The relationship between an increasing Barnacle Goose *Branta leucopsis* population and the number and size of colonies in Svalbard

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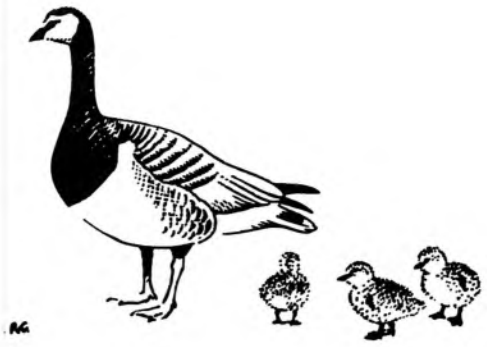

This paper documents the current numbers and distribution of Barnacle Goose colonies in Svalbard, Norway. Using the data from the literature and current censuses we investigate the possibility that the recent increase in numbers in this population is slowing due to a limited number of nesting places and conclude that nesting space per se is not limiting. More likely density dependent effects operate through the interaction between the geese and their food supply on the nesting and brood rearing areas.

In two long-term studies on expanding goose populations evidence of density dependent effects is accumulating. In the Lesser Snow Goose colony *Anser caerulescens caerulescens* at La Perouse Bay, Manitoba, Canada, the mean clutch size has declined by 16% as the population increased from 3000 to 8000 breeding pairs (Cooch *et al.* 1989). The Svalbard Barnacle Goose *Branta leucopsis* population has increased from 300 individuals in the 1940s to 12,100 in 1988, but since 1980 the growth rate has slowed considerably (Owen & Black 1989, in press a). This population has shown an increase in the numbers of non-breeding birds, and an increase in female mortality during summer and migration (Owen 1984, Owen & Black in press a,b). In addition, in 1986, when breeding density was high, 35% of the fledged goslings failed to return from the breeding grounds (Owen & Black 1989).

The reasons for these density dependent effects have been more difficult to quantify. Cooch *et al.* (1989) suggest that the Lesser Snow Geese are no longer able to acquire sufficient fat and nutrient reserves, and the Barnacle Geese are thought to be limited through lack of suitable nesting areas (Owen & Norderhaug 1977), competition for food on the breeding grounds (Owen 1984, Prop *et al.* 1984, Owen & Black 1989) and perhaps on the spring staging areas (Black *et al.* in press).

When Svalbard Barnacle Geese were discovered last century their nests were found only on cliff faces and rocky slopes in the mountains (Jourdain 1922, Lovenskiold 1964). In the 1950s and 60s, the birds began to make use of offshore islands mainly in the southern and western parts of Spitsbergen (Norderhaug 1970, Owen & Norderhaug 1977). In addition to documenting the current numbers and distribution of the Barnacle Goose colonies, we investigate the possibility that the population expansion is slowing due to a limited number of nesting places (*sensu* Owen & Norderhaug 1977).

Methods

During the period 1982–86 most colonies on the west coast of Spitsbergen were visited several times, usually by boat and less often on foot or by helicopter. Nests were counted either while the birds were nesting or by identifying used nests after departure. During incubation on island colonies, nests were counted from only two or three vantage points to avoid disturbance so inevitably some of the pairs were missed. Similarly these can be over-estimates because there may be pairs which are apparently on nests but are not breeding. After hatching, nests were recognised by the presence of down, fresh droppings surrounding the nest scrape, and eggshells. The grey/white appearance of the goose down was easily distinguished from the

brownish down of the Eider Ducks *Somateria mollissima* that also nest on the islands. Counts of used nests gave an accurate figure for those pairs that began incubating (most down is plucked in the first few days of incubation). Pairs which lost their nests during laying were not, however, detected; incubation surveys may also have missed some of the early losses. Most nest losses, however, occur towards the end of incubation when the pairs' energy reserves are depleted and they have to leave the nest to feed (Prop *et al.* 1984). Despite the potential errors, where incubation counts and those of used nests coincided, they gave very similar results. The islands were surveyed by both methods and, taking the midpoint of the incubation estimate, that estimate was within 7% of the count results: incubation counts (by E. Persen) and used nest counts in parentheses --Olsholmen 80–100 (98), Fjorholmen 80–100 (92), S. Dunoya 250–320 (245).

Counts that were made when the birds were present are given as a range, the lower number is the actual count and the higher is an estimate of the nests based on the size of the unseen area and nest density of the censused area. In some of the older counts in the literature and counts from cliff nesting areas, the best measures of numbers were counts of family parties; these are presented as minimum estimates.

Results

Expansion of colonies

Figure 1 depicts the numerical distribution of nests in the 1960s and in the 1980s. The number of nests has increased in all older colonies and at least 20 new colonies have developed. Appendix 1 lists the latest counts for each colony. The great majority of colonies are located on the west coast of Spitsbergen which becomes ice-free each summer.

By comparing the data from Diabas Island, the colony with the most complete coverage, it is apparent that the increase in nests was positively and significantly related to the increase of potential breeders in the population (Fig. 2). However, since 1981 nest numbers have not increased (see below).

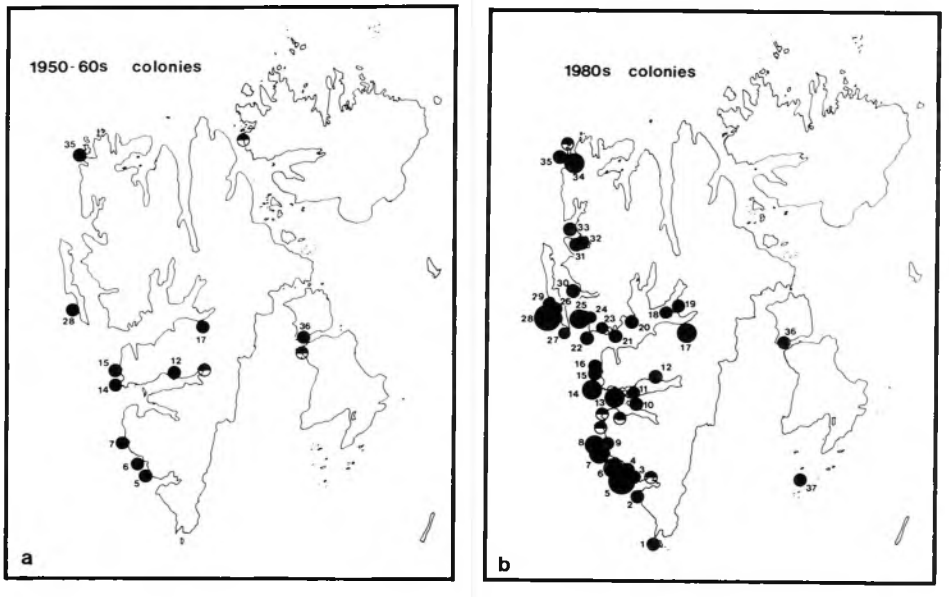

Figure 1. The distribution of Barnacle Goose colonies (closed circles) in the Svalbard archipelago in the (a) 1950–60s (Norderhaug 1970) and in the (b) 1980s. Half-filled circles represent probable breeding colonies that need further confirmation. The numbers correspond to the names listed in Appendix 1 and Table 2 and the size of circle represent relative colony sizes; less than 100, less than 300 and greater than 300.

Size and type of nesting areas

The colonies consisted of three types: coastal sites (islets and rocks near or on the shore), inland sites (cliffs and canyons) and offshore islands. Apart from the new and unusual nests (n = 15) near the buildings in the village, Ny Alesund, only a few were accessible to Arctic Foxes *Alopex lagopus*. Table 1 lists the mean number of nests for each of these colony types. The range was from single nests on shorelines (rock/stacks) to just over 700 nests in the three Dunoyane islands.

Table 1. Number of Barnacle Goose nests in various colony types in Svalbard.

	% of Total	Nests n	Mean Colony Size
Coastal Sites	6.4%	85	5 nests (SD= 2)
Inland Sites	6.8%	195	10 nests (SD= 8)
Offshore Islands	86.8%	2480	113 nests (SD=160)

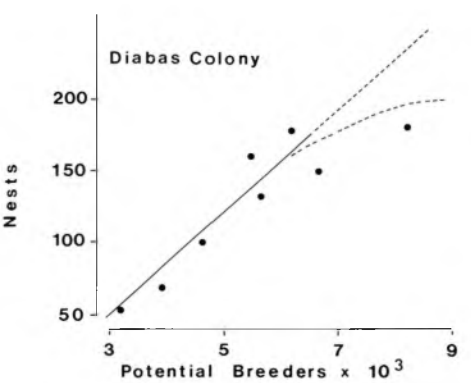

Figure 2. The number of Barnacle Goose nests on the Diabas Island colony in relation to the proportion of potential breeders in the population. The overall regression was significant and positive (r^2 = 0.95, df = 5, t-test = 9.94, P<0.001). Data from the 70s and early 80s were from Ebbinge and Ebbinge (1975) and Prop *et al.* (1984).

Factors effecting the rate of expansion

From the literature it was possible to determine the approximate year that colonies were initiated and to calculate the "historical" rate of expansion from this date to the present (current number of nests/age of colony). Figure 3 depicts the increase in numbers for nine colonies and Table 2 lists their statistics.

The peak nest number (logarithmically transformed, r^2 = 0.83, df = 7, t-test = 5.91, P<0.001) and the historical rate of expansion (logarithmically transformed, r^2 = 0.76, df = 7, t-test = 4.65, P<0.01) showed positive regressions with island size. Neither longitude nor latitude nor age of colony was significantly related to the rate of expansion.

Limiting factors of colony expansion

Figure 2 shows that after 1981 the number of nests on the Diabas Island colony stopped increasing. This occurred despite the continued increase in potential breeders in the population. As a result a larger number of non-breeding geese appeared in the area (Prop *et al.* 1984) and a larger proportion of the entire population returned to the wintering grounds without young (Owen 1984, Owen & Black 1989).

Only three of nine colonies in Table 2 (and Fig. 3) appeared to have reached their limit in recent years (colonies 6, 14, 15). In view of the high nest densities on smaller islands there is plenty of room for more nests on the larger islands. Nest densities of the stabilising colonies (i.e. Isoyane 5.11 nests/ha) are similar to those that are still expanding (i.e. Forlandsoya 7.6 nests/ha). Therefore, nest density does not appear to be the only factor that limits colony size.

Discussion

According to Fretwell & Lucas (1970) when a population expands new individuals establish themselves in second rate areas because the prime areas should already be occupied. This assumes that the animal fights and protects its territory which is certainly the case with Barnacle Geese (Owen & Wells 1979, Prop *et al.* 1984). When numbers in Svalbard increased in the early 1960s and again in the 1970s the geese

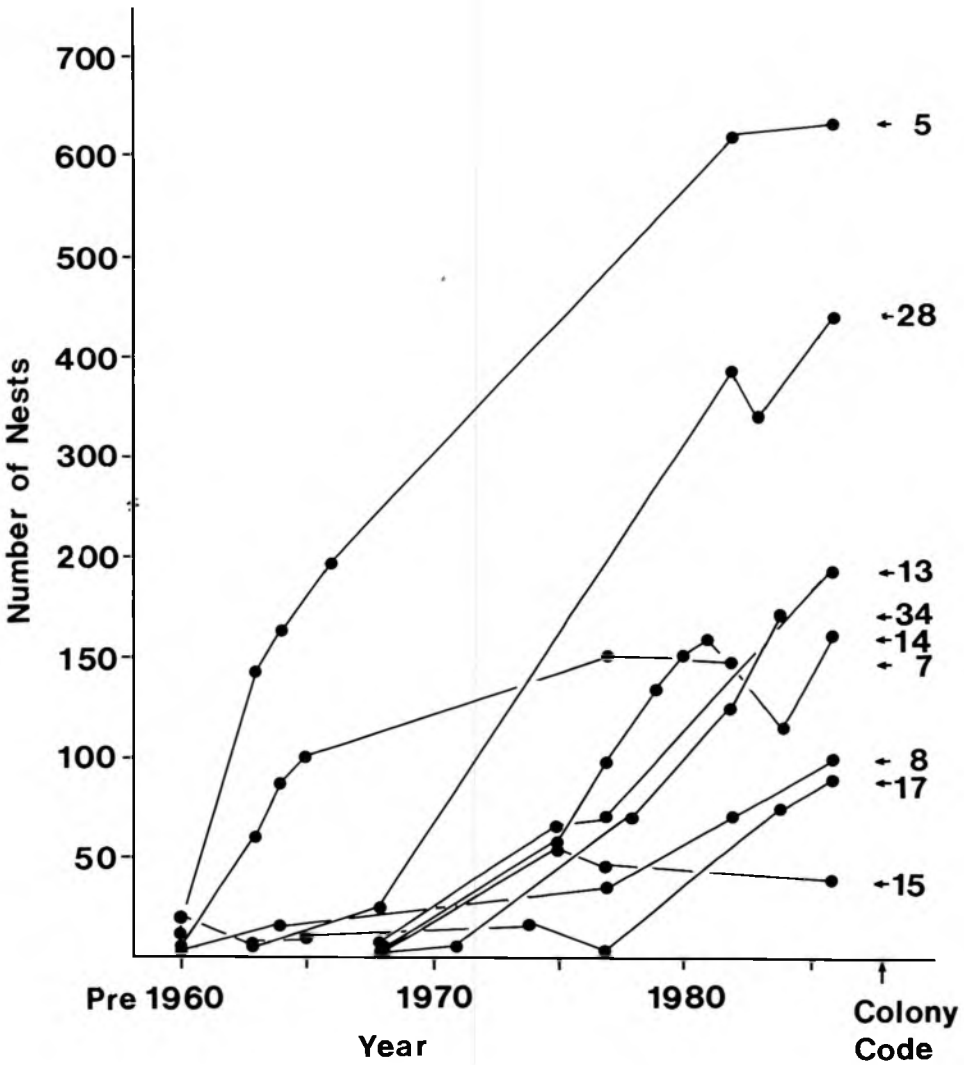

Figure 3. Change in Barnacle Goose colony size from pre 1960s to 1986 for nine colonies. Pre-1982 data were obtained from the Norsk Polarinstitutt data base and from sources in Norderhaug (1970). The names of colonies can be found in Appendix 1.

did indeed range to several new areas (Fig. 1). Similarly, from the mid-1970s through the eighties numbers have increased and over 20 new nesting areas are recorded in this paper.

The fact that nest numbers are levelling out in some colonies at low densities (relative to those on the densest colonies) suggests that resources other than nest sites are limiting. Prop *et al.* (1984) estimated that there was space for an additional 200 nests on the Diabas colony if similar densities occurred over the entire island; the modal nearest nest distance was 7 m. In each year of their study, between 11%–26% of birds aged three years or more did not establish nests (also see Owen & Black in press b on lifetime strategies). Prop *et al.* suggested that nest density is limited by feeding opportunities around the nest, field

Table 2. Historical and geographical statistics for nine Barnacle Goose colonies in Svalbard. The ID number matches those in Figure 1 and Appendix 1. Apart from Sassendalen (17) all colonies are offshire islands.

ID.	Colony	Growth[a] Rate	Age in 1986	Latitude	Longitude	Island[b] size	Nests/ha
5.	Dunoyane	17.64	36+[c]	77.10N	15.00E	130.41	4.87
7.	Isoyane	5.55	36+[d]	77.20N	14.70E	29.34	5.11
8.	Olsholmen	2.78	36+[d]	77.30N	14.30E	0.21	466.70
13.	Reiniusoyane	9.14	21[e]	77.70N	14.30E	7.84	24.49
14.	Diabasoya	9.94	21	77.75N	13.73E	3.26	49.80
15.	St Hansholmane	4.75	23	77.88N	13.68E	0.06	950.00
17.	Sassendalen	2.37[f]	36+[d]	78.30N	16.80E	–	–
28.	Forlandsoyane	19.26	23	78.30N	11.50E	58.28	7.60
34.	Moseoya	10.63	20	79.70N	11.00E	31.65	5.37

[a] The number of nests/age of colony.
[b] Hectares.
[c] Possibly established in 1940s but confirmed counts in 1950s (see d).
[d] Established in the 1950s (1950 was used in calculating historical rate).
[e] Assumed to be same age as Diabasoya which is in the same area.
[f] Calculated to 1988; nests on canyon slopes and cliffs.

of view from the nest and competitive exclusion in the more dense areas.

Despite the fact that female geese are highly phylopatric and males follow females to the nesting area (Cooke *et al.* 1975, Black & Owen unpubl. data) many geese have recently discovered new colonies. Little is known about the relative productivity of these areas and their impact on population dynamics, although we have documented differences in gosling size at fledging, adult size and reproductive success in a few of the more established colonies (Owen & Black 1989). There is some indication that productivity in some new areas may be less good; in Tusenoyane (number 37) Polar Bears *Ursus maritimus* destroyed a small colony in 1987 (Madsen *et al.* in press). Cliff nesting may be a successful alternative providing the distance from brood rearing areas is not too great (S. Newton and D. Cabot pers. comm.). About 90 nests were counted in 1988 in the Sassen valley, 20 of which were on small ledges in steep canyons 3 km away from the brood rearing area. Broods have been seen in this area in the 1960s, 70s and every year since 1983.

We conclude that on off-shore islands nesting space *per se* is not limiting numbers in this population. Rather, the amount of available vegetation around the nest is limiting nesting density and the vegetation in brood rearing areas is also inhibiting the recruitment of young (Owen 1984, Prop *et al.* 1984, Owen & Black 1989) and causing the population to stabilise around 12,000 individuals. The present population size that was predicted through use of the data on the long-term ringing programme (Owen 1982), will probably be maintained given the continued protected status of the species throughout its range and the continued designation of sanctuary areas in Svalbard and Scotland. Currently about 58% of nests occur within Svalbard national park sanctuaries and the population spends about half of the winter months (and a higher proportion during the shooting season) on the N.C.C./Wildfowl Trust reserve (Prestrud & Borset 1984, Owen *et al.* 1987). The effect of the changing quality and quantity of the birds' spring staging habitat in Helgeland, Norway remains less certain (Black *et al.* in press).

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Appendix 1. Current Barnacle Goose nest counts of major colonies in Svalbard. Colony types include OI = Offshore Island, Rocks and Stacks = RS and Cliffs and Slopes = CS, Within Ny Alesund Village = WV, Island in a Lake = IL.

ID.	Colony Name	Type	Number of Nests	Lastest Counts
1	TOKROSSOYA	OI	5 – 10	1984
2	HORNSUNDNESET	OI	Broods	1973
3	ISLETS OFF STEINVIKA	OI	5 – 10	1982
4	DUNOYSKJAERA	RS	10 – 20	1982
5	DUNOYANE	OI	550 – 720	1982–1986[a]
6	THORKELSHOLMEN	OI	Broods	1986
7	ISOYANE	OI	135 – 260	1982
8	OLSHOLMEN	OI	80 – 100	1982,1986[a]
9	GRAAHOLMANE	OI	100 – 120	1982
10	MIDTERHUKEN	CS	10 – 20	1984–1985
11	MARIAHOLMEN and W. ISLETS	OI	12 – 20	1984–1985
12	REINDALEN	CS	10 – 30	1984–1985
13	REINIUSOYANE	OI	190	1984, 1986
14	DIABASOYA	OI	160	1982–1984,1986
15	ST HANSHOLMANE	OI	39	1984–1986
16	BAATTODDENHOLMEN	OI	9	1986
17	SASSENDALEN	CS	80 – 100	1983–1988
18	GAASOYANE	OI	10 – 30	1983,1985
19	GIPSHUKEN	CS	5 – 10	1983
20	BOHEMANNESET	OI	45 – 65	1982[b],1983
21	SELMANNESET	OI	28	1982[b]
22	DAUDMANNSOYRA ISLETS[b]	OI	37	1982[b]
23	BAAKEVATNA	IL	2	1982[b]
24	HAMNETANGEN	CS	5	1982[b]
25	MARINEHOLMANE and GUDRUNHOLMANE	OI	140 – 150	1982[b], 1985
26	STORKOBBEN & SNADDEN	RS	20 – 40	1985
27	PLANKEHOLMANE	OI	10 – 15	1984
28	FORLANDSOYANE	OI	380 – 505	1982–1986[a]
29	LORTHOLMEN	OI	35 – 55	1985
30	HERMANSENOYA	OI	15 – 20	1984, 1985
31	NY ALESUND	WV	15	1987[d]
32	KONGSFJORDERN	OI	25 – 40	1987
33	KAPP GUISSEZ	RS	7 – 10	1984
34	MOSEOYA	OI	100 – 180	1984
35	SKORPA	RS	10 – 15	1984
36	BARENTSOYA	OI	10 – 15	1983, 1985
37	TUSENOYANE	OI	30 – 40	1985, 1987[e]

Other Single Records = Gravdal[f] (1 nest), Moffen[a] (1–3 nests)
Hinlopen (1 nest)[g]

[a] Endre Persen provided 1986 counts.
[b] Prokosch (1982).
[c] Kanoukulene to Askjera.
[d] Per Espen Fjeld, pers. comm.
[e] Endre Persen (1985) unpubl. report; Madsen *et al.* (in press).
[f] Duggleby, T.R. & Evans M. 1987. Bird Observations from the Ekmanfjord area, Svalbard July–August 1987.
[g] A. Borset observation in 1983.