foxes at Ny-Ålesund in the following years as well (1993–1995), but despite the foxes, a few nests located on rocks were successful. In 1996 and 1997, no foxes were observed in the village and a few successful nests were found on the tundra near the village.

At Ny-Ålesund, and nearby, there are plenty of potential nesting sites for barnacle geese. The area is also extensively used for feeding in the brood rearing period (Loonen 1997). Restrictions in space and food availability during nesting are presumably not the limiting factor for nest numbers at this location, fox predation being more likely to determine nest numbers at Ny-Ålesund. Predation by foxes is also thought to be the main reason why barnacle geese are basically cliff or island nesters (Norderhaug 1970; Mehlum & Ogilvie 1984). In years with late break-up of sea ice, however, Ny-Ålesund may be the best alternative for nesting because geese nesting on the islands suffer relatively more from fox predation, as is the case with common eiders (Mehlum 1991b).

The Ny-Ålesund islands

The Ny-Ålesund islands are located close to the

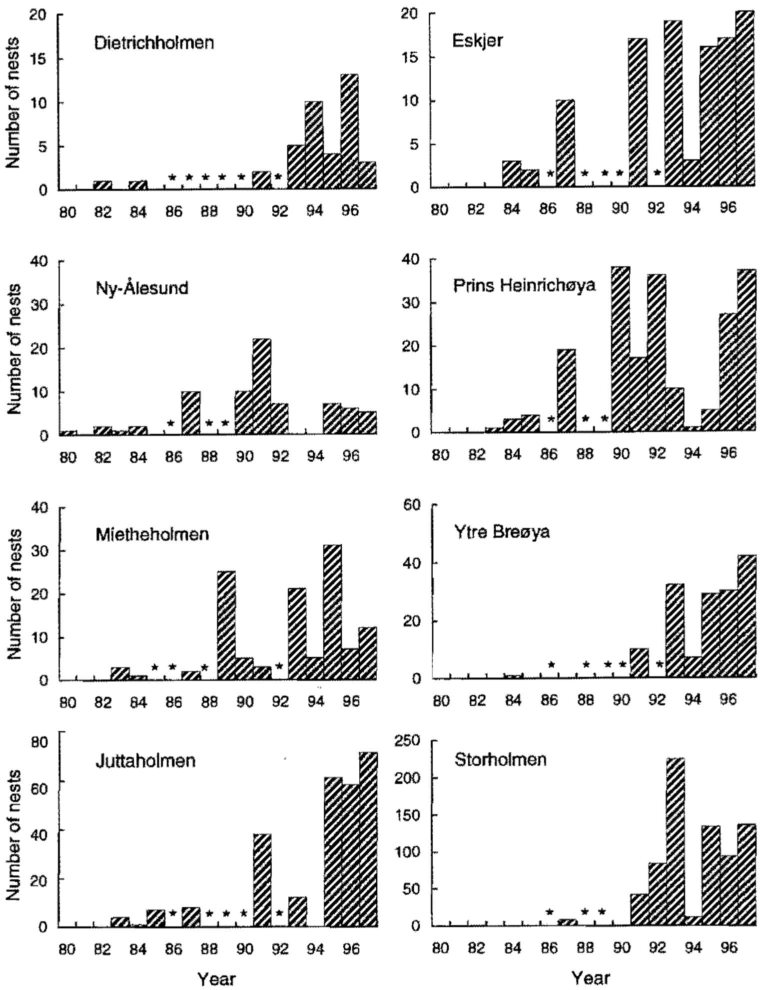

Fig. 2. Barnacle goose nests in breeding locations in the Kongsfjorden area, 1980–1997. Stars indicate years without nest recordings. Note the different scales on the y-axes. Since 1980, there has been a general increase in nest numbers, except in the Ny-Ålesund village were numbers have been low since the first pairs were recorded.

mainland. Due to shallow water, Prins Heinrichøya in particular often has an ice-bridge connecting the island to the mainland. The timing of ice break-up does not necessarily occur at the same time for the different islands because ice conditions are influenced by differences in local factors such as sea depth and distance from the mainland (Table 2). After 1991, peak nest numbers occurred in years when the islands were ice-free before June (Table 2, Fig. 2), with a few exceptions. Dietrichholmen and Mietheholmen were ice-free in late May in both 1996 and 1997 but had fewer nests in those years (except Dietrichholmen in 1996). In both years, Prins Heinrichøya had ice conditions similar to those of the other two islands, and some geese may have shifted to this larger island. For eiders, unfavourable sea ice conditions have been found to force the birds to nest at higher densities on small islands (Parker & Mehlum 1991). On Prins Heinrichøya, at least in the early season, the geese can feed on the island during the incubation period. On the small islands, the geese have no opportunities to feed during incubation, and the islands are also further away from the preferred feeding areas at Ny-Ålesund (Loonen 1997). Unfortunately, there are no data to confirm such a shift in nesting sites since ring readings from Dietrichholmen and Mietheholmen are limited in 1995 and 1996.

Based on the number of nests, the last successful years suggest an upper limit in carrying capacity of goose nests on these islands. In addition to geese,

Table 2. The dates when different islands were free of sea ice, 1992–1997. Note that there were no foxes in Kongsfjorden in 1996 and 1997.

Year	Prins Heinrichøya	Mietheholmen	Date Dietrichholmen	Storholmen	Juttaholmen	Eskjer
1992	1 June (–)[1]	*[2]	*	1 June (–)	*	*
1993	25 June	11 June	11 June	3 June	*	*
1994	23 June (+)[3]	14 June	10 June	25 June	20 June (+)	16 June
1995	18 June	1 June	1 June	15 June[4]	10 June	1 June
1996[5]	31 May	28 May (–)	28 May (–)	16 May	15 May	28 May (–)
1997[5]	2 June (–)	2 June (–)	2 June (–)	2 June	15 June	2 June (–)

[1] (–) = ice gone before this date.
[2] * = lack of information.
[3] (+) = ice-bridge also after this date.
[4] The island was 'guarded' from early June to prevent egg-predation by foxes.
[5] No foxes in Kongsfjorden.

common eiders breed in dense concentrations on these islands (Mehlum 1991a). Common eiders may therefore influence the space available for nests (see below).

Lovénøyane

Due to their geographical position, the inner-fjord islands are more exposed to fox predation than the Ny-Ålesund islands in years with late break-up of fjord-ice (except Prins Heinrichøya, see earlier). In general, these islands are larger, and on Storholmen, the largest island, the geese usually feed on the island during the whole nesting period (Alsos 1995; Tombre & Erikstad 1996).

The total production of young in Kongsfjorden was high in 1991, resulting in many new nests in 1993 (29 first-time breeders on Storholmen) (Dalhaug et al. 1996; Loonen 1997). On Storholmen, 84 nests in 1992 increased to 224 nests in 1993. On Juttaholmen, however, only 12 nests were found in 1993, probably because a late break-up of sea ice (late June) for this island. In recent years, there has been an increase in the number of nests on Juttaholmen (Fig. 2). Females may therefore have moved from Storholmen to Juttaholmen since fewer geese nested on Storholmen in 1995–1997 than in 1993. Ten of 20 females (50%) with known rings breeding on Juttaholmen in 1996 have bred on Storholmen in earlier years (breeding at least once on Storholmen), and eight of 17 females (47.1%) on Juttaholmen in 1997 have bred on Storholmen earlier. The shift in breeding island after 1993 could have been caused by the breeding conditions in 1994. In 1994, the fjord-ice surrounded Lovénøyane until late June and several foxes were harvesting eggs from the island. Only 11 nests on Storholmen (late breeders) hatched successfully (successful defined as at least one gosling leaving the nest) in 1994 (Fig. 2). The low success may therefore have caused some Storholmen breeders to move to Juttaholmen the following years instead (and vice versa). As research activity has been more frequent on Storholmen than on Juttaholmen in recent years, some geese may have preferred Juttaholmen over Storholmen because of human disturbance. However, as research activity has continued since 1992, we would have expected a shift earlier than in 1995 if disturbance was the main reason for the shift in nesting site. The extreme breeding conditions in 1994 probably caused some geese to change nest site, but whether or not human activity is the main cause of shift in nesting sites can only be determined by continued monitoring in future breeding seasons.

The 1993 count at Storholmen demonstrates that the island can support at least 224 barnacle goose nests (Fig. 2). The island has therefore been carrying less that its potential capacity of goose nests in 1994–1997.

Nest numbers have remained relatively stable on Eskjer since 1991, except the extreme season in 1994, and this island may have reached its maximum for potential goose nests. The island provides little vegetation and is also relatively distant from alternative feeding areas. Because nest numbers have increased on Juttaholmen, it is difficult to predict the upper limit of goose nests there.

Ytre Breøya

Barnacle geese breeding on Ytre Breøya are somewhat isolated from the rest of the colony. In the brood rearing period at Ny-Ålesund, there are fewer sightings of families from Ytre Breøya than sightings of families from the other islands (Loonen unpubl.). Geese ringed during moult at Ny-Ålesund and recorded as breeders at Ytre Breøya have not been seen breeding on any other nest location in Kongsfjorden. Numbers have increased on this island, and currently there are no signs of nest numbers levelling off (Fig. 2).

Nest site fidelity

Almost two thirds of the females seen in at least three different seasons in Kongsfjorden (66.1%, n = 74) were classified as showing a high level of nest site fidelity. Only 6.3% (n = 7) of the females showed a low nest site fidelity, while 27.6% (n = 31) of the females had medium fidelity to their nest location. These results support the general high level of fidelity, both to nest sites and feeding areas, found for most waterfowl (Owen & Black 1990; Anderson et al. 1992; Cooke et al. 1995). For arctic-nesting geese, fidelity is suggested to be highly advantageous because the short breeding season favours familiarity to the breeding grounds (Owen & Black 1990). For common eiders, nest site fidelity on the breeding ground has been found to be positively correlated with nesting success (Bustnes & Erikstad 1993) and results from the present study suggest that this may be the case also for the barnacle geese in Kongsfjorden. The poor breeding season in 1994 was probably one of the main reasons why some females switched breeding island in 1995 and 1996. Even if almost 70% of the females nesting in Kongsfjorden showed a high nest site fidelity, it is obvious that females sometimes do change nest site within the colony if breeding conditions for some reasons become unfavourable. The philopatry on a larger scale is also high, and more than 85% of the females are known to return to Kongsfjorden every spring (Loonen et al. 1998, this volume; Tombre et al. 1998, this volume).

Clutch sizes

The variation in clutch sizes was small, both between years and between different nest sites (Table 3). The most frequent clutch size consisted of four eggs, with two exceptions. The most common clutch size on Storholmen in 1993 was three eggs and because young barnacle geese produce fewer eggs (Forslund & Larsson 1992), smaller clutches were probably due to the high proportion of first time breeders on this island in 1993. In 1995, the most common clutch size on Eskjer was three eggs, but the age of the breeding birds was unknown.

There were no significant differences between years in average clutch sizes on Eskjer, Prins

Table 3. The average clutch size (±SE) on six different islands for barnacle geese in Kongsfjorden, Svalbard. No complete clutches were found in 1994 due to extreme sea ice conditions and heavy egg-predation by arctic foxes. A comparison of clutch sizes among years (ANOVA) was made separately for Storholmen and Juttaholmen, two important nest locations. Similar letters indicate no significant differences between years. Sample sizes in parentheses, asterisks indicate missing data.

Year	Prins Heinrichøya	Mietheholmen	Storholmen	Juttaholmen	Eskjer	Ytre Breøya
1991	4.0 ± 0.2 (17)	*	4.2 ± 0.1 (41) A	3.9 ± 0.1 (38) AB	4.3 ± 0.3 (16)	3.6 ± 0.3 (10)
1992	3.5 ± 0.2 (30)	*	3.4 ± 0.1 (73) C	*	*	*
1993	*	*	3.3 ± 0.1 (194) C	*	*	*
1995	*	4.0 ± 0.1 (30)	3.9 ± 0.1 (94) B	4.1 ± 0.1 (53) A	3.5 ± 0.3 (13)	3.8 ± 0.2 (28)
1996	3.8 ± 0.2 (25)	*	4.0 ± 0.1 (186) AB	3.5 ± 0.1 (45) BC	*	3.8 ± 0.1 (28)
1997	3.9 ± 0.2 (37)	3.7 ± 0.3 (12)	3.7 ± 0.1 (113) B	3.4 ± 0.1 (63) C	4.1 ± 0.2 (19) 3	3.9 ± 0.1 (32)

Heinrichøya or Ytre Breøya (ANOVA, Eskjer: $F = 2.63$, $df = 2, 45$, $p = 0.1$, Prins Heinrichøya: $F = 1.43$, $df = 4, 129$, $p = 0.2$, Ytre Breøya: $F = 0.37$, $df = 3,94$, $p = 0.8$). On Juttaholmen and Storholmen, mean clutch sizes varied between years but there were no trends in either direction over the last seven years (Table 3). Average clutch sizes partly followed the dates when the sea ice broke up (Table 2 and Table 3).

Clutch sizes were compared among islands in 1991, 1995, 1996 and in 1997 (limited data in 1992 and 1994, Table 3). In 1991 and 1995, average clutch size was similar on all islands (ANOVA, 1991: $F = 1.72$, $df = 4, 117$, $p = 0.15$, 1995: $F = 0.98$, $df = 4, 214$, $p = 0.42$). In 1996, the average clutch size was largest on Storholmen (ANOVA, $F = 2.81$, $df = 3, 180$, $p = 0.04$, Table 3) and in 1997, average clutch size was largest on Eskjer (ANOVA, $F = 2.66$, $df = 5, 270$, $p = 0.02$, Table 3). A seasonal decline in clutch size of barnacle geese has been found in the Kongsfjorden colony (Dalhaug et al. 1996) where late-nesting females allocated fewer body reserves into eggs. This is advantageous because late-nesting females have a shorter period to regain body reserves after incubation. In a study from the same area on common eiders, clutch size was found to be negatively correlated to the time of egg-laying (Mehlum 1991b). An early break-up of sea ice may therefore result in larger clutches, although in 1996 and 1997 most islands were free of sea ice early. Accordingly an early break-up of sea ice is not the only explanation for larger clutches at Storholmen and Eskjer in 1996 and 1997. Age distribution of the breeding birds could be an alternative explanation (see above).

Including all years and nest locations, no significant correlation between average clutch size and total number of nests on the islands were found (linear regression, all islands: $R^2 = 0.14$, $n = 23$, $p = 0.08$, all islands except Storholmen in 1993 (over-represented with young breeders): $R^2 = 0.02$, $n = 22$, $p = 0.5$). Moreover, including nest site and year in addition to total nest number on the island in the model, none of the variables seemed to determine clutch sizes (GLM, Type III sum of squares, all p-values >0.5). The traditional theory is that clutch size in arctic-nesting geese is determined by processes going on before the nests are established; namely by available body reserves at the start of egg laying (Lack 1967; Ryder 1970; Ankney & MacInnes 1978; Ankney et al. 1991). Several studies have also presented evidence that clutch size in precocial birds is ultimately determined by the interaction between the use of body reserves for egg production and later use for incubation and care of young (Gloutney & Clark 1991; Erikstad & Tveraa 1995; Tombre & Erikstad 1996). The geese in this colony also spend a considerable amount of time feeding elsewhere before they arrive at Ny-Ålesund and feeding conditions before arrival are therefore crucial to their reproductive success (Tombre et al. 1996). However, early breakup of sea ice may contribute to early egg laying and larger clutches, and, in addition to the presence of foxes, this could proximately influence breeding conditions on the different islands in Kongsfjorden.

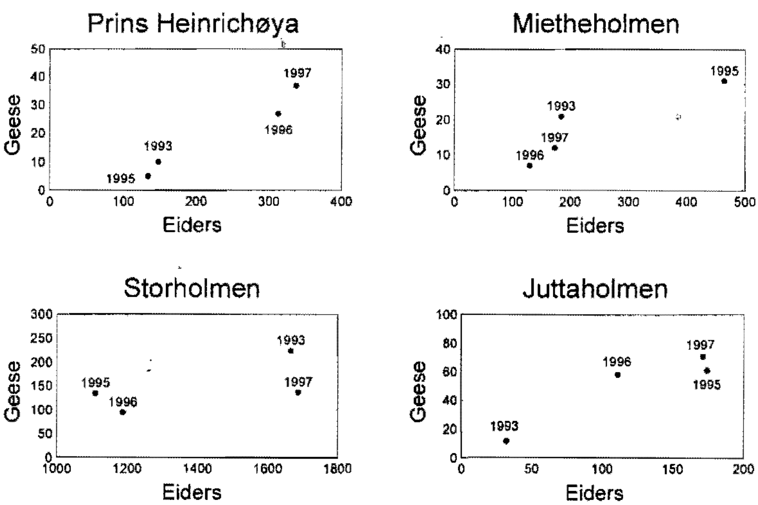

Fig. 3. Breeding numbers of common eiders and barnacle geese of four islands in 1993 and 1995–1997 in Kongsfjorden, Svalbard.

Table 4. Percentage of barnacle goose nests in relation to common eider nests on four islands in Kongsfjorden, Svalbard (see Fig. 3 for sample sizes).

Year	Prins Heinrichøya	Mietheholmen	Storholmen	Juttaholmen
1993	11.4	6.8	13.4	7.4
1995	6.7	3.7	12.1	4.4
1996	5.4	8.6	7.9	4.7
1997	6.9	10.9	8.1	7.6

Barnacle goose nests and common eider nests

In Fig. 3, the numbers of barnacle goose nests on four important breeding locations in 1993 and 1995–1997 are plotted against the numbers of common eider nests on each location during the same years. The variation between years in nest numbers is considerable, and there is obviously a positive correlation between the number of nests on the different islands for the two species (although sample sizes are too small to perform a statistical test). Good breeding conditions for geese are also good breeding conditions for common eiders, presumably reflecting the sea-ice conditions and the islands' availability for nesting. Comparing the percentage of goose nests in relation to common eider nests, the number of goose nests does not seem to have increased at the expense of common eider nests over the last five years (Table 4). Accordingly, no obvious competition for nest sites was found between the two species.

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