Does arctic vegetation change when grazed by barnacle geese? A pilot study

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The effects of grazing by barnacle geese *Branta leucopsis* on arctic vegetation was studied. Two plots where grazers had been excluded five and six years previously were compared with grazed vegetation nearby. The exclosed plots contained more live biomass than the area with grazed vegetation. However, there was no significant difference in density of shoots and number of leaves per shoot in the heavily grazed *Poa arctica*. Within the exclosed plots, there was a slow build-up of dead material and the moss carpet had grown thicker than in the grazed plots. The number of inflorescences was the most prominent feature, which differentiated the exclosed vegetation from the grazed surrounding. There is no evidence for habitat deterioration caused by increased grazing pressure from the expanding barnacle goose population as has been reported for the snow goose on the Hudson Bay lowlands in Canada. The increased activity of nitrogen fixation by cyanobacteria in grazed vegetation might be a mechanism which compensates for the nitrogen deficit caused by the migratory geese.

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Introduction

Increasing numbers of lesser snow geese *Anser caerulescens caerulescens* in the southern region of Hudson Bay, Canada, are destroying their grazing habitat (Kotanen & Jefferies 1997; Jano et al. 1998). During snow-melt, the geese grub and destroy large areas of vegetated salt marsh in search for rhizomes. In the open areas salinity increases, which hampers revegetation (Srivastava & Jefferies 1996). This large-scale destruction of sub-arctic habitat has led to an increasing effort to reduce the size of the present population of the mid-continental lesser snow goose (Ankney 1996).

In the same area it is shown that goose grazing during summer can have a positive effect on vegetation production. The frequently produced goose droppings are a source of nitrogen for the nitrogen-poor vegetation, and the production of grasses and sedges eaten by the geese is enhanced because of the acceleration of the nitrogen cycle (Bazely & Jefferies; Hik & Jefferies 1990). The exporting of nitrogen out of the ecological system by the autumn migration of the newly produced goslings is compensated by the enhanced nitrogen fixation of cyanobacteria in the grazed vegetation (Bazely & Jefferies 1989).

In areas that are located more to the north, no positive effect of goose grazing on plant production has been found (Gauthier et al. 1995; Bakker & Loonen 1998). Here, less grubbing by geese is observed and not all goose-grazed areas are situated on salt marshes. Fresh water lake areas and tundras, where salt stress is absent, are also used. However, the great increase in most goose populations since 1970 has caused a growing concern about the effect of the increase on arctic vegetation and associated wildlife. In the High Arctic, after the geese have migrated out there is less time for the area to recuperate from grazing because of the short summer.

The effects of grazing by the barnacle goose *Branta leucopsis* have been examined at two sites. At each site, a plot where grazing by geese had been excluded for many years was compared with grazed vegetation nearby.

Material and methods

The study was performed in the direct vicinity of the village of Ny-Ålesund, where barnacle geese have been grazing since 1980. The number of

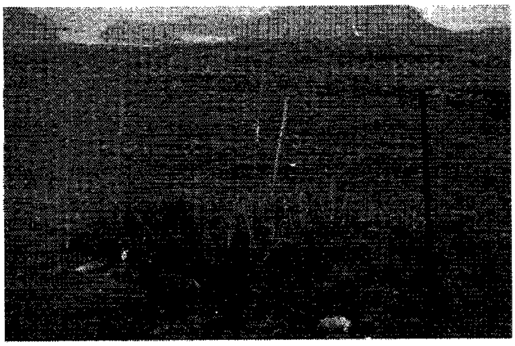

Fig. 1. The exclosure on site A, built in 1993 and photographed in 1998.

barnacle geese at this study area has been steadily increasing, together with the entire population of Svalbard barnacle geese (Loonen et al. 1998, this volume). Two 0.7 m^2 exclosures were defined, one in 1992 and one in 1993. These exclosures survived until 1998 when the vegetation inside the exclosures was then compared with grazed control plots directly outside the fence. We assume that there was no difference on either side of the fence in microclimate or timing of snowmelt and that any difference between the vegetation inside and outside of each exclosure is caused by grazing only. The exclosure built in 1993 on site A was situated in a wet, moss area at a site where shoots of *Poa arctica* were relatively abundant (Fig. 1). The exclosure built in 1992 on site B was built on a slightly dryer area, where *P. arctica* also dominated. No bare ground was present in either of the vegetation types. All vascular plants protruded through a completely closed moss carpet. Both sites were heavily grazed by barnacle geese during the summer period and had vegetation types comparable with, respectively, the moss areas and the meadows in Stahl & Loonen (1998, this volume).

On 11 August 1998, the vegetation was described at both sites. Sixteen randomly placed frames (5 × 5 cm^2) were placed both inside and outside the exclosed plot. The following seven parameters were measured in each plot: (i) Coverage of live biomass of *P. arctica* (percentage); (ii) Coverage of dead biomass of *P. arctica* (percentage); (iii) Density of shoots of *P. arctica* (calculated as density per m^2); (iv) Length of all live leaves per shoot of *P. arctica* (mm per shoot); (v) Number of live leaves per shoot of *P. arctica*; (vi) Width of a full-grown *P. arctica* leaf (mm); (vii) Coverage of other plant species (all dicots; percentage).

Furthermore, the following three parameters were measured once per area: (i) Total number of live inflorescences of *P. arctica* per m^2; (ii) Total number of live inflorescences of dicots per m^2; (iii) The maximum difference in height of the moss carpet inside the exclosure, compared to the grazed environment from a lateral view.

The nitrogen fixation activity of cyanobacteria present on the vegetation was measured by collecting two times five samples of vegetation with a surface area of 1.13 cm^2 on each site and measuring ethylene formed by incubating the vegetation samples for 3 h in daylight at 20°C in 10 ml vials with 10% acethylene in the atmosphere as described in Solheim et al. (1996). Nitrogen fixation activity was expressed as nmol ethylene produced h^{-1} cm^{-2} vegetation.

The difference between exclosed and grazed vegetation in each site was tested by Mann-Whitney U-tests.

Results

Two years after the exclosing, the most prominent feature in the exclosures was the presence of numerous inflorescences. This was still the case in 1998, when site A had been enclosed for 5 years and site B for 6 years (Table 1). The standing crop of *P. artica* was considerably larger inside the exclosures than outside. Both the coverage and the total leaf length per shoot were significantly higher inside the exclosures. There was also a clear build-up of dead material in the standing crop within both exclosures. No difference was evident in the number of shoots per m^2 and the number of leaves per shoot, suggesting little effect of grazing on the occurrence of *P. artica*. However the grass leaves in the exclosed plots where broader than in the grazed control plots.

Site A had fewer vascular plant species than site B. At site A, *P. artica*, *Saxifraga cernua* and *Ranunculus hyperboreus* were present in the exclosure, and *P. artica* and *R. hyperboreus* were present in the grazed area. At site B, *P. artica*, *Deschampsia alpina*, *S. cernua*, *Saxifraga cespitosa*, *Cerastium arcticum*, *Cardamine nymanii* and *Polygonum viviparum* were present in the exclo-

Table 1. Comparison of grazed plots with plots which have been exclosed for at least five years from grazing. For a full explanation of the variables and the units of measurement see the Material and methods section. Significance is based on a Mann-Whitney U-test: *: $P < 0.05$; **: $P < 0.01$; ***: $P < 0.001$; n.s.: not significant; [a]no test, n = 1; [b]: n = 5; all other comparisons: n = 16.

		Poa arctica							Didcots		
		Coverage (%)									
Site		Live	Dead	Shoot number (m^{-2})	Total leaf length (mm)	Leaves per shoot	Leaf width (mm)	Inflorescences (m^{-2})	Coverage (%)	Inflorescences (m^{-2})	N fixing activity (nmol C_2H_4 h^{-1} cm^{-2})
A	Exclosed	29.7	5.8	8320	164	3.1	2.0	108	5.5	5	0.7
	Grazed	10.8	1.4	9720	31	3.0	1.1	0	0.1	0	2.6
	Significance	***	***	n.s.	***	n.s.	*	[a]	**	[a]	**[b]
B	Exclosed	17.1	11.9	3760	70	2.8	2.5	2	18.3	410	0.5
	Grazed	4.1	0.3	3680	18	3.0	1.5	0	15.6	72	1.2
	Significance	***	***	n.s.	***	n.s.	*	[a]	n.s.	[a]	n.s.[b]

sure and *P. artica*, *Sagina cernua*, *S. cespitosa*, *C. nymanii* and *S. nivalis* were present in the grazed area. Most plants were growing in small tussocks except *P. artica* and *S. nivalis*. At site A, *Calliergon richardsonii* was the most dominant moss species, while at site B, *Sanionia uncinata* was dominant, but several other moss species were also present. At site A the moss surface had grown almost 50 mm higher in the exclosure than in the grazed environment. For site B, this difference was only 2 mm.

At both control sites the grazed vegetation had a higher level of nitrogen fixation by cyanobacteria than the exclosed vegetation, though the difference was only significant at site A.

Discussion

Though *P. artica* was grazed intensively during summer on the tundra around Ny-Ålesund and 66% of the annual production was removed by the geese (Bakker & Loonen 1998), there was no long-term effect of goose grazing on the occurrence of *P. artica* as measured in the density of shoots and the number of leaves per shoot. Grazed plots had a lower standing crop (measured as percentage cover and as total leaf length per shoot), but this was mainly due to recent grazing in 1998.

The build-up of dead material was a prominent feature in the exclosed plots. In the grazed plots, dead material was rare because most leaves were eaten before senescence occurred, resulting in a reduced flow of senescing tissue (Bakker & Loonen 1998). Dead material may eventually hamper vegetation growth due to reduced light availability, as shown by Wegener and Odasz (1997) in a pot experiment, though this was not evident after 6 years in our field study.

The flowering of *P. artica* and various dicots was also a prominent feature in the exclosures. The seeds and flowers of most plants were favoured food items for the barnacle geese (own obs.), but flowering was rare in the grazed vegetation. The flowering may enhance the fitness of the plants, though vegetative propagation and clonal growth are common alternatives for establishment in arctic plants (Chou et al. 1992).

Grasses in the exclosed plots had substantial broader leaves. This might be the result of less nutrients being taken from the plant. The reserves stored in the roots of the arctic plants are important for future production and the amount of nutrients stored is related to the amount of above-ground biomass (Archer & Tieszen 1983). Both the appearance of thicker leaves and the flowering became obvious when the exclosures were two years old, and were still visible after six years of exclusion.

At both study sites, there were more plant species growing in the exclosures than in the grazed plots. A similar effect was also observed in the snow goose study of Bazely and Jefferies (1986).

The fact that barnacle geese also feed on moss resulted in a difference in height of the moss surface level in and outside the exclosures. It is not clear if an interaction existed between the moss and the vascular plants which could be affected by the grazing.

Nitrogen fixation is an expensive physiological process. Only when nitrogen is limiting does cyanobacteria transform atmospheric nitrogen into ammonia. In areas where nitrogen was abundant (for example under bird cliffs in the Arctic where the vegetation was fertilised by the faeces of seabirds), nitrogen fixation was never found even though the bacteria were usually present (Solheim et al. 1996). In grazed areas, there is a net export of nitrogen by migratory barnacle geese because nitrogen is deposited in the goose body. The females increase about 300 grams in weight while recuperating from the incubation period, and the goslings grow from 70 grams to 1,250 grams (own obs.). Around 15 August, at the end of the moulting period, the goslings fledge and the barnacle geese leave the study area in preparation for migration to Scotland. The response of the cyanobacteria to the scarcity of nitrogen at the heavily-grazed moulting site was increased nitrogen fixation. This mechanism compensated for the removal of nitrogen by the geese. Similar results have been found on the Hudson Bay salt marsh. There, the cyanobacteria occurred mainly on bare ground and the larger nitrogen fixation in grazed areas was attributed to the presence of more bare ground (Bazely & Jefferies 1989). In our study area, the cyanobacteria were attached to the moss plants and their presence varied among moss species (Solheim et al. 1996).

Geese were not the only herbivores present in our study area. Svalbard reindeer *Rangifer tarandus plathyrhynchus* also visited the study area. However, there was little harvestable vegetation left for them after the geese had grazed the area because the geese were very efficient in removing a substantial part of the annual production. The reindeer focused more on eating goose droppings (van der Wal & Loonen 1998) and probably had a minor impact on our study site, which disappears under a thick snow carpet in winter.

In conclusion, although there was no evidence that the vegetation was destroyed by the increasing number of barnacle geese, the structure of the vegetation was clearly affected by grazing. This might have an effect on breeding waders, which rely on tussocks as safe nest sites. In addition, plants which depend largely on flowering (for example *Saxifraga cernua*) were less abundant in grazed vegetation. However, these effects cannot be seen as threats to the arctic environment. Though this study was based on two sites only, the results suggest a prudent approach before translating the habitat destruction observed in the Hudson Bay lowlands to a universal problem caused by increasing goose populations.

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