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S04-1 The impact of goose grazing on arctic and temperate wetlands

Gilles GAUTHIER[1], Jean-François GIROUX[2], Line ROCHEFORT[3]

1. Dept. of Biology and Centre d'études nordiques, Université Laval, Quebec, Qc G1K 7P4, Canada; gilles.gauthier@bio.ulaval.ca
2. Dept. of Biological Sciences, Université du Québec à Montréal, P.O. Box 8888, Stn Centre-ville, Montréal, Qc H3C 3P8, Canada; giroux.jean-francois@uqam.ca
3. Dept. of Phytology and Centre d'études nordiques, Université Laval, Quebec, Qc G1K 7P4, Canada; line.rochefort@plg.ulaval.ca

Abstract Geese are large, herbivorous birds that graze in huge flocks in ways that may have a considerable impact on vegetation. This is exemplified best in two subspecies of snow geese, the lesser and the greater, both of which have increased dramatically in numbers in recent decades. In arctic coastal salt marshes, moderate goose grazing on *Puccinellia phryganodes* enhances plant production, but if it intensifies beyond a certain threshold it destroys the plant cover, leading to hypersalinity, soil erosion and little revegetation for long periods. In freshwater tundra wetlands dominated by *Dupontia fisheri*, *Eriophorum scheuchzeri* and brown mosses, grazing changes plant composition and reduces production of *Eriophorum*. Grazing may also favor mosses at the expense of grasses and sedges because mosses short-stop most of the nitrogen released from goose faeces. In temperate salt marshes, damage to the binding plant *Spartina alterniflora* from goose grubbing has been locally severe and has led to the devegetation of large areas. In temperate brackish marshes, geese heavily grub the rhizomes of *Scirpus pungens*. Their grubbing depresses *Scirpus* production, alters plant species composition, and influences marsh dynamics by enlarging ice-made depressions which are then colonized by other species. Grazing and grubbing in arctic and temperate freshwater wetlands apparently leads to a low-level production equilibrium between geese and the plants, but not in salt marshes.

Key words Snow geese, Grazing, Grubbing, Herbivory

1 Introduction

Herbivores can have a profound effect on ecosystems. Large mammalian herbivores, such as the ungulates on the African savannas and Caribou on the arctic tundra, commonly affect production, structure and species composition in plant communities. Geese are among the few herbivorous groups of birds; and, in some circumstances, they too can impact significantly on natural plant communities. In this paper, we examine the impact of goose grazing on four different communities: arctic salt marsh, arctic freshwater meadow, temperate salt marsh, and temperate freshwater/brackish marsh. Due to their migratory habits, geese use arctic marshes in summer and temperate habitats during winter and on spring and fall migration. Our focal goose is the snow goose (*Anser caerulescens*), an abundant and widespread species in North America.

Several factors predispose geese to have a large impact on ecosystems. First, they are strictly herbivorous. Secondly, they have a low digestive efficiency (~35%) and thus eat large quantities of forage daily, of up to 1/3 of body mass, to meet energy requirements. Thirdly, geese are gregarious and feed in flocks, often numbering in the thousands. Fourthly, geese forage by two methods in natural habitats: grazing on above-ground leaves and shoots, and grubbing below the ground for rhizomes and bulbs. Fifthly, many goose populations have increased recently in North America, due in part to a fortuitous supply of food on agricultural lands in winter and spring. This is especially true for the two subspecies of snow goose, both lesser (*A. c. caerulescens*) and greater (*A. c. atlanticus*), which have exploded exponentially in recent decades to reach about 6 and 0.8 million birds, respectively (Abraham and Jefferies, 1997; Menu et al., 2002).

2 Arctic salt marshes

The west coast of Hudson Bay in subarctic Canada is a breeding site for lesser snow geese. Broad intertidal coastal flats dominated by a grass (*Puccinellia phryganodes*) and a sedge (*Carex subspathacea*) are the most important foraging habitat there. Grazed at a moderate level, the graminoids overcompensate in growth, so that by the end of a season under such a grazing regime, total above-ground production is higher there than in un-grazed sites (Cargill and Jefferies, 1984; Hik and Jefferies, 1990). Such a response results from the fertilizing effect of goose faeces and the colonization of bare sediments in grazed swards by nitrogen-fixing cyanobacteria (Bazely and Jefferies, 1985, 1989). Thus, moderate goose grazing increases productivity in this nutrient-poor community by speeding up the cycling of nutrients, especially nitrogen.

The state of the system can change dramatically, nevertheless, if this threshold in grazing intensity is exceeded. When this has happens, due, for example, to exploding population goose populations, the pseudostems of the grasses are damaged and the regrowth of swards severely impaired. Even more serious is the intense spring grubbing by staging geese en route to more northern breeding colonies. At snowmelt, geese excavate rhizomes around ponds and can strip vegetation from large areas (Jefferies, 1988).

When bare soil is exposed by such foraging, evaporation rate increases from surface sediments; and inorganic salts, which are abundant in the underlying marine clay sediments, rise to the surface. Salt accumulation at the surface leads to hypersalinity (>32‰), which is deleterious to graminoid growth and other vascular plants. Hypersaline conditions can lead further to death of surrounding vegetation (Iacobelli and Jefferies, 1991), which in turn exposes more sediments and promotes further evaporation and increase in salinity. Thus, goose damage to vegetation can lead to a runaway process of increasing destruction of salt marsh swards that is analogous to desertification (Srivastava and Jefferies, 1996). These processes have led to vegetation loss over large expanses of the Hudson Bay lowlands (Jano et al., 1998).

Goose-driven degeneration of the arctic salt marsh ecosystem has had an impact on the goose population itself, as goslings have undergone a dramatic drop in growth and survival (Williams et al., 1993). Destruction in this ecosystem also affects other bird species. Thus passerines and shorebirds such as the semipalmated sandpiper (*Calidris pusilla*) have declined in habitats damaged by geese (Gratto-Trevor, 1994; Abraham and Jefferies, 1997).

3 Arctic freshwater wet meadows

In many arctic landscapes, geese, such as the expanding breeding colony of snow geese on Bylot Island in the Canadian High Arctic, use freshwater wetlands for feeding. Their preferred feeding habitats are fens, often called wet sedge meadow (Gauthier et al., 1996). The fens are peat-accumulating systems because brown mosses cover them. They also have a lush graminoid cover dominated by the grass *Dupontia fisheri* and the sedges *Eriophorum scheuchzeri* and *Carex aquatilis*. The first two species are preferred by foraging geese (Manseau and Gauthier, 1993).

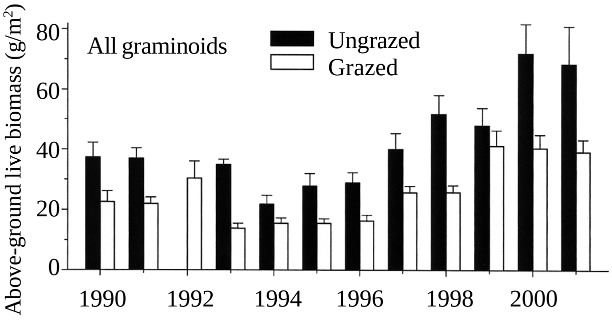

Fig. 1 Live above-ground biomass (mean ± *SE*, dry mass) of graminoids at mid August in grazed and ungrazed wet meadows on Bylot Island, Canadian High Arctic (n = 12) Graminoids include *Eriophorum scheuchzeri*, *Dupontia fisheri* and *Carex aquatilis*.

We have been monitoring the impact of goose grazing on Bylot Island since 1990, comparing the biomass at peak production in August inside and outside 1×1 m exclosures set up for one year. We have also been monitoring long-term changes in vegetation in the absence of grazing in 4×4 m permanent exclosures since 1994. Annual exclosures show that goose grazing reduces the standing crop but does so variably between years (Fig. 1; Gauthier et al., 1995). For example, the reduction in standing crop in 1993 was >60% whereas in 1999 it was negligible. *Eriophorum* also tends to be more heavily grazed than *Dupontia*.

Against the trend in increasing goose population, there has been no corresponding decline in plant production over the past decade. On the contrary, the highest productions have followed immediately on from a very low production in 1994, a drought year. Such annual variations in grazing impact can be explained by variations in the size of the "local" goose population. In that population, there is a close association between the young to adult ratio at the end of the summer (an index of reproductive effort and hence goose density), and the proportion of biomass grazed. In the high Arctic, the reproductive effort of geese is strongly affected by climatic events.

Moderate goose grazing does not enhance plant production as occurs in salt marshes, i.e., there is no overcompensation (Gauthier et al., 1995; Beaulieu et al., 1996), because goose faeces do not seem to have the same fertilizing effect on graminoids. The results of Pineau (1999) indicate that this is due to the presence of a thick layer of mosses in fens. When nitrogen is added to the surface to simulate nutrient leaching from faeces, mosses readily absorb it, but not the roots of vascular plants which are buried in the moss. Thus, mosses appear to act as a sponge, soaking up most nutrients released from goose faeces and preventing vascular plants from benefiting.

Results from our long-term exclosures show that moderate to chronic goose grazing still has an impact on plant communities in this ecosystem. After five years of goose exclusion on the permanent plots, the *Eriophorum* biomass grew 5-fold compared to the increase in control plots (one year exclosures); but not the *Dupontia* (Fig. 2). The number

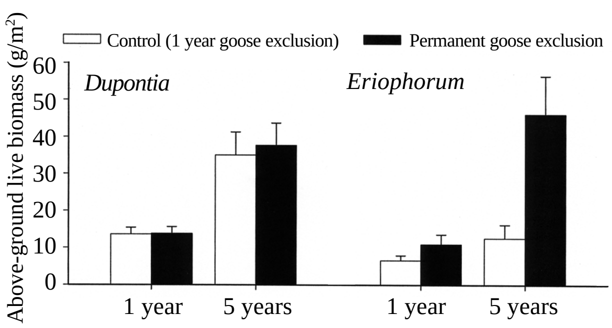

Fig. 2 Annual above-ground biomass of *Dupontia* and *Eriophorum* in permanent exclosures protected from goose grazing for 5 years (n = 17) and in annual control exclosures protected from grazing only for 1 year (n = 12), Mean ± *SE*

of *Eriophorum* tillers also more than doubled, and the number of flowering heads increased almost 10-fold. Hence, after 5 years of goose exclusion, *Eriophorum* had become the dominant plant in the long-term exclosures (>50% of biomass, compared to only 36% of biomass at the start of monitoring). Total above-ground graminoid biomass in exclosures averaged 87 g/m^2 per year over 5 years, compared to only 52 g/m^2 when grazing was stopped for a single year. In this ecosystem, therefore, it appears that grazing reduces plant production and changes specific composition due to selective grazing of *Eriophorum*.

4 Temperate salt marshes

Grubbing is the most common method of foraging used by snow geese in temperate marshes. On their wintering grounds along the Atlantic coast of North America, they can reduce significantly the primary production of *Spartina alterniflora*, which then requires several grubbing-free years to recover fully (Smith and Odum, 1981). These areas, commonly referred as “eat-outs”, occur mostly in wildlife refuges and occupy a small proportion of the total area of salt marshes along the Atlantic coast. Degraded areas have not increased in the last decade because of hunting controls in the refuges and increased use of adjacent agricultural lands by the geese.

5 Temperate freshwater/brackish marshes

During spring and fall, greater snow geese feed in tidal brackish marshes along the St. Lawrence River estuary in southern Quebec. These marshes are dominated by three-square bulrush (*Scirpus pungens*, formerly *S. americanus*), with a sparse growth of wild rice (*Zizania aquatica*) and arrowhead (*Sagittaria latifolia*) (Giroux and Bédard, 1988). The rhizomes of three-square bulrush comprise >75% of the diet of geese feeding in the marshes in those seasons.

We have been monitoring plant production and goose use in the Montmagny and Cap St-Ignace marshes on the south shore of the river for several years, using exclosures. Giroux and Bédard (1987) estimated that up to 62 g/m^2 of rhizomes were eaten annually, which represented 23% of the below-ground biomass available and 59% of the net below-ground primary production. At a wildlife refuge at Cap Tourmente on the north shore of the river, Reed (1989) estimated that geese removed 55 g/m^2 during their fall staging period, or 32% of the below-ground biomass available.

In the heavily-used marshes of Montmagny, Giroux and Bédard (1987) observed that after two years *Scirpus pungens* production was 62% higher in plots protected from geese. The higher biomass in the control plots was due to both a greater number and mass of shoots. Similar results were obtained in the Cap St-Ignace marshes: 28% higher plant biomass in control plots after one year of goose exclusion. However, the above-ground biomass in the grubbed plots remained stable at both sites (Fig. 3). In the mid eighties, Giroux and Bédard (1987) concluded that geese maintained the system at a low-level steady state, and this seems still to be the case. Boyd (1995) reached similar conclusions in the Fraser River delta marshes along the west coast of Canada. Bélanger and Bédard (1994a) argued that this equilibrium resulted from the geese shifting their foraging sites within the marsh as soon as available food reached a minimum threshold. Despite an increase in goose numbers and foraging along the St. Lawrence River over the last two decades, grazing pressure on the marshes has remained stable because the geese have taken increasingly to feeding on adjacent agricultural fields.

Selective feeding on bulrush rhizomes by the geese also alters the species composition of the marsh plant communities. At Cap Tourmente, Reed (1989) found an inverse relationship between three-square bulrush and wild rice stem densities in grubbed marsh; and at Montmagny, Giroux and Bédard (1987) found a greater production of wild rice in grubbed plots than in the controls. The small depressions created by geese when grubbing may offer a good substrate of unconsolidated sediments for the germination of wild rice, an annual plant. This prediction is supported by the results of Bélanger and Bédard (1994b) who observed a greater production of wild rice in grubbed, disturbed patches (ice-made depressions) than in undisturbed patches. *Scirpus pungens* does not respond to goose grubbing by increasing sexual reproduction. This may be re-

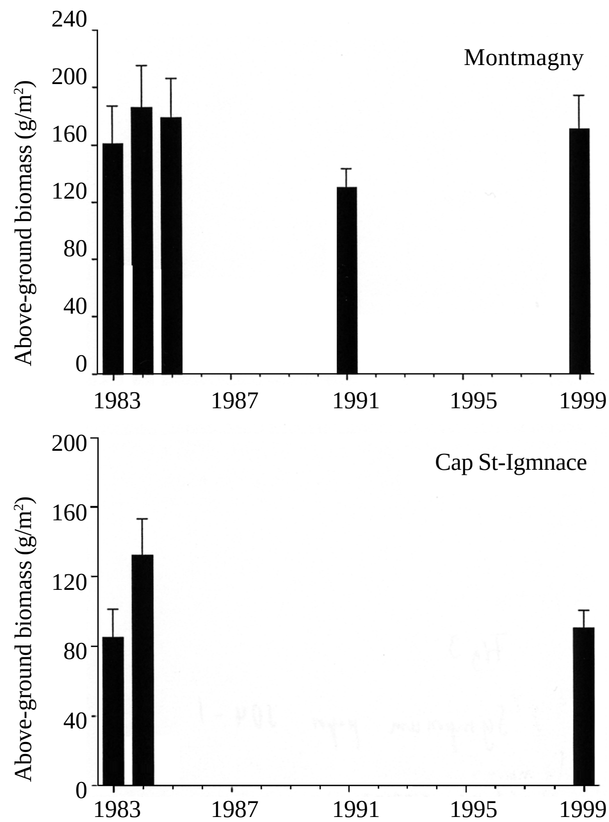

Fig. 3 Above-ground biomass of three-square bulrush (mean ± 1 *SE*) in grazed plots at Montmagny and Cap St-Ignace, 1983–1999

Means are calculated on 27 plots, each with 9 nested quadrats.

lated to poor seedling establishment due to sediment accretion in the marshes in such circumstances (Giroux and Bédard 1987, 1995).

6 Conclusions

Snow goose grazing in arctic freshwater fens decreases overall production and leads to a low level equilibrium between the herbivore and the plants. At present, the system on Bylot Island appears stable despite the increase in goose density, as no long-term decline has been observed in plant production in the annual exclosures. Certainly there has been no damage on the scale observed in the salt marshes of west Hudson Bay. Whether this is because the arctic freshwater fen/goose interaction is inherently more stable than that for salt marshes (e.g., due to differences in soil type, absence of salt or low intensity of grubbing), or because the response threshold of fen plants has not yet been exceeded, is not yet known.

A similar situation seems to pertain in temperate freshwater/brackish marshes. Snow goose grubbing in bulrush marsh appears to be affected by a minimum threshold in food availability, beyond which feeding becomes unprofitable: this may be sufficient to maintain the marshes at a low-level steady state. Three-square bulrush has the capacity to withstand high, chronic grubbing, judged by its rapid recovery once geese are removed. In contrast, the limited information from temperate salt marshes suggests that damage to vegetation due to goose grubbing can be locally severe and lead to the disappearance of vegetation over large areas.

Based on these data, we suggest that goose grazing/ grubbing of high intensity grubbing may be less harmful to plants in freshwater and brackish marshes than in salt marshes, both in arctic and temperate ecosystems. Adaptations to salt tolerance in plants may limit their capacity to withstand other perturbations, in this case herbivory.

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