POPULATION STUDY OF GREATER SNOW GEESE ON BYLOT ISLAND (NUNAVUT) IN 2006: A PROGRESS REPORT

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INTRODUCTION

In 2006, we continued our long-term study of the population dynamics of Greater Snow Geese (*Chen caerulescens atlantica*) and of the interactions between geese, plants and their predators on Bylot Island. Like many goose populations worldwide, Greater Snow Geese have increased considerably during the late XXth century (annual growth rate of ~10%). The exploding population of snow geese has imposed considerable stress on its breeding habitat, while extensive use of agriculture lands provides an unlimited source of food during winter and migratory stopovers for them. Remedial management during autumn, winter and spring has been undertaken since 1999 to curb the growth of this population. The long-term objectives of this project are to (1) study changes in the demographic parameters of the Greater Snow Goose population, and especially the effects of the recent spring conservation harvest, (2) determine the role of food availability and fox predation in limiting annual production of geese, and (3) monitor the impact of grazing on the vegetation of Bylot Island.

OBJECTIVES

Specific goals for 2006 were as follows:

1) Monitor productivity (egg laying date, clutch size and nesting success) of Greater Snow Geese on Bylot Island.
2) Mark goslings in the nest to provide a sample of known-age individuals to be used to assess the growth of goslings by their recapture in late summer.
3) Band goslings and adults, and neck-collar adult females at the end of the summer to continue the long-term study of demographic parameters such as survival and breeding propensity.
4) Mark adult females with radio-transmitters to monitor their behaviour, migration, and subsequent reproduction on Bylot Island.
5) Monitor the level of intestinal parasite infestations in goslings.
6) Participate in the Canadian Inter-Agency Wild Bird Influenza Survey by collecting cloacal and throat swab samples during banding.
7) Monitor the abundance of lemmings and study their demography.
8) Monitor the breeding activity of other bird species and in particular avian predators (Snowy Owls, jaegers and Glaucous Gulls).
9) Monitor the breeding activity of foxes at dens.
10) Capture and mark adults Arctic Foxes and their pups with ear-tags to study their movements and demography.
11) Sample plants in exclosures to assess annual production and the impact of goose grazing on plant abundance in wet meadows.
12) Maintain and upgrade our automated environmental and weather monitoring system.

FIELD ACTIVITIES

Field camps. — In 2006, we operated two field camps on Bylot Island: the main camp, located at 6 km from the coast in the largest glacial valley on the island ("Base-camp Valley", 73° 08' N, 80° 00' W), was occupied from 31 May to 21 August. A secondary camp, located in a narrow valley 30 km south of the Base-camp and 5 km from the coast ("Camp-2 area", 72° 53' N, 79° 54' W) was occupied from 5 June to 20 July (Fig. 1). Both of these camps are now protected by semi-permanent bear-deterring fences. Finally, eight fly camps were also established for 4-8 days at various times throughout the island, west of Pointe Dufour.

Field parties. — The total number of people in both camps ranged from 2 to 17 depending on the period. Members of our field party included project leaders Gilles Gauthier, Dominique Berteaux and Joël Bêty. There were also numerous graduate and undergraduate students whose thesis projects addressed several of the objectives mentioned above. Students were: Cédric Juillet (PhD, objectives 1, 2 and 3), Arnaud Tarroux (PhD, objectives 9 and 10), Peter Fast (PhD, objective 4), Maude Graham-Sauvé (MSc, objectives 1 and 11), Manon Morrissette (MSc, objective 1), Dominique Deshaies, Alisa Guérette-Montminy (BSc thesis, objective 7), and Benoît Laliberté. Other people in the field included Gérald Picard, a technician in charge of the banding operation (objectives 3 and 5); Marie-Christine Cadieux, a research professional in charge of plant sampling (objective 11); Denis Sarrazin, a research professional responsible of the maintenance of the weather stations (objective 12); Josée Lefebvre and François Fournier, two biologists from the Canadian Wildlife Service (CWS) responsible for collecting samples to test for avian influenza (objectives 3 and 6). Finally, we hired 4 persons from Pond Inlet to work with us: Ivan Koonoo (marking goslings in the nests and goose banding), Joasie Otoovak (goose banding) and, Enook Muktar and Bernie Kulishuak (for fox den visits).

Other people shared our camp for part of the summer. They were the field party of Esther Lévesque (UQTR) and Line Rochefort (Université Laval), which included Mathieu Charette (PhD student), Mylène Marchand-Roy (MSc student) and Heidi Kristenson (BSc student) who studied plant ecology; Laura McKinnon (PhD student) and Ludovic Jolicoeur (BSc student) who studied shorebirds under the supervision of Joël Bêty; and the party lead by Reinhard Pienitz (Université Laval), which included Ghislain Côté (MSc student), Martin Sirois (BSc student) and Gaute Velle (Post-doc) who studied the impact of geese on water quality using paleolimnological techniques. Several persons from Parks Canada also visited our camp at different moment of the summer. They include the director general of Parks Canada for Western and Northern Canada, Nancy Anilniliak (superintendant of Parks Canada for the Nunavut), Carey Elverum (chief warden of *Sirmilik National Park*), Mike Wong (Parks Canada public relation officer), Brian Koonoo and Israel Mablick (Parks warden), Terry Kallut (Parks patrol person), and Marco Dussault and Gary Mouland (Parks personnel from Iqaluit). Finally, Andy McMullen from Bearwise (Yellowknife) visited both camps in June for the maintenance of our electrical bear fences.

Environmental and weather data. — Environmental and weather data continued to be recorded at our four automated stations. Our network includes 3 full stations, two at low and one at high elevation (20 m and 370 m ASL, respectively) where air and ground temperature, air humidity, solar radiation, wind speed and direction are recorded on an hourly basis throughout the year (Fig. 1). A fourth station monitors soil surface temperature in areas grazed and ungrazed by geese (i.e. exclosures). All automated stations were visited during the summer to download data and were found to be operating normally. Finally, daily precipitation was recorded manually during the summer and snowmelt was monitored by measuring snow depth at 50 stations along two 250-m transects at 2-day intervals.

Monitoring of goose arrival and nesting. — We monitored goose arrival in the Base-camp Valley by counting goose pairs every two to three days from our arrival on the island until the end of snowmelt on sample plots. Nest searches were carried out within walking distance (~6 km) of both the Base-camp Valley and the Camp-2 area between 8 and 21 June. Nests are found by systematic searches conducted over various areas in the field. At the Base-camp Valley where nest density is always low, nests searches are conducted throughout the valley. At Camp-2, nest searches are conducted in two ways: 1) over the same restricted area (ca 50 ha) located in the centre of the colony every year, and 2) within a variable number of 2.25-ha plots randomly located throughout the colony. We also attempted to find the nests of as many neck-collared females as possible throughout both study areas. All nests were revisited at least twice to determine laying date, clutch size, hatching date and nesting success. During the hatching period, we visited a sample of nests almost every day to record hatch dates and to web-tag goslings.

Tracking of radio-marked geese. — During spring staging in Québec, we captured snow geese at Île-aux-Oies using canon-nets. We captured 5 adult females previously banded on Bylot Island and marked them with a VHF radio-transmitter (i.e. we replaced their plastic neck-band with a new one on which a transmitter had been glued; total package mass: 60g). On Bylot Island, we installed two automated receiving station with antenna on high grounds immediately after arrival, one in the Base-camp Valley and one at Camp-2. The receiving stations scanned 24-h a day for the presence of radio signals from 3 June to 22 July. Additional manual scans were conducted on snowmobile and on foot during the prelaying and early nesting periods (31 May to 15 June). We also conducted aerial tracking with the helicopter over most of the south plain of Bylot Island (on 8, 18 and 24 June) to locate radio-marked geese. Nests of geese with radio-transmitters were found on foot using a portable antenna and a receiver.

Goose banding. — From 5 to 14 August, we banded geese with the assistance of local Inuit people and a helicopter. All geese captured were sexed and banded with a metal band, and all recaptures (web-tagged or leg-banded birds) were recorded. A sample of young and adults was measured (mass and length of culmen, head, tarsus and 9^{th} primary) and a sample of adult females were fitted with coded yellow plastic neck-collars. We also collected oral and cloacal swab samples from goslings for the Canadian Inter-Agency Wild Bird Influenza Survey. These samples will be tested for the possible presence of this virus. We marked some adult females with GPS/ARGOS solar radio-transmitters mounted on the back of the bird with an elastic Teflon harness. These birds will tracked throughout their annual cycle to relate events occurring during the spring migration with subsequent reproduction and to produce an unbiased continental population estimate over the next 3 years. Finally, we collected the intestine from a sample of goslings that died accidentally during banding to examine the level of parasite infection.

Breeding activity of foxes at dens and marking. — In 2006, we increased our search area of fox denning sites by 50 km^2, mainly along the Dufour river, and near the Base-camp Valley.

The total area of Bylot Island surveyed for the presence of dens now covers 475 km^2. Dens were visited from one to five times during the summer and inspected for signs of use by foxes and/or presence of reproductive foxes with pups. We attempted to trap adult foxes using padded leghold traps around dens showing signs of use by foxes and at locations where foxes were seen hunting or travelling. At dens used for reproduction, we noted the species (Arctic Fox, *Alopex lagopus*, or Red Fox, *Vulpes vulpes*) and minimum litter size, and, whenever possible, we trapped pups with Tomahawk© collapsible live traps (cage traps). All traps were either kept under continuous surveillance or at least visited every 12 hours depending on the site. Captured foxes were measured, weighed and tagged on both ears using a unique set of coloured and numbered plastic tags. Adult foxes were anaesthetized using Telazol®, an anaesthetic commonly used for dogs, to allow safe manipulation. Among adult Arctic Foxes, five were also fitted with ARGOS satellite collars to study their large-scale movements and habitat use during the winter. Samples of winter and summer fur, blood, collagen and scats were also collected for diet analysis.

Small mammals. — We continued to participate in the small-mammal survey coordinated across the NWT and Nunavut by the Department of Environment and Renewable Resources in Yellowknife. We used Museum Special traps baited with peanut butter and rolled oats. We sampled lemming abundance at two sites in the Base-camp Valley (one in wet meadow habitat and one in mesic habitat) and one site at the Camp-2 (mixed habitat) in July. At each site, we used 50 traps set at 10-m intervals along two parallel transect lines 100 m apart (25 traps/transect) and left open for ~10 days. Our new sampling program based on live-trapping of lemmings initiated in 2004 was continued this year. We trapped on 2 permanent grids at the Base-camp Valley (one in wet meadow habitat and one in mesic habitat). In 2006, we increased the size of the grids to 360×360 m (compared to 300 × 300 m in 2004 and 2005) and the number of traps per grid to 144 (compared to 100 traps in 2004 and 2005) to increase the trapping effort. We used Longworth© traps baited with apples and set at each grid intersection every 30-m. We trapped during 4-consecutive days every 14 days on each grid from mid-June to mid-August. All trapped animals were identified, sexed, weighed and marked with electronic PIT tags (or checked for the presence of such tags).

Other bird monitoring. — We monitored the nesting activity of Snowy Owls (*Bubo scandiacus*), Jaegers (*Stercorarius* spp.), Glaucous Gulls (*Larus hyperboreus*), and Lapland Longspurs (*Calcarius lapponicus*). Nests were found through systematic searches of suitable habitats and revisited to determine their fate (successful or not) until fledging. We also collected food pellets at gull nests to determine their diet based on prey remains.

Monitoring of plant growth and goose grazing. — The annual plant production and the impact of goose grazing was evaluated in wet meadows dominated by graminoid plants at 3 sites (Fig. 1): the Base-camp Valley and Pointe Dufour (brood-rearing areas), and the Camp-2 area (nesting colony). At each site, 12 exclosures (1 × 1 m) were installed in late June, and plant biomass was sampled in ungrazed and grazed areas (i.e. inside and outside exclosures) at the end of the plant-growing season between 12 and 14 August. Plants were sorted into sedges (*Eriophorum scheuchzeri* and *Carex aquatilis*) and grasses (*Dupontia fisheri*). Use of the area by geese was monitored by counting faeces on 1 × 10 m transects located near each exclosure every 2 weeks in the Base-camp Valley and once at the end of the season at Pointe Dufour and the Camp-2 area.

PRELIMINARY RESULTS

Weather conditions. — The spring of 2006 was characterized by a normal snowmelt at the Base-camp although the conditions during the critical period of goose arrival and egg-laying were quite variable. Air temperature averaged 0.17°C between 20 May and 20 June (0.30°C above normal) and was especially mild during the period of goose arrival and just before at the end of May. In contrast, the temperature turned cold during the normal period of egg-laying (average of 0.97°C during 1-15 June, 0.40°C below normal). Snow depth on 1 June was 29 cm compared to a long-term average of 31 cm (Fig. 2). However, there was some indication that snow may have been deeper at the Camp-2 (i.e. in the goose colony) than at the Base-camp and thus that snow-melt may have been slightly delayed there compared to previous years. Precipitation was low in June (17.5 mm of rain), moderately high in July (64 mm) but mostly concentrated during the first 5 days (39.5 mm) and low in August (13 mm up to 21 August). Weather in most of July and August was exceptionally good with lots of sunshine and warm temperature.

Goose arrival and nesting activity. — The number of geese counted on the hills surrounding the Base-camp Valley (the first area used by geese upon arrival) increased from 165 pairs on 1 June to a peak of 580 pairs on 7 June (Fig. 3). These values were about twice the number observed in 2005 and were actually among the highest values ever recorded. This indicates that geese arrived relatively early and in large numbers on Bylot Island this year.

Median egg-laying date was 14 June, which is later than the long-term average (Table 1). Our field observations indicate that the nest density in the colony was lower than last year and thus that the reproductive effort of geese was relatively low at the main colony (Camp-2). No nests were found at the Base-camp Valley (predominantly a brood-rearing area), a situation common in years when no Snowy Owls are nesting and lemming abundance is very low (see below). Average clutch size was 3.68, which is very close to the long-term average (Table 1).

Nesting success of geese. — Nesting success (proportion of nests hatching at least one egg) was low this year (42%, a value below the long-term average, Table 1). Activity of predators at goose nests, especially Arctic Foxes, was higher than in 2005. During nesting and brood-rearing, 286 neck-collared birds were sighted, a number higher than last year (200). Peak hatch was on 10 July, which is slightly later than the long-term average (Table 1). We tagged approximately 2130 goslings in nests at hatch, all in the main colony at Camp-2.

Density of broods. — In 2006, the density of goose faeces at the end of the summer in wet meadows of the Base-camp Valley was very high (11.4 ± 2.1 [SE] faeces/m^2, Fig. 4) and was the highest value ever recorded. Accumulation of faeces started relatively late in July but increased rapidly thereafter and continued until the end of the summer in contrast to other years where it often tended to level off in August. We believe that this reflects a sustained use of the wet meadows by broods until the end of the summer and the absence of movement toward upland habitats in August as it often occurs at that time. Faeces density at the end of the summer was low in the wet meadows of the nesting colony at Camp-2 (3.2 ± 0.5 faeces/m^2 vs. 2.2 ± 0.3 in 2005) but also high at Pointe Dufour, another brood-rearing area, (11.3 ± 2.0 faeces/m^2 vs. 6.6 ± 1.0 in 2005).

Goose banding. **—** The banding operation was again successful this year even though the density of broods was relatively low, especially in upland areas. This forced us to band geese over a larger portion of the island and further away from our Base-camp than usual in order to find enough flocks. We conducted a total of 13 drives: 5 drives in our usual banding area, i.e. in the lowlands and hills bordering the Base-camp Valley (<8 km), and 8 additional drives further away, i.e. 4 in the Camp-2 area, and 4 half-way between the Camp 2 and the Base-camp Valley. We banded a total of 4603 geese, including 675 adult females marked with neck-collars and 281 young which were marked with web-tags at hatch and recaptured. We also marked 25 adult females with GPS/ARGOS radio-transmitters. In addition, we had 352 recaptures of adults banded in previous years. We collected samples (cloacal and throat swabs) from 411 goslings for the avian influenza survey.

The gosling:adult ratio among geese captured at banding (1.03:1) and mean brood size toward the end of brood-rearing (2.2 young, SD = 1.11, n = 144; counts conducted from 30 July to 3 August) were lower than the long-term averages (Table 1). By combining information on brood size and young:adult ratio at banding, we estimated that 67% of the adults captured were accompanied by young, also a low value compared to the long-term average, which suggests a high mortality rate of young during the summer. Overall, these results are indicative of a relatively low production of young on Bylot Island by the end of the summer.

Tracking of geese fitted with radio-transmitters. **—** We detected on Bylot Island the signal of all 5 geese that were marked with VHF radio-transmitters during the spring migration in Québec, and we were able to find the nest of 2 of these females. The nest of one of these females was preyed upon before hatch, and the fate of the other one is unknown. The tracking of birds marked with satellite transmitters in August has been going well so far. Data downloaded on 27 September indicated that 15 birds were in northern Québec (Nunavik), 2 were in south Baffin Island, 4 were apparently still on Bylot Island (these birds may have died or lost their transmitter) and we have no information for the remaining 4. The migration away from Bylot Island started around 12 September for most birds.

Breeding activity of foxes at dens and marking. **—** We found 10 new fox dens on the island in 2006, bringing the total to 120 known denning sites. Among the 115 dens that were visited this summer and found to be intact (a few denning sites are destroyed by erosion and collapse every year), we found signs of activity (fresh digging and/or footprints) at 33 of them, a relatively low number. The breeding activity of foxes was very low as we found only 2 different litters (2% of known denning sites) of Arctic Foxes and none of Red Foxes. Two Red Foxes were observed using a den but no young were seen. The level of den use was lower than last year (7% of dens used in 2005) and typical of the proportion of fox dens used in previous years of low lemming abundance (~2-3%). Minimum litter sizes were 1 and 5 pups. A total of 19 adult and 6 juvenile Arctic Foxes were captured during trapping sessions and marked with ear-tags. We also recaptured 5 adults that had been marked in previous years and we resighted 4 foxes that had been ear-tagged in previous years.

Small mammals. **—** During our survey using snap traps, we cumulated 1100 trap-nights at our 2 trapping sites of the Base-camp Valley from 23 July to 1 August, and 550 trap-nights at the Camp-2 from 7 to 17 July. In the Base-camp sites, we caught 1 Collared Lemmings (*Dicrostonyx* *groenlandicus*) in the mesic site and none in the wet meadow site, and no Brown lemmings (*Lemmus sibiricus*) were caught, which yielded a combined index of abundance of 0.09 lemmings/100 trap-nights, a very low value (Fig. 5). In the Camp-2 site, 2 Collared Lemmings were caught, for an index of 0.37 lemmings/100 trap-nights, also a low value. For the third year of our live-trapping survey, we captured 47 different lemmings (compared to 55 in 2005 and 180 in 2004), of which 25 were captured more than once. However, considering that the trapping effort was 44% higher than in previous years (i.e. 144 traps/grid vs 100 in previous years), the total number of lemmings captured alive was 41% lower in 2006 than in 2005. We captured 12 Brown Lemmings and 11 Collared Lemmings in the mesic habitat, and 10 Collared and 14 Brown ones in the wet habitat. Both indices of lemming trapping therefore suggest that lemmings continued to decline in 2006 in the Base-camp Valley and that lemmings were in the low phase of their cycle.

Other bird monitoring. — We found 17 nests of Glaucous Gulls, 6 nests of Long-tailed Jaegers, 1 nest of Parasitic Jaegers and 89 nests of Lapland Longspurs. Nesting success (proportion of nests successful in fledging at least one young) was moderate for gulls (38% vs 80% in 2005) but was very low for jaegers (0% vs 8% in 2005) and longspurs (9% vs 19% in 2005). Therefore, nesting success of all these species declined compared to 2005. Average clutch size was 2.1 eggs for gulls (vs 2.9 eggs in 2005), and 5.1 eggs for longspurs (idem in 2005); data was insufficient for jaegers. No Snowy Owls were found nesting in our study area in 2006.

Plant growth and grazing impact. — Plant production in wet meadows of the brood-rearing area was very similar to last year and above the long-term average (Fig. 6). Above-ground biomass of graminoid plants in the Base-camp Valley reached 58.3 ± 7.6 [SE] g/m^2 in ungrazed areas in mid-August compared to 57.1 ± 8.2 in 2005 (long-term average since 1990: 45.2g/m^2). Plant production was therefore good this year in wet meadows. At the Camp-2 area (colony), graminoid biomass in 2006 was similar to last year (26.2 ± 3.9 vs. 25.1 ± 4.9 g/m^2 in 2005) but still below the average value recorded since 1998 (30.6 g/m^2), and much lower than the plant production recorded in the Base-camp Valley (Fig. 6 vs Fig. 7). Graminoid biomass at Pointe Dufour in 2006 was higher than last year (56.5 ± 9.3 vs. 42.3 ± 6.0 g/m^2 in 2005) and above the long-term average recorded since 1998 (50.3 g/m^2; Fig. 8).

Goose grazing was relatively high in the wet meadows of the Base-camp Valley where geese removed 40% of the above-ground biomass (difference between paired grazed and ungrazed plots) by mid-August compared to 46% in 2005 (long-term average: 35%; Fig. 6). At the Camp-2 area (colony), the grazing impact was much lower with only 10% of the graminoid biomass removed by geese compared to 41% in 2005 (long-term average at this site: 29%; Fig. 7). Similarly, at Pointe Dufour, another brood-rearing area, geese removed 19% of the total biomass, a value also lower than in 2005 when it was 39% (long-term average: 25%; Fig. 8).

DISCUSSION

Although the phenology of migration appeared to be early in 2006 (i.e. geese arrived on the island in large numbers relatively early), they initiated laying relatively late and their reproductive effort (i.e. nest density) tended to be low. In the first few years of the spring harvest (1999-2001), we measured the body condition of Greater Snow Geese upon departure from the spring staging areas in Québec and we found a reduction in both their fat and protein reserves (Féret et al. 2003). This reduction was apparently the main cause of the reduced reproductive effort and late laying dates of geese in those years (Mainguy et al. 2002, Bêty et al. 2003, Reed et al. 2004). In 2006, we revisited this question by collecting a sample of adult females shortly before departure from the staging area in Québec. We found that abdominal fat reserves in 2006 were intermediate between average values reported before and during the first years of the spring harvest (2006: 98.7 g, 1979-1990: 113.4 g, 1999-2001: 78.0 g), whereas breast protein reserves had come back to values encountered before the spring harvest (2006: 76.7 g, 1979-1990: 75.2g, 1999-2001: 69.4 g; Féret et al. 2003, Gauthier, unpubl. data). These results suggest that the negative impact of the spring harvest on the body condition of geese has decreased markedly since the first few years of the spring harvest. Therefore, it seems unlikely that this was the main cause of low reproductive effort of Greater Snow Geese on Bylot Island in 2006. The cold temperature at the onset of egg-laying may be the main reason of the reduced nesting effort.

Egg predation was high this year and resulted in a low nesting success of the geese. Predation rate on goslings was also apparently high as shown by the low brood size (despite a normal clutch size to start with) and especially the high proportion of total brood loss (as only 67% of the adults were still accompanied by young at banding). Predation is the most likely cause because weather conditions during brood-rearing were favourable and plant production was high. The combination of all these effects (i.e. low reproductive effort, late laying, high predation rate on eggs and goslings) lead to a low young:adult ratio at banding, which is indicative of a relatively poor production of young on Bylot Island this year. Based on this young:adult ratio, we anticipate a proportion of young in the fall flock of 10%, a value much lower than the observed production in 2005 (21%) and the long-term average (24%). We usually consider years where production of young is below 10% as years of breeding failure in this population.

Results from our dead and live-trappings showed that lemming abundance, which was already low in 2005 following the moderate peak of 2004, continued to decline and was very low in 2006. Not surprisingly, the number of breeding foxes followed the same trend and the number of dens with pups was very low this year. Non-breeding foxes were nonetheless present on the island as shown by the large number of unmarked foxes that were captured this year and of previously marked ones that were re-encountered. The abundance of foxes, which are the main predator of geese, combined with the very low abundance of lemmings, can explain why both goose eggs and goslings suffered heavily from predation this year.

In 2006, plant production in the wet meadows of the brood-rearing areas located outside the nesting colony (Base-Camp Valley and Dufour Point) was high compared to previous years. In contrast, plant production continued to be much lower at the goose colony than in those peripheral brood-rearing areas. The warm conditions that prevailed early in spring and during

July and August likely contributed to the good plant production in 2006. Surprisingly, the density of broods (as indicated by our fecal counts) and their grazing impact in wetlands of the Base-camp Valley were relatively high even though the overall production of young on the island was low. The reason for this discrepancy is probably because these two measures apply at different scales, i.e. at the local scale for the grazing impact measurement and at the whole island scale for the production of young. The high density of faeces and ensuing grazing impact in wet meadows suggest a sustained use of these preferred feeding areas until the end of the summer and the absence of movement toward upland, mesic habitats in late summer. The absence of late summer movement in 2006 may be a consequence of the good plant production in wet meadows and, perhaps more importantly, of the high predation pressure that promoted the use of lowland feeding areas where presence of ponds and lakes provided a good refuge against predation by foxes. In addition, flooding of wet meadows due to high rainfall in July in August apparently favoured such movements in the past (e.g. 2003 and 2004) but precipitation was low this year and no such flooding was observed.

A SYNTHESIS OF THE KEY FINDINGS

The Greater Snow Goose research project on Bylot Island has been running since 1989. Over the years, this project was supported by numerous partners, including the Arctic Goose Joint Venture. During the period 1999-2006, funding from the Arctic Goose Joint Venture was through Project #66, which is in its last year in 2006. However, a proposal to renew this project for the period 2007-2012 has been submitted to the Arctic Goose Joint Venture committee for endorsement and funding. We will summarize below the main findings and output of this project, which have already been published in scientific papers and reports for the most part.

Since the beginning in 1989, this research project was highly successful and generated a considerable scientific output. Over this 17-year period, it has produced 5 PhD and 25 MSc theses (3 PhD and 13 MSc since 1999), 69 scientific papers in refereed journals (48 since 1999), numerous technical reports, including annual progress reports, and 3 PhD and 2 MSc theses are still underway (see appendix at the end for a full publication list). However, the most important contribution of this project for the Arctic Goose Joint Venture is probably the two major scientific reports edited by Batt (1998) and Reed and Calvert (2006). In both reports, the bulk of the data presented and analysed came from the Bylot Island project. The Reed and Calvert (2006) report in particular is largely based on the data collected by Project #66 during the period 1999-2006 and before. As an illustration of that, among the 54 figures or tables presented in this extensive report, 29 (54%) included data generated by Project #66. Presenting these results and their analysis in details here would duplicate these publications. Therefore, we have included below only the key findings of Reed and Calvert (3006), and updated them in a few instances.

Distribution

- Long-term changes in staging distribution observed during the period of rapid population growth have persisted since the implementation of the special measures in 1999, with a continued spreading of geese toward southwest and north-central Québec. Increasing use of farmlands in a changing landscape may be the main reason for these historical changes, but the new conservation measures probably also contributed in recent years. The wintering distribution showed a northward shift in the mid-1980s, also likely linked to increased use of farmlands and changes in agricultural practices, but appears to have changed little since then.

- The liberalization of regular season regulations likely increased disturbance to geese, but the consequences for fall and winter distribution are unknown. There is, however, evidence that the spring conservation harvest increased disturbance levels of geese and modified their spring movements, most notably by increasing westward migratory (i.e. reverse migration) movements and possibly also by increasing the spread of geese throughout southern Québec.

Breeding and productivity

- Productivity indices for the total population and for the breeding colony at Bylot Island show high inter-annual variation, due to the importance of environmental fluctuations. During the first 5 years of implementation of special measures (1999-2003), most breeding parameters have been negatively affected: breeding propensity was reduced, egg-laying was delayed, and clutch size was reduced, although nesting success and the age-ratio at the end of the summer showed no change. The result of these negative impacts was that fall age ratio and brood size were lower in years with a spring conservation harvest. However, this impact has apparently been attenuated in recent years.

- The spring conservation harvest caused increased disturbance to staging Greater Snow Geese, reducing their ability to store nutrients for migration to nesting grounds and for reproduction. This extra energetic cost and corresponding decline in body condition appear to be the main reason for the reduction in productivity during the first few years following the implementation of special conservation measures. However, this impact has apparently been attenuated in recent years and may have disappeared completely.

Harvest, hunting mortality and survival

- Harvest rates remained low from the mid-1980s until the initiation of the new hunting regulations in 1998-99; harvest rates have increased since then, especially for adult geese, and the increase was stronger in the Atlantic Flyway winter harvest than during fall in Québec. When taking into account the spring harvest, total annual harvest rates of adults during the period 1998-2002 has exceeded the high values encountered during the late 1970s-early 1980s, though not in juveniles. However, in recent years (2003-2005), the harvest rate of adults has declined (mostly during the spring harvest and the winter regular season) and may no longer be enough to stop the growth of this population.

- For adult Greater Snow Geese, the increase in total harvest with the special conservation measures brought an increase in hunting mortality rates and a corresponding decline in survival from an average of 83.0% during 1990-97 to 72.5% during 1998-2002. A negative relationship between harvest rate and adult survival was detected as expected, but harvest did not fully explain the strong temporal variation observed in survival.

- The spring harvest was the most drastic regulation change implemented and it contributed to the increase in annual hunting mortality of adults over the period 1998-2002. However, hunting mortality also increased during winter in the U.S. as a result of changes in regulations, though apparently not in fall in Québec.

- Although juvenile harvest increased following regulation changes, their hunting mortality only increased slightly and their survival rate did not change over the period 1998-2002. However, analysis of the impact of hunting on juveniles is complicated by the large annual variation in both production of young and fall migration survival.

Impact on natural habitat

- Greater Snow Goose grazing on Arctic graminoids during the breeding season is high and reduces the plant production in wetlands, although vegetation has not been damaged past the point of recovery, as observed in Lesser Snow Goose populations. Goose abundance on Bylot Island, one of the largest breeding colonies, was still at only half the estimated carrying capacity of the island's wetlands in 1997. Plant production has been especially high in recent years but we cannot determine if this is a consequence of special conservation measures.

Projected growth rate of the population under alternative harvest scenarios

- The population model accurately predicted population growth rate before the implementation of special conservation measures and after. Without conservation measures, the model predicted that the population would have grown at a rate of 7.8 % annually over the period 1999-2003. With conservation measures in place, it predicted a decline of 8%.

- The spring harvest had the greatest influence on the reduction of the growth rate, mainly through mortality of adults and a reduction in fecundity.

- All scenarios that included a spring harvest resulted in a projected reduction of the population, even if the spring harvest were only to occur in alternating years.

- Significant increases in present day adult harvest rates during fall and winter would be required to maintain a stable population in the absence of a spring conservation harvest.

CONCLUSIONS

Our results showed that the initial success of the special conservation measures was largely due to the increased harvest and reduced fecundity resulting from the spring conservation harvest in Québec (Reed and Calvert 2006). At the onset of the special conservation measures in 1999, the spring population size was estimated at 1,008,000 ± 172,000 [95% CI] geese. Over the next few years, the population declined although the magnitude of the decline is difficult to assess because an unknown proportion of geese were likely missed by the survey (Reed and Calvert 2006). In 2002, the spring survey yielded an estimate of 639,275 ± 55,000 although the real population size may still have been around 800,000 at that time. However, the population has shown an increasing trend since then and, in spring 2006, it was estimated at 1,017,000 ± 79,000 geese (J. Lefebvre, pers. comm.). It thus appears that the population is presently at a level comparable to what it was when the special conservation measures were implemented. The most recent population trend may be due to the decreasing harvest rate, especially during the spring harvest, and to the lessening of the negative impact of this activity on fecundity.

There can be no doubts that all objectives laid out in the original proposal of Project #66 in 1998 have been met, in most cases far exceeded. Results of this project over the period 1998-2006 (see Reed and Calvert 2006 for details) showed how the quality of our monitoring program allowed for a rigorous and unprecedented evaluation of management actions on a goose population. Such scientific evaluation was easier to achieve with the Greater Snow Goose than with most other goose populations because: *i*) the Greater Snow Goose is a fairly well isolated population restricted to the Atlantic Flyway; *ii*) its population size has not yet reached “unmanageable” level; *iii*) considerable background information was already available; *iv*) the absence of density-dependent effects on demographic parameters during the population growth period of the 1990s (Menu et al. 2002), which was therefore not a confounding factor in our analyses.

Data from Project #66 were also instrumental in updating the Greater Snow Goose population model presented in Reed and Calvert (2006), which formed the basis of the recommendations presented in the current Greater Snow Goose Action Plan (Bélanger and Lefebvre 2006). The most recent data, however, show that the current success in managing the Greater Snow Goose remains fragile and a continued evaluation of current and future management actions, and especially of possible changes in their effectiveness, are essential.

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Table 1. Productivity data of Greater Snow Geese nesting on Bylot Island over the past decade.

	1997	1998	1999	2000	2001	2002	2003	2004	2005	**2006**	Average[2]
Number of nest monitored	326	350	266	386	296	470	585	676	346	**393**	--
Median date of egg-laying	10 June	7 June	17 June	16 June	13 June	16 June	9 June	11 June	12 June	**14 June**	12 June
Clutch size	4.27	4.00	3.09	3.51	3.43	3.43	3.90	3.65	3.60	**3.68**	3.70
Nesting success[1]	83%	79%	12%	83%	57%	53%	82%	78%	66%	**42%**	63%
Median date of hatching	7 July	4 July	13 July	13 July	9 July	11 July	6 July	7 July	8 July	**10 July**	9 July
Number of geese banded	3956	3998	1717	4269	3430	2650	5259	3617	5304	**4603**	--
Ratio young:adult at banding	1.06:1	1.09:1	0.54:1	1.08:1	1.03:1	0.81:1	1.31:1	0.94:1	1.03:1	**0.74:1**	1.02:1
Brood size at banding	2.47	2.70	1.67	2.78	2.37	1.67	2.74	2.50	2.42	**2.20**	2.46
Proportion of adults with young at banding	86%	81%	65%	78%	87%	97%	96%	75%	86%	**67%**	82%

[1] Mayfield estimate

[2] Period 1989-2006

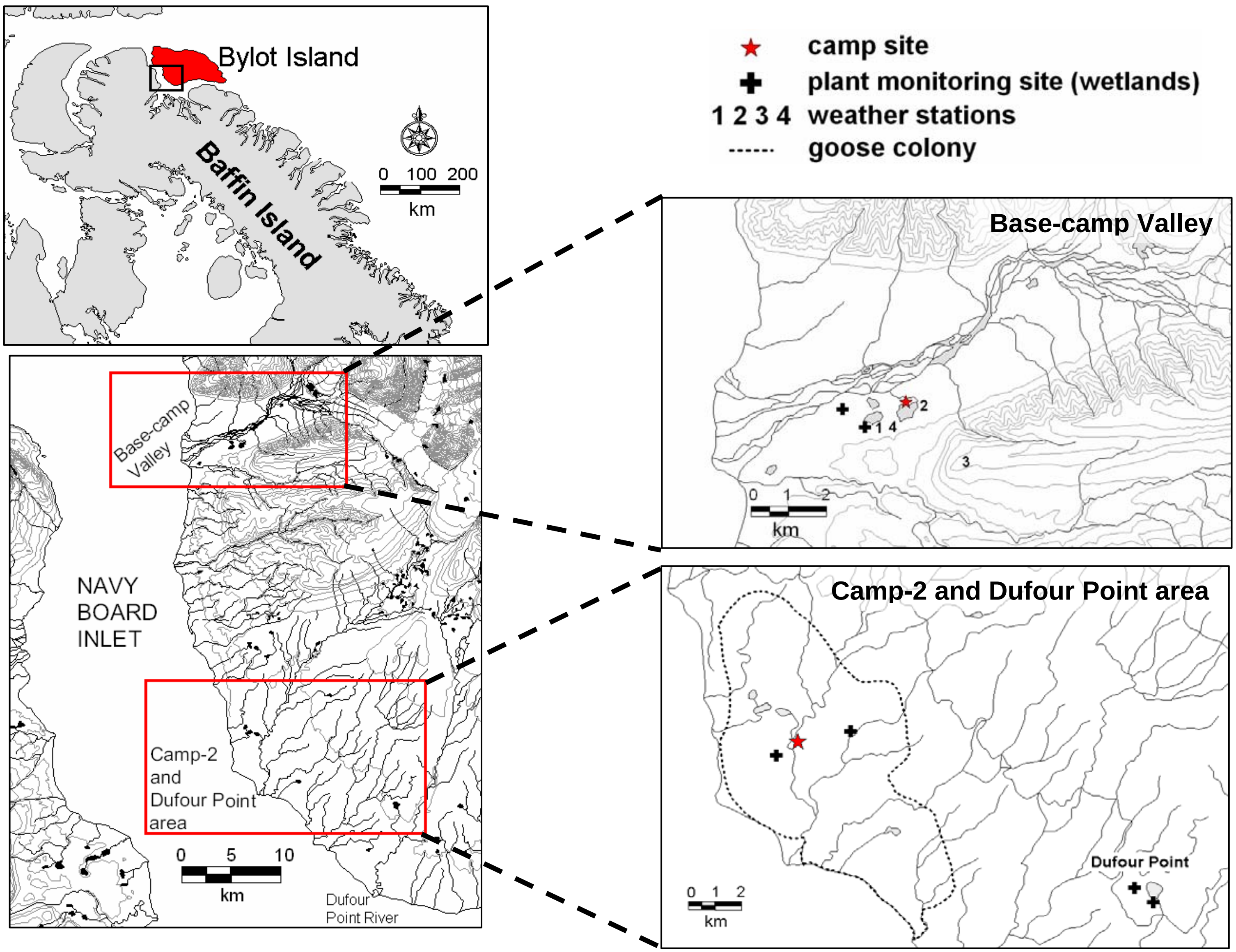

Figure 1.General location of the study area, Bylot Island, Nunavut, and of the two main study sites (Base-camp Valley and the Camp-2 area) on the South plain of the island. Enlarged maps on the right present these study sites in more details, including camp locations, sampling sites and our four weather stations.

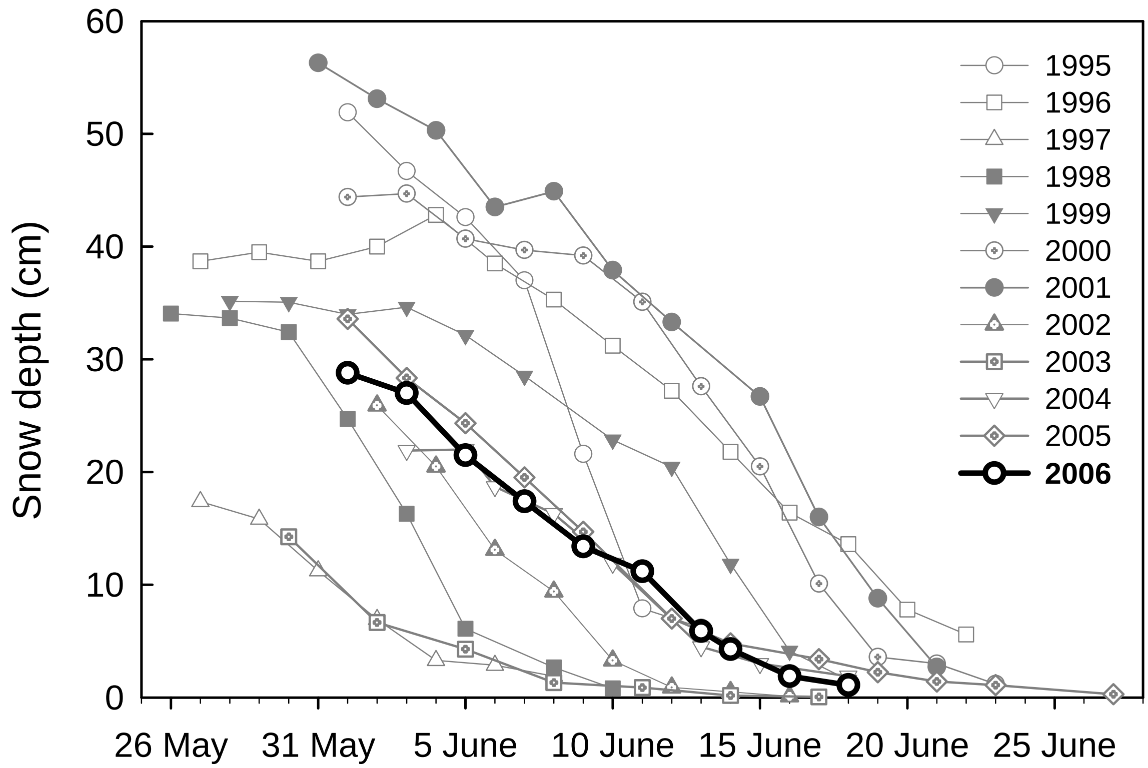

Figure 2. Average depth of snow along 2 transects showing the rate of snowmelt in Bylot Island lowlands (n = 50 stations).

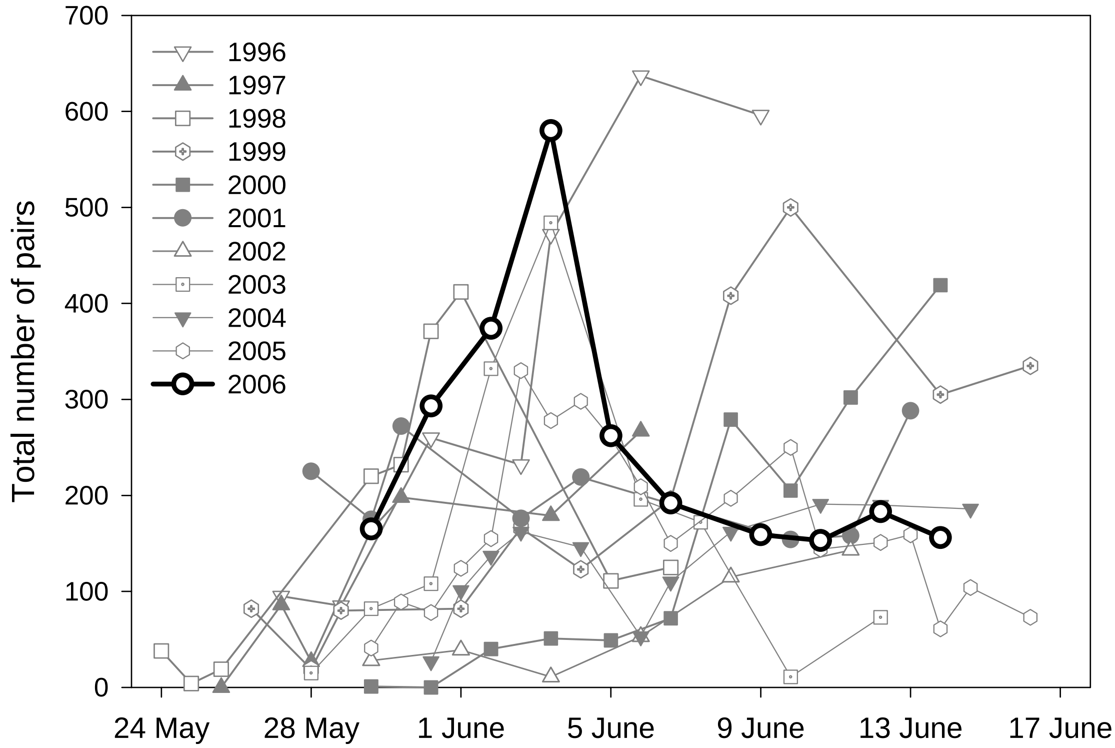

Figure 3. Total number of goose pairs counted in the Base-camp Valley from arrival of our crew on Bylot Island until the end of snowmelt.

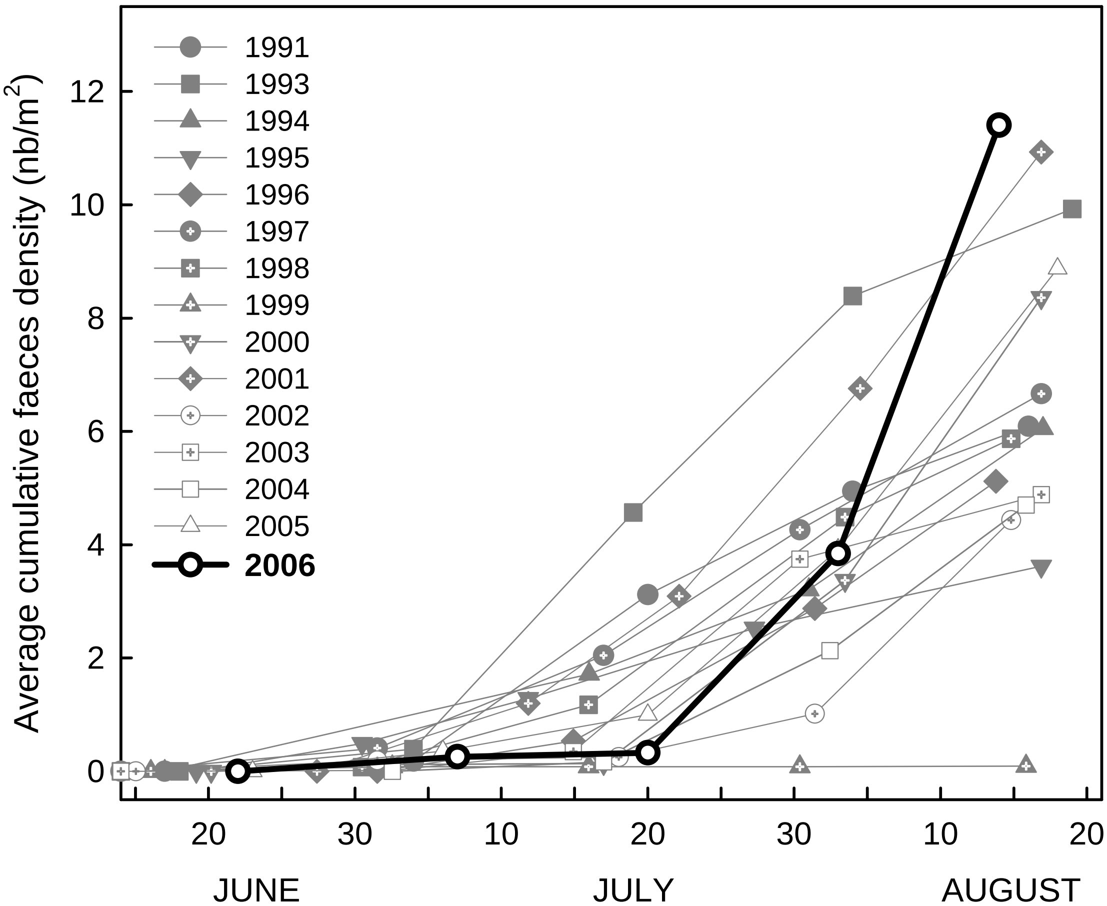

Figure 4. Average cumulative faeces density showing the use of the Base-camp Valley by Greater Snow Goose families on Bylot Island throughout the summer (*n* = 12 transects of 1 x 10 m).

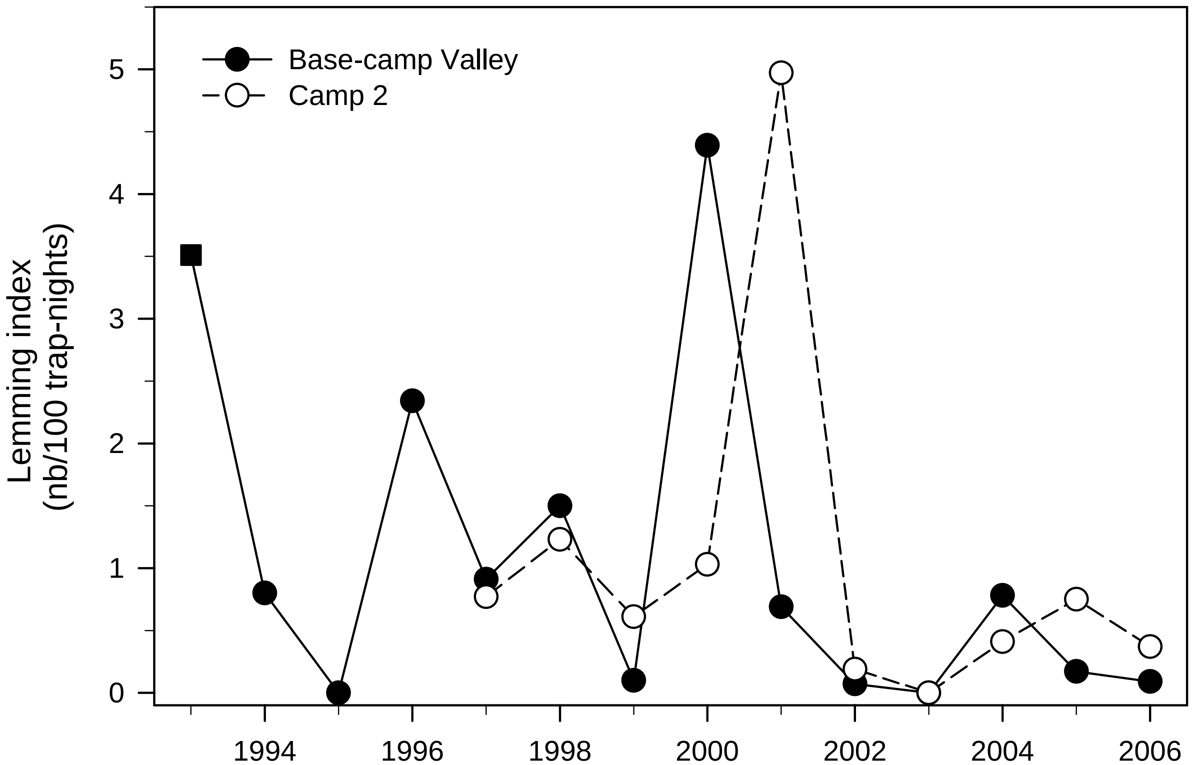

Figure 5. Annual abundance of lemmings at two study areas (Base-camp Valley and Camp-2) located 30 km apart on Bylot Island.

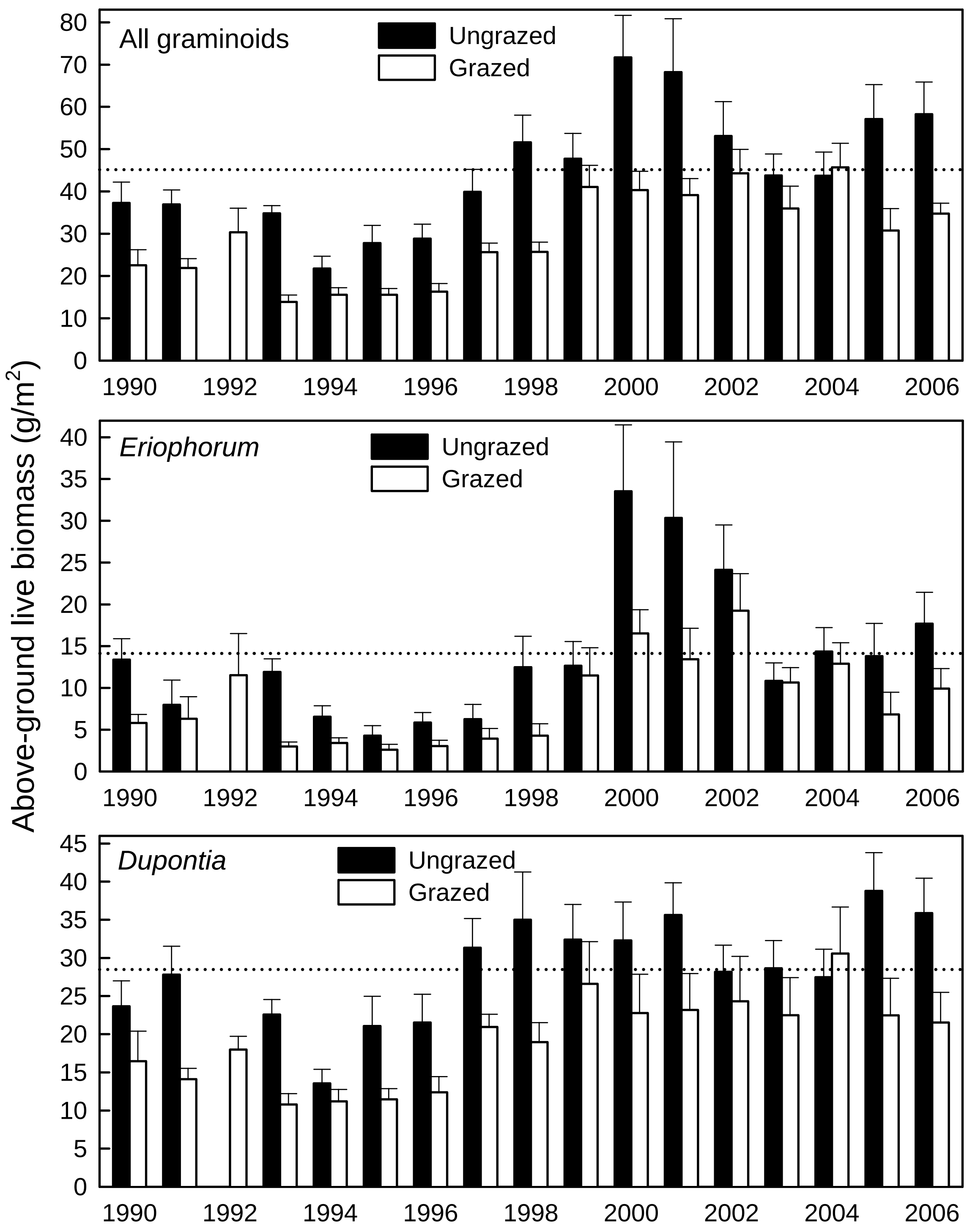

Figure 6. Live above-ground biomass (mean + SE, dry mass) of graminoids on 12 August in grazed and ungrazed wet meadows of the Base-camp Valley, Bylot Island (*n* = 12). Total graminoids include *Eriophorum scheuchzeri*, *Dupontia fisheri* and *Carex aquatilis*. There is no data from ungrazed area in 1992. The dashed line is the long-term average for ungrazed area.

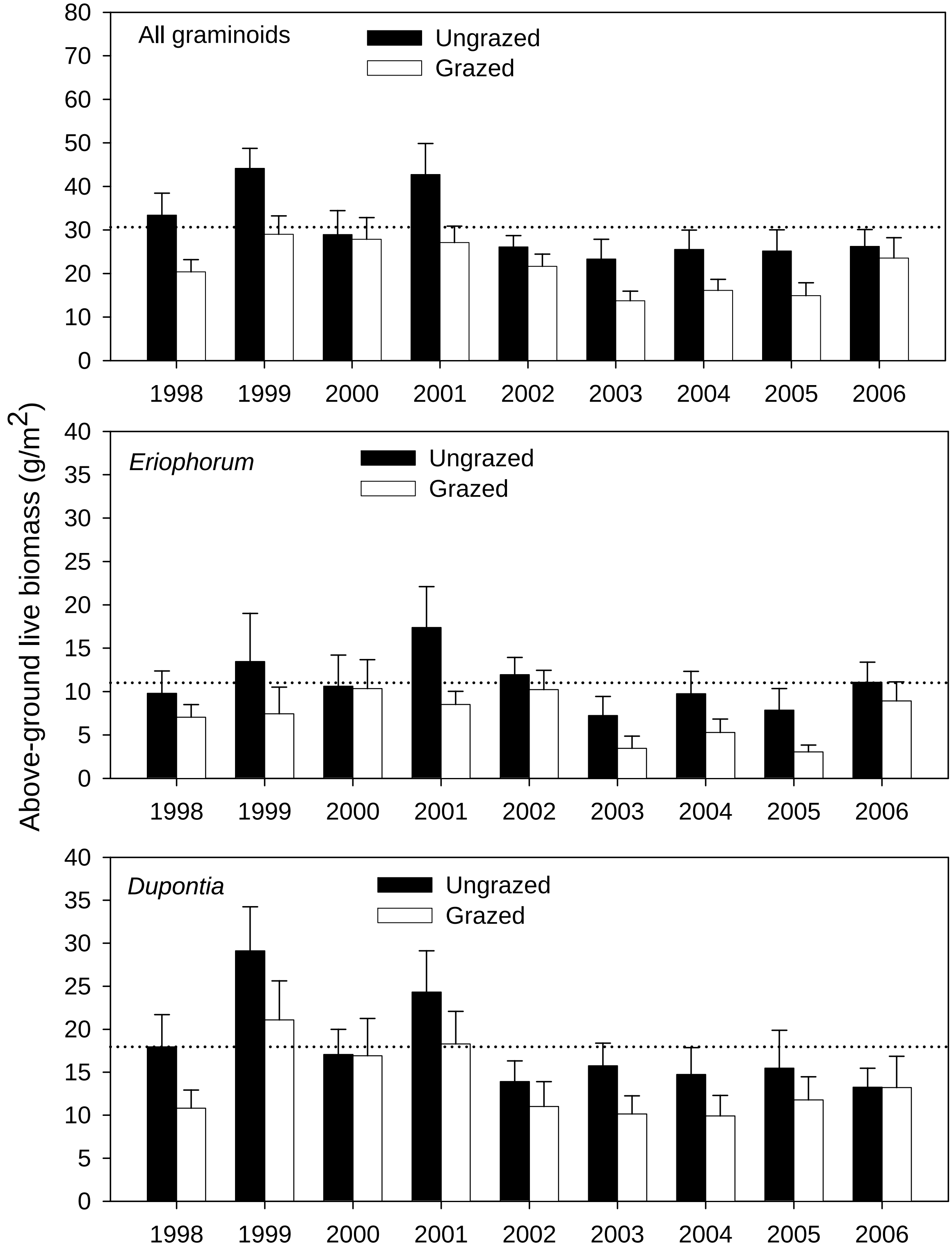

Figure 7. Live above-ground biomass (mean + SE, dry mass) of graminoids on 13 August in grazed and ungrazed wet meadows of the Camp-2 (goose colony), Bylot Island (n = 12). Total graminoids include *Eriophorum scheuchzeri*, *Dupontia fisheri* and *Carex aquatilis*. The dashed line is the long-term average for ungrazed area.

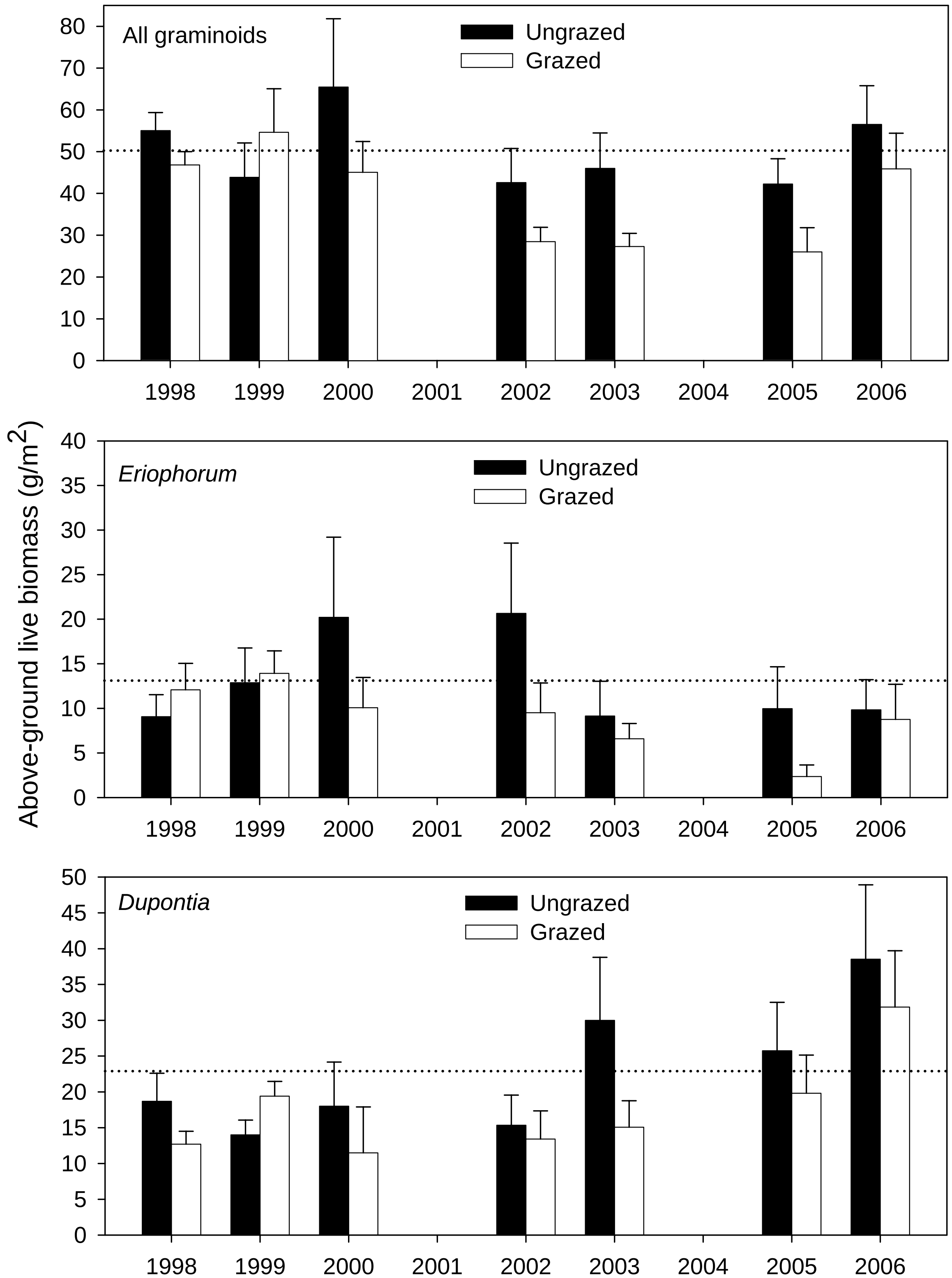

Figure 8. Live above-ground biomass (mean + SE, dry mass) of graminoids on 13 and 14 August in grazed and ungrazed wet meadows of Pointe Dufour, Bylot Island (n = 12). Total graminoids include *Eriophorum scheuchzeri*, *Dupontia fisheri* and *Carex aquatilis*. There is no data in 2001 and 2004. The dashed line is the long-term average for ungrazed area.