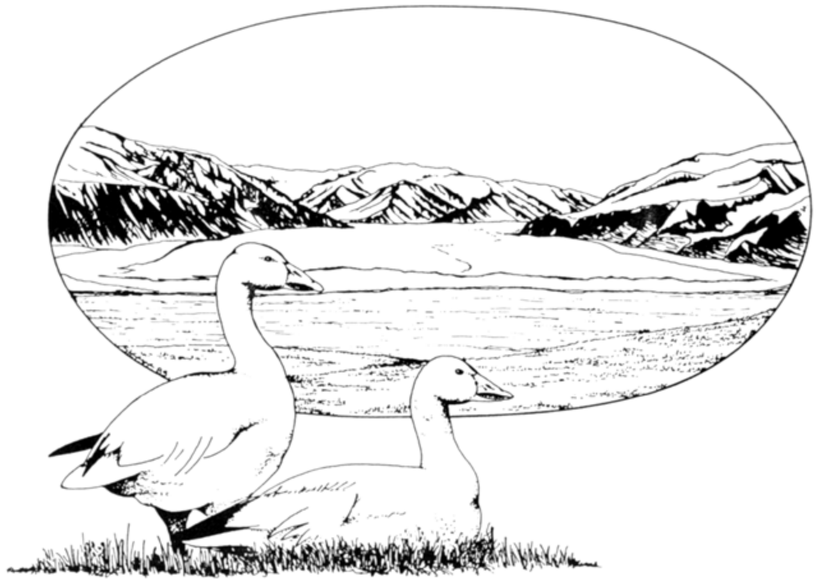
POPULATION STUDY OF GREATER SNOW GEESE AND ITS NESTING HABITAT ON BYLOT ISLAND, NUNAVUT IN 2019: A PROGRESS REPORT



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INTRODUCTION

In 2019, 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 other goose populations worldwide, Greater Snow Geese have increased considerably during the late 20th century. The exploding population 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 actions during autumn, winter and spring have been undertaken since 1999 in Canada and 2009 in the United States to curb the growth of this population. A synthesis report produced in 2007 evaluated the initial success of these special conservation measures. However, both the Avian Monitoring Review Steering Committee Final Report and the Greater Snow Goose Action Plan released in 2012 by the Canadian Wildlife Service called for a continued monitoring of the dynamic of this population and of its habitats. In response to those needs, the long-term objectives of this project are to (1) monitor changes in the demographic parameters of the Greater Snow Goose population, and especially the effects of the spring conservation harvest on those parameters, (2) determine the role of food availability and predation in limiting annual production of geese, and (3) monitor the impact of grazing on the Arctic vegetation.

OBJECTIVES

Specific goals for 2019 were as follows:

1) Monitor the productivity (egg laying date, clutch size and nesting success) and nesting distribution of Greater Snow Geese on Bylot Island.
2) Study the migration phenology of geese and its impact on reproductive success.
3) Mark goslings in the nest to provide a sample of known-age individuals to assess the growth and pre-fledging survival of goslings by their recapture in late summer.
4) 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.
5) Monitor the abundance of lemmings and study their demography in relationship with snow conditions and the impact of predation on their cyclic fluctuations of abundance.
6) Monitor the breeding activity of other bird species and in particular avian predators (Snowy Owl, jaegers, Glaucous Gull and Rough-legged Hawk).
7) Monitor the breeding activity of foxes at dens.
8) Capture and mark adult foxes and their pups to study their movements, demography and foraging activity.
9) Sample plants in exclosures to assess annual production and the impact of goose grazing on plant abundance in wet meadows.
10) Maintain our automated environmental and weather monitoring system.

FIELD ACTIVITIES

Field camps. — In 2019, we operated two camps on Bylot Island: the main field station, located 6 km from the coast in the largest glacial valley on the island (Qarlikturvik Valley, 73° 08' N, 80° 00' W), was occupied from 11 May to 21 August. A secondary camp, located in a narrow valley 30 km south of the main field station and 5 km from the coast ("Camp 2 area", 72° 53' N, 79° 54' W) was occupied from 22 May to 25 July (Fig. 1). Finally, 8 fly camps were also established for periods ranging from 2 to 14 days at various times throughout the island, west of Dufour Point.

Field parties. — The total number of people in both camps ranged from 3 to 16 depending on the period. Members of our field party included project leaders Gilles Gauthier, Joël Bêty, Dominique Berteaux, Josée Lefebvre, Pierre Legagneux and several graduate students whose thesis projects addressed many of the objectives mentioned above: Frédéric LeTourneux (PhD, objectives 1, 2, 3 and 4), Frédéric Dulude-de Broin (PhD, objective 2), Mathilde Poirier (PhD, objective 5), Yannick Seyer (PhD, objective 6), Marianne Valcourt (MSc, objective 5), Gabriel Bergeron (MSc, objectives 5 and 6), Alexis Grenier-Potvin (MSc, objective7) and Jeanne Clermont (PhD, objective 8). Several other students assisted them in the field, including Bryan Mayhew, Richard Gravel, Gabrielle Roy and Marie-Pier Poulin. Other people in the field included Marie-Christine Cadieux, a research professional in charge of goose banding and plant sampling (objectives 4 and 9); Denis Sarrazin, research professional responsible of the maintenance of the weather stations (objective 10); Dominique Fauteux, a researcher from the Canadian Museum of Nature (objective 5) and Christian Marcotte, a wildlife technician from the Canadian Wildlife Service (CWS, Quebec region). Finally, we hired 1 person from Cape Dorset and 2 persons from Pond Inlet to work with us. They were Niviasqsi Liz Qavavau (marking goslings in nests: 2-15 July), Dwayne Nutarariaq (goose banding: 5-15 August) and James Akpaleeapik (lemming monitoring: 30 June-7 July and goose banding: 5-15 August).

Several other people also used our camps during the summer. They were Andréanne Beardsell (PhD student), Éliane Duchesne (MSc student), Louis Moisan and Madeleine-Zoé Corbeil-Robitaille who studied shorebirds, lapland longspurs and insects under the supervision of Joël Bêty; the field party of Daniel Fortier (Université de Montréal), which included Élisabeth Hardy-Lachance (MSc student), Yuri Shur, Mikhail Kanevskyi and Torre Jorgenson (researchers at the University of Alaska Fairbanks), who studied the permafrost and geomorphology; the field party of Esther Lévesque, Christophe Kinnard and Vincent Maire (Université du Québec à Trois-Rivières), which included Lucas Deschamps (PhD student), Hadi Mohammadzadeh Khani (PhD student), Matthieu Loyer (MSc student), Jennifer Paillassa (PhD student), François Tanguay and Véronique Roy-Blais, who studied plant ecology and hydrology; the field party of Isabelle Laurion and Jérôme Comte (Institut National de la Recherche Scientifique), which included Vincent Laderrière (PhD student), who studied the carbon cycle in ponds; the field party of Florent Dominé (Takuvik, Université Laval/CNRS), Anne Ola (post-doctoral fellow) and Maria Belke, who studied the snow physical properties and the field party of Jean-François Therrien (Hawk Mountain Sanctuary) which included Rebecca McCabe, who studied raptors. Carey Elverum and Brian Koonoo from Parks Canada inspected both camps during the summer. Brian Koonno and Terry Kalluk also guided the research teams of Christophe Kinnard and Gilles Gauthier in snowmobiles to bring them to the main field station in early May.

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 312 m ASL, respectively) where air and ground temperature, air humidity, precipitations, snow depth, solar radiation, wind speed and wind direction are recorded on an hourly basis throughout the year (Fig. 1). A fourth station measures 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. Daily precipitation was also recorded manually during the summer. Finally, snowmelt was monitored by measuring snow depth at 50 stations along two 250-m transects and by visually estimating snow cover in the Qarlikturvik Valley, both at 2-day intervals.

Monitoring of goose arrival and nesting. **—** We monitored goose arrival in the Qarlikturvik Valley by counting goose pairs across the valley every two to three days from our arrival on the island on 22 May until the end of snowmelt. Nest searches were carried out within walking distance (~6 km) of both the main field station and the Camp 2 between 8 and 18 June. Nests were found by systematic searches conducted over various areas in the field. At Camp 2, where the main goose colony is located, nest searches were conducted using two methods: 1) over an intensively-studied core area (ca 50 ha) located in the centre of the colony every year, and 2) within a variable number of 1 and 2-ha plots randomly located throughout the colony. Nest density was calculated over a fixed 20-ha area within the intensively studied core area. We also attempted to find the nests of as many neck-collared females as possible through intensive searches on foot throughout the nesting colony. 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 daily to record hatch dates and to web-tag goslings. Nests of other goose species, and in particular Cackling Geese (*Branta hutchensii*), were also systematically recorded during our field activities throughout Bylot Island.

Tracking of geese radio-marked in the south. **—** During spring staging in Quebec, we equipped eight adult female snow geese with VHF radio transmitters and another ten were with GPS/GSM transmitters. We also banded an additional 751 individuals and among those 360 adult females were marked with yellow neck collars. On Bylot Island, we installed three telemetry towers (Camp 1, Camp 2, Dufour Point) to detect the presence of geese marked with a VHF transmitters and we subsequently conducted intensive aerial and ground surveys (31 May to 18 June) of breeding areas to find and monitor the nests of those radio-marked and collared geese.

Goose banding. **—** From 6 to 15 August, we banded geese with the assistance of a helicopter. Goose flocks of a few hundred birds were rounded up and driven by people on foot into a holding pen made of plastic netting. All captured geese 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 (body mass and length of culmen, head, tarsus and 9^{th} primary) and some adult females were fitted with coded yellow plastic neck-collars. We also collected oral and cloacal swab samples from goslings for the Centre de recherche en infectiologie, CHU de Québec-Université Laval.

Small mammals. **—** We sampled the annual abundance of lemmings at two sites in the Qarlikturvik Valley (one in wet meadow and one in mesic habitat) and one site at the Camp 2 (mixed habitat) in July using snap-traps. At each site, we used 240 Museum Special traps set at 80 stations (3 traps per station), spaced 15-m apart along two to four parallel transect lines 100 m apart and left open for 3 days. We also sampled lemming abundance and demography using live-traps. We trapped on 2 grids (330 × 330 m) in the Qarlikturvik Valley (one in wet meadow habitat and one in mesic habitat) with 144 traps per grid and on a 3rd grid (200 × 340 m; 96 traps) in mesic habitat where a predator exclosure experiment was set up in 2012-2013 (the grid is surrounded by a chicken wire fence and covered by criss-crossing fishing line on top). We also trapped at three other sites (270 × 270 m grids with 100 traps; mixed habitat): one between the main field station and Camp 2, one at Camp 2 and one at Dufour Point. We used Longworth traps set at each grid intersection every 30-m. We trapped for 3 consecutive days during 3 periods (mid-June, mid-July and mid-August) on grids of the Qarlikturvik Valley and during one period in mid-July elsewhere. All trapped animals were identified, sexed, weighed and marked with electronic PIT tags or ear-tags (or checked for the presence of such tags). Finally, we sampled the abundance of lemming winter nests along 164 500-m transects randomly distributed in different habitats (wetlands, mesic tundra, streams in mesic tundra and willow shrubs) at the four sites where live-trapping was conducted.

Breeding activity of foxes at dens and marking. — All known fox dens located within a 600 km^2 area ranging from the Qarlikturvik Valley in the north to Dufour Point in the south and from the coast to approximately 10 km inland. Dens were visited one to five times during the summer and inspected for signs of use and/or presence of reproductive adults with pups. Automated cameras were deployed at dens showing signs of activity. We attempted to live-trap adults with padded leghold traps at locations where foxes were seen hunting or travelling. At reproductive dens, we noted the species (Arctic Fox, *Vulpes lagopus*, or Red Fox, *Vulpes vulpes*) and minimum litter size, and, whenever possible, we live-trapped pups with Tomahawk collapsible cage traps. Cage traps were kept under continuous surveillance and leghold traps were visited at least every 6 hours. Captured foxes were measured, weighed and tagged on both ears using a unique set of coloured and numbered plastic tags. Samples of winter and summer fur, blood, saliva, claws and scats were also collected for genetic, microbiome and diet analyses.

Monitoring of other bird species. — We monitored the nesting activity of Snowy Owls (*Bubo scandiacus*), Long-tailed and Parasitic Jaegers (*Stercorarius longicaudus* and *S. parasiticus*), Glaucous Gulls (*Larus hyperboreus*), Rough-legged Hawks (*Buteo lagopus*) and Lapland Longspurs (*Calcarius lapponicus*). Gull and Long-tailed jaeger nests were only monitored in the Qarlikturvik Valley and the Camp-2 area, but nests of other avian predators were monitored throughout the same 600 km^2 area than for foxes. Nests were found through systematic searches of suitable habitats or opportunistically and revisited to determine their fate (successful or not) until fledging. Jaegers were captured at the nest and banded.

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 2 sites (Fig. 1): the Qarlikturvik Valley (brood-rearing areas), and the Camp 2 area (nesting colony). At each site, 12 exclosures (1 × 1 m) were installed in late June in two groups of 6 in the same general area every year. At Camp 2, one of the groups of 6 exclosures was moved about 200 m in 2011 due to the natural drainage of some wetlands. Plant biomass was sampled in ungrazed and grazed areas (i.e. inside and outside exclosures) at the end of the plant-growing season between 11 and 14 August. Plants were sorted into sedges (*Eriophorum scheuchzeri* and *Carex aquatilis*) and grasses (*Dupontia fisheri*), dried and weighed. 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 Qarlikturvik Valley and once at the end of the season at the Camp 2 area.

PRELIMINARY RESULTS

Weather conditions. — Temperatures in spring were exceptionally warm. Air temperature averaged 2.4°C (2.3°C above normal) between 20 May and 20 June, the period of goose arrival and egg-laying, and 3.4°C (1.9°C above normal) during 1-15 June, which is the most critical period for egg formation and egg-laying. Snowpack at the end of the winter was thin (snow depth was 27.6 cm on 18 May; Fig. 2). This, combined with the warm temperature, resulted in one of the earliest snowmelt on record as virtually all snow had disappeared by 3 June. Temperatures were warm and the sky mainly clear and sunny throughout most of the summer. Rainfall was below average and concentrated mostly in June and July (cumulative rainfall from 1 June to 18 August: 66 mm, long-term average: 78 mm).

Goose arrival and nesting activity. — The first geese were detected on the hills surrounding the Qarlikturvik Valley, usually the first area used by geese after arrival, around 22 May. This number increased rapidly over the next few days to peak at 606 pairs on 1 June, a high number (Fig. 3). This indicates that goose arrival on Bylot Island was quite early compared to last year and among the earliest arrival date recorded since 1996. The subsequent decline in goose numbers was due to the movements of geese to the nesting colony, away from the Qarlikturvik Valley. This movement was also very early in 2019.

Nest density in the center of the colony was higher than last year (5.7 vs. 3.5 nests/ha in 2018) and above the long-term average (Table 1). Egg-laying date in the colony (median: 7 June) was much earlier than the long-term average on Bylot Island (Table 1) and was the second earliest date on record (6 June in 1993). Average clutch size was 4.0, which is also above the long-term average and the highest value of the last decade (Table 1). Twenty-four nests were also found in the Qarlikturvik Valley, which is predominantly a brood-rearing area for geese. Across the island, we found 76 nests of Cackling Geese compared to 61 in 2018 (Table 1).

Nesting success of geese. — Nesting success (82%; proportion of nests hatching at least one egg) was above to the long-term average (Table 1). This was largely due to a relatively low activity of Arctic Foxes and avian predators around goose nests, which destroyed fewer nests than last year. During the summer, 161 neck-collared birds were sighted in the colony. Peak hatch was on 4 July, which is also earlier than the long-term average (Table 1). We tagged 2468 goslings in nests at hatch (2436 in Camp 2 area and 33 in the Qarlikturvik Valley). Overall, nesting parameters of geese in 2019 were much higher than normal.

Density of broods. — The density of goose faeces on transects was high at the end of the summer in wet meadows of the Qarlikturvik Valley (12.6 faeces/m^2; long-term average: 6.7; Fig. 4). Accumulation of faeces began in early July, which is earlier than normal, and increased steadily thereafter until mid-August. The rapid increase of faeces in early July indicates that geese appeared earlier on brood rearing areas than in previous years. Faeces density at the end of the summer was also above average in the wet meadows of the nesting colony at Camp 2 (6.1 faeces/m^2; long-term average: 4.2).

Tracking of geese radio-marked in the south. — Breeding phenology and success was available for 16 of the 18 radio-marked individuals. Among the 8 birds equipped with VHF radios, one was shot before migration, 6 were detected on Bylot and the nest of 3 of them was found, and one was resighted in the fall as successful breeder (female with 1 young). We successfully tracked the migration of 9 adult females marked with GPS/GSM transmitters from southern Québec to the Arctic. These birds left Québec around 24 May and arrived on their breeding grounds in Nunavut around 1 June. GPS-tracked birds attempted to nest either on Ellesmere, Baffin and Bylot islands. We also tracked the autumn migration of these females and most of them were in Pensylvannia on 20 January.

Goose banding. — The banding operation was challenging this year despite the generally good weather in August. Since geese nested earlier than normal, most families had already left their usual brood-rearing habitats and were found further south on the island. In addition, many adults had already regained flight capabilities and several goslings were able to fly in early August. Finally, bad weather (rain or fog) prevented us from banding for two days. We conducted 11 drives between the Camp 2 area and the Qarlikturvik Valley. We banded a total of 2985 geese, including 410 adult females marked with neck-collars and 47 young that had been marked with web-tags at hatch. In addition, we recaptured 176 adults that were banded in previous years. The young:adult ratio among geese captured at banding (1.20:1) was much higher than last year and above the long-term average (Table 1). Mean brood size toward the end of brood-rearing (2.65 young, n = 96; counts conducted between 30 July and 4 August) was also above the long-term average. By combining information on brood size and young:adult ratio at banding, we estimated that 91% of the adults captured were accompanied by young, a value higher than the long-term average (Table 1). Overall, these results are indicative of a high production of young on Bylot Island by the end of the summer.

Small mammals. — During our survey using snap traps, we cumulated 1409 trap-nights at our 2 trapping sites of the Qarlikturvik Valley from 25 to 30 July, and 711 trap-nights at the Camp 2 from 13 to 15 July. In the Qarlikturvik sites, we caught 2 Brown Lemmings (*Lemmus trimucronatus*) and 1 Collared Lemming (*Dicrostonyx groenlandicus*), which yielded a combined index of abundance of 0.33 lemming/100 trap-nights (Fig. 5). The index of abundance was higher in the Camp 2 area, as 4 Brown Lemmings and 1 Collared Lemming were caught, for an index of 1.07 lemming/100 trap-nights. However, the live trapping conducted throughout the summer in the Qarlikturvik Valley revealed a somewhat different picture, with higher values. Overall, we captured 161 Brown Lemmings and 19 Collared Lemming, for an index of 6.16 lemmings/100 trap-nights, a high number compared to last year (0.06 lemmings/100 trap-nights). A formal estimation of density using capture-recapture methods confirmed that both lemming species had increased compared to 2018 but that their density decreased during the summer, except on the predator-exclusion grid (Fig. 6). The live-trapping survey conducted at the three sites outside the Qarlikturvik Valley also indicated an increase in lemming abundance across Bylot Island compared to the previous year. We captured a total of 10 Brown Lemmings and 5 Collared Lemmings at these three sites in mid-July, for an overall index of 1.69 lemmings/100 trap-nights (compared to 0.11 in 2018). Finally, the number of lemming winter nests found along our transects also revealed an increase in lemmings during winter as we counted 431 nests in 2019 compared to 76 in 2018.

Breeding activity of foxes at dens and marking. — A total of 114 known fox denning sites were monitored in 2019. Among these dens, we found signs of activity (fresh digging and/or footprints) at 56 of them, a high number. The breeding activity was also high as we found 24 different litters (21% of denning sites) of Arctic Foxes compared to only 7 litters in 2018). No Red Fox litters were found in 2019. The high breeding activity of foxes is typical of what we normally observed in years of high lemming abundance (average: 22%). Minimum litter size of Arctic Fox varied between 1 and 14 pups (7 pups on average). A total of 41 Arctic Foxes were captured during the summer, including 26 juveniles and 15 adults marked in previous years. All new individuals were marked with ear-tags.

Monitoring of other bird species. — We found 36 active nests of Glaucous Gulls (vs. 42 in 2018), 5 nests of Parasitic Jaegers (vs. 4 in 2018), 37 nests of Long-tailed Jaegers (vs. none in 2018), 42 nests of Rough-legged Hawks (vs. 3 in 2018) and 10 nests of Snowy Owls (vs. none in 2018). The high nesting activity of avian predators is typical of what we encountered in a year of high lemming abundance. We found 67 nests of Lapland Longspurs compared to 56 in 2018. Average clutch size of gulls was higher than last year (2.8 eggs vs 2.3 in 2018) as well as for longspurs (6.0 eggs vs. 5.3 in 2018). Nesting success was high for gulls, hawks and owls (92%, 94% and 100%, respectively) and unknown for most jaegers. Fledging success (proportion of nests successful in fledging at least one young) was moderate for longspurs (50%). We captured 1 Parasitic Jaeger (a recapture from previous years) and 36 Long-tailed Jaegers (22 recaptures and 14 newly marked birds).

Plant growth and grazing impact. — Plant production in wet meadows of the brood-rearing area was higher than last year and above the long-term average (Fig. 7). Above-ground biomass of graminoid plants in the Qarlikturvik Valley reached 56.0 g/m^2 in ungrazed areas in mid-August compared to 42.0 in 2018 (long-term average since 1990: 51.0 g/m^2). Biomass of both *Eriophorum* and *Dupontia* also increased compared to last year (Fig. 7). At the nesting colony (Camp 2 area), graminoid biomass was slightly lower compared to last year (60.9 vs 64.1 g/m^2 in 2018, Fig. 8). Above-ground biomass of *Eriophorum* in the exclosures was higher than last year but biomass of *Dupontia* decreased compared to last year.

Grazing pressure was high in the wet meadows of the Qarlikturvik Valley in 2019 as geese had removed 51% of the above-ground biomass (difference between paired grazed and ungrazed plots) by mid-August (long-term average: 32%; Fig. 7). Grazing pressure was much higher on *Eriophorum* (74% of biomass removed), the preferred plant of geese, than *Dupontia* (47% of biomass removed). Grazing pressure at the Camp 2 area (nesting colony) was slightly lower than at the Qarlikturvik Valley (46% of the graminoid biomass removed by geese) but higher than the long-term average at this site (27%; Fig. 8). Geese removed 54% of the *Eriophorum* biomass and 37% of the *Dupontia* biomass at this site.

CONCLUSIONS

All indicators of goose reproduction on Bylot Island were excellent in 2019. Geese arrived early and in large numbers on the island, the nesting effort (indexed by nest density in the colony) was high, egg-laying was exceptionally early and clutch size was high. This was undoubtedly the consequence of the very warm spring and thin snowpack, which resulted in one of the earliest snow melt on record. Because of these conditions, food availability was probably high during the pre-laying period, providing a lot of nutrients for egg formation, and nesting sites became snow free very early. Nesting success was also high, a consequence of a lower activity of the predators and of the high density of geese in the colony, which strengthened the predator-swamping effect. Even though we had a large number of fox dens with pups, they concentrated their foraging activity on lemmings, their main prey, rather than on goose eggs. Even though lemmings had increased considerably in 2019 after 2 years of near absence, their density was not as high as in previous years of peak abundance, which may explain why goose nesting success was slightly lower than what is typically encountered in lemming peak years.

The proportion of young recorded in our catches at banding shows that production of geese on Bylot Island was very good in 2019, which is in agreement with the nesting parameters recorded earlier during the season. Based on the young:adult ratio recorded at banding, we predicted a percentage of young in the fall flock of 27%, a much higher value than the one predicted last year (17%) and the long-term average (22%). As expected, the percentage of young measured during juvenile counts conducted in southern Quebec this fall was very high, 32% (n = 20,053). This value suggests that breeding conditions for greater snow geese were very good throughout their breeding range and perhaps even better than on Bylot Island in some other areas because our predicted value was slightly lower than the productivity observed on the fall staging area. However, it is also possible that the young:adult ratio observed during banding on Bylot Island was an underestimation of the real value. Because the nesting phenology of geese was very early in 2019 and we did not advance the dates of banding, some goslings and their parents had most likely reached flying stage before the end of banding, and thus could not be captured. Since early nesting birds are typically the most productive ones (high clutch size and pre-fledging survival), missing some of them at banding may have biased low our young:adult ratio.

An emerging phenomenon on Bylot Island is the growing number of nesting Cackling geese. Until 2010, their presence was a rare and anecdotal event, with 1 or 2 nests occasionally found annually. However, as we noticed an increase in their number after that, we started around 2013 to systematically record the number of nests found. The number of nests has grown steadily since then and reached a new record in 2019 with 76. Joêl Bêty has initiated a study to understand better this phenomenon, especially by looking at the habitat selected by Cackling geese to nest, their reproductive success and the wintering site of these birds.

Above-ground graminoid production in wet meadows of the Qarlikturvik Valley, a prime brood-rearing area, was good this year, though less so in the nesting colony. However, faeces counts revealed that use by broods was high at both sites due to the good production this year, which resulted in a high impact of goose grazing at both sites. As expected in years of high brood density, grazing impact was much higher on the sedge *Eriophorum*, the preferred plant of geese in this system, than on the grass *Dupontia*. Previous studies on Bylot Island had shown that even though goose grazing removes a significant proportion of the standing crop each year, plant production has not decreased over the long-term and actually showed an increasing trend due to climate warming. Our most recent results still support this conclusion. Annual change in plant production in wetlands seem to be more related to variations in summer temperature, often with a 1 or 2-year lag, than to variations in goose grazing pressure.

PLANS FOR 2020

The long-term objectives of our work are to study the population dynamics of Greater Snow Geese, and the interactions between geese, plants, and their predators on Bylot Island. A major focus of the project is to monitor changes in demographic parameters (such as survival rate, hunting mortality, breeding propensity, reproductive success, and recruitment) and habitat (annual plant production and grazing impact) in response to the spring conservation harvest and other special management actions implemented since 1999 in Canada and since 2009 in the United States. Other aspects of the project include *i*) understanding better the links between events occurring during the spring migration and the subsequent breeding success of geese; *ii*) determining the long-term effects of geese on the arctic landscape; *iii*) studying indirect interactions between snow geese and lemmings via shared predators; *iv*) studying the ecology of the main predator of geese, the Arctic Fox; and *v*) assessing the impact of climate change on goose reproduction and the carrying capacity of the habitat for geese. In 2020, we anticipate to:

1) Monitor productivity (egg laying date, clutch size and nesting success) and nesting distribution of Greater Snow Geese on Bylot Island.
2) Study the migration phenology of geese and its impact on reproductive success.
3) Mark goslings in the nest to provide a sample of known-age individuals to assess the growth and pre-fledging survival of goslings by their recapture in late summer.
4) 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.
5) Monitor the abundance of lemmings and study their demography in relationship with snow conditions and the impact of predation on their cyclic fluctuations of abundance.
6) Monitor the breeding activity of other bird species, in particular avian predators (Snowy Owls, jaegers, Glaucous Gulls and Rough-legged Hawks).
7) Monitor the breeding activity of foxes at dens
8) Capture and mark adult foxes and their pups to study their movements, demography and foraging activity.
9) Sample plants in exclosures to assess annual production and the impact of goose and lemming grazing on plant abundance in wet meadows.
10) Maintain our automated environmental and weather monitoring system.

In 2020, at least 6 graduate students will be involved in the Bylot Island snow goose project. **Frédéric LeTourneux** (PhD) will complete his study of the impact of recent management actions on the survival and population dynamics of snow geese. **Mathilde Poirier** (PhD) will complete her study on the population dynamics of lemmings and how it is impacted by snow physical properties. **Marianne Valcourt** (MSc) will continue her study on habitat use by lemmings. **Gabriel Bergeron** (MSc) will continue his study of the role of predator-prey interactions in the population dynamics of lemmings. **Thierry Grandmont** (MSc) will start a study on the timing of snow goose migration and its effect on reproduction. Finally, **Ilona Grentzmann** (PhD) will start a study on the effect of senescence on the population dynamics and physiology of snow geese.

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

	2010	2011	2012	2013	2014	2015	2016	2017	2018	**2019**	Average[2]
Number of nests monitored	372	382	375	451	491	347	337	342	277	**422**	--
Nest density (n/ha)	2.95	4.89	5.24	8.85	7.89	9.26	5.50	8.14	3.46	**5.70**	4.93
Median date of egg-laying	13 June	13 June	12 June	13 June	11 June	12 June	13 June	11 June	14 June	**7 June**	12 June
Clutch size	3.68	3.74	3.80	3.58	3.85	3.48	3.36	3.53	3.50	**4.04**	3.71
Nesting success[1]	80%	90%	54%	67%	91%	77%	73%	56%	50%	**82%**	67%
Median date of hatching	10 July	8 July	9 July	10 July	8 July	9 July	9 July	8 July	11 July	**4 July**	9 July
Number of geese banded	4267	3802	2512	4865	2001	3675	4357	3216	2951	**2985**	3524
Ratio young:adult at banding	1.18:1	1.19:1	0.92:1	1.10:1	1.19:1	0.99:1	0.91:1	0.88:1	0.94:1	**1.20:1**	1.03:1
Brood size at banding	2.39	2.80	2.54	2.51	2.58	2.08	2.35	2.14	2.34	**2.65**	2.49
Proportion of adults with young at banding	98%	85%	73%	88%	92%	95%	78%	83%	81%	**91%**	83%
Number of Cackling goose nests found	2	6	6	10	22	11	28	40	61	**76**	--

[1] Mayfield estimate
[2] Period 1989-2019

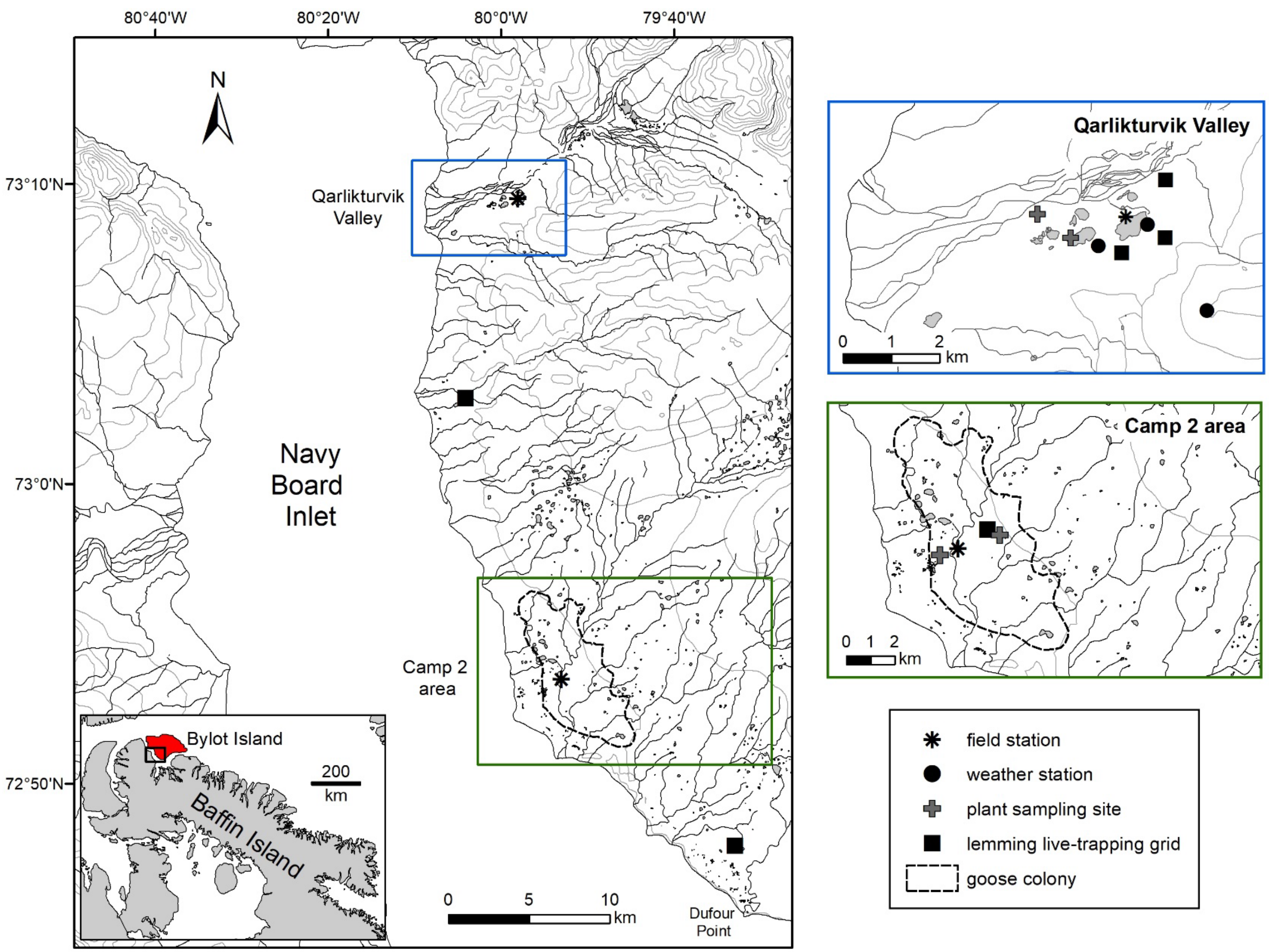

Figure 1. Location of the two main study sites (Qarlikturvik Valley and the Camp 2 area) on the South Plain of Bylot Island, Nunavut. Enlarged maps on the right present these study sites in more details, including locations of our field stations, automated weather stations, wetland sampling sites for plants, lemming live-trapping grids and the extent of the main snow goose colony. The Qarlikturvik Valley is predominantly a brood-rearing area for geese.

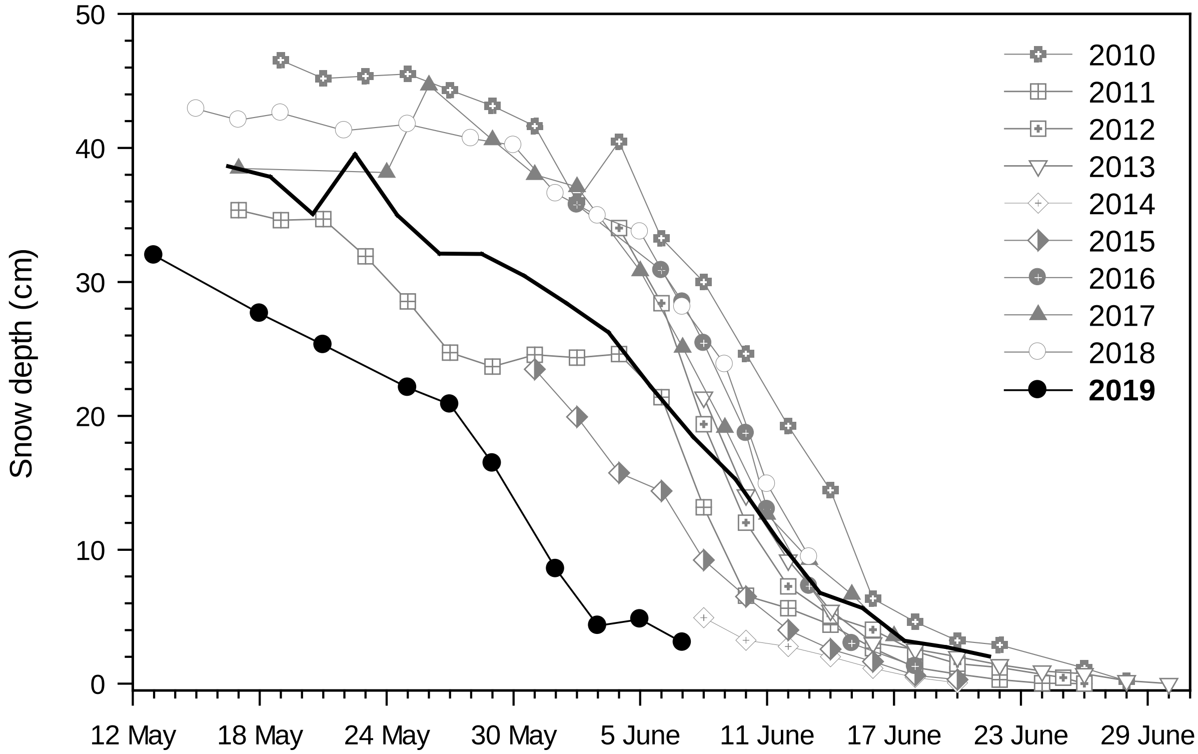

Figure 2. Average snow depth along 2 transects showing the rate of snowmelt in the lowlands of Bylot Island in spring over the past decade (*n* = 50 stations). The thick solid line represents the average snowmelt rate since 1995.

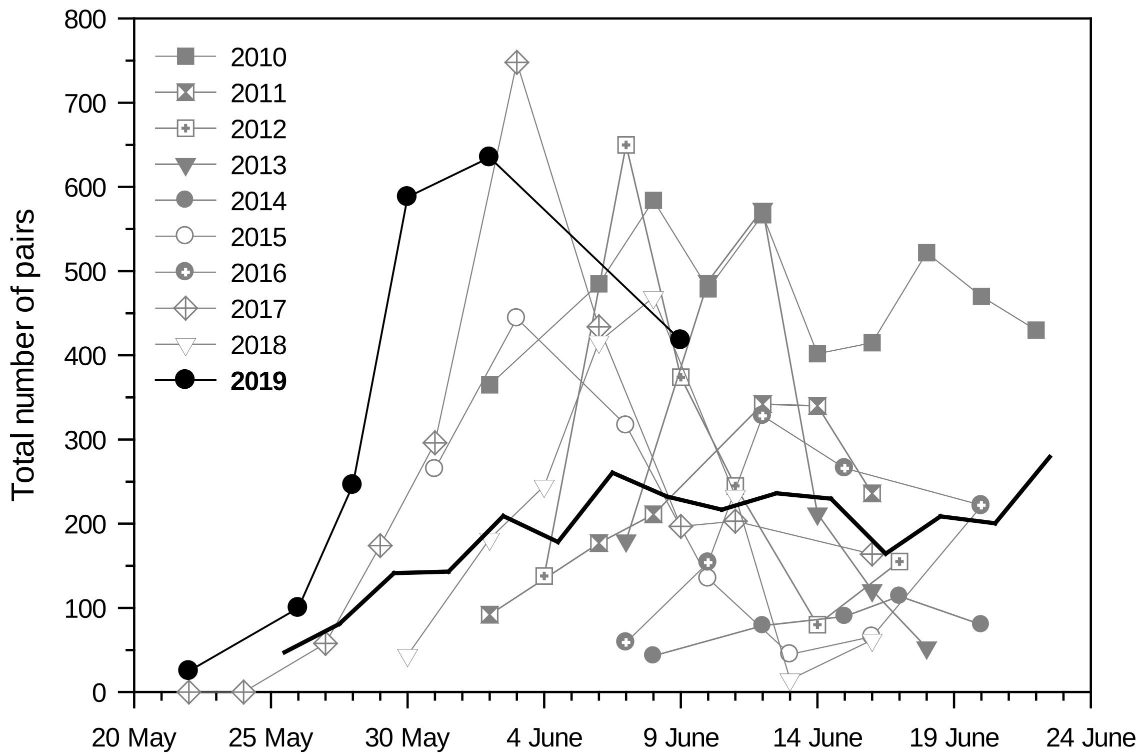

Figure 3. Total number of goose pairs counted in the Qarlikturvik Valley from arrival of our crew on Bylot Island in late May until the end of snowmelt over the past decade. The thick solid line represents the average number of goose pairs counted since 1996.

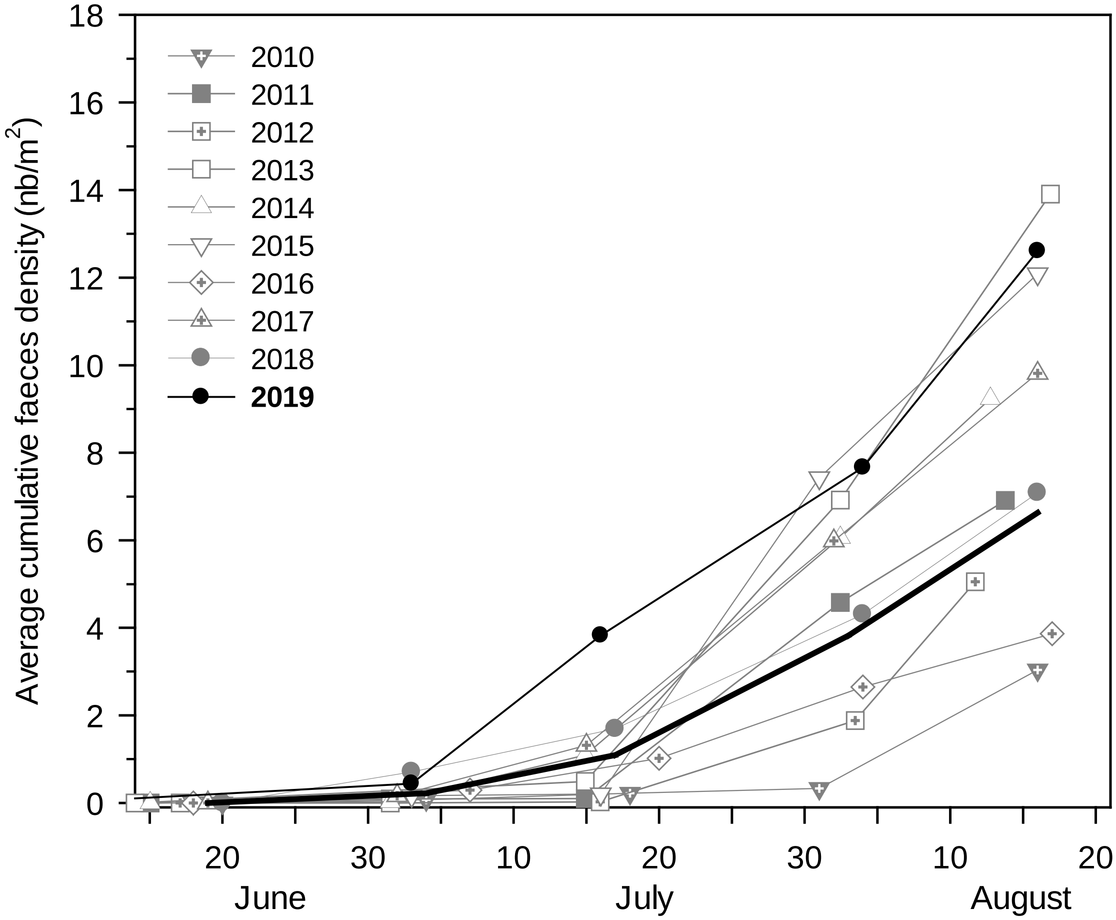

Figure 4. Average cumulative faeces density showing the use of the Qarlikturvik Valley by Greater Snow Goose families on Bylot Island throughout the summer over the past decade (*n* = 12 transects of 1 x 10 m; except 2013 *n* = 5 and 2016 *n* = 11). The thick solid line represents the average cumulative faeces density since 1990.

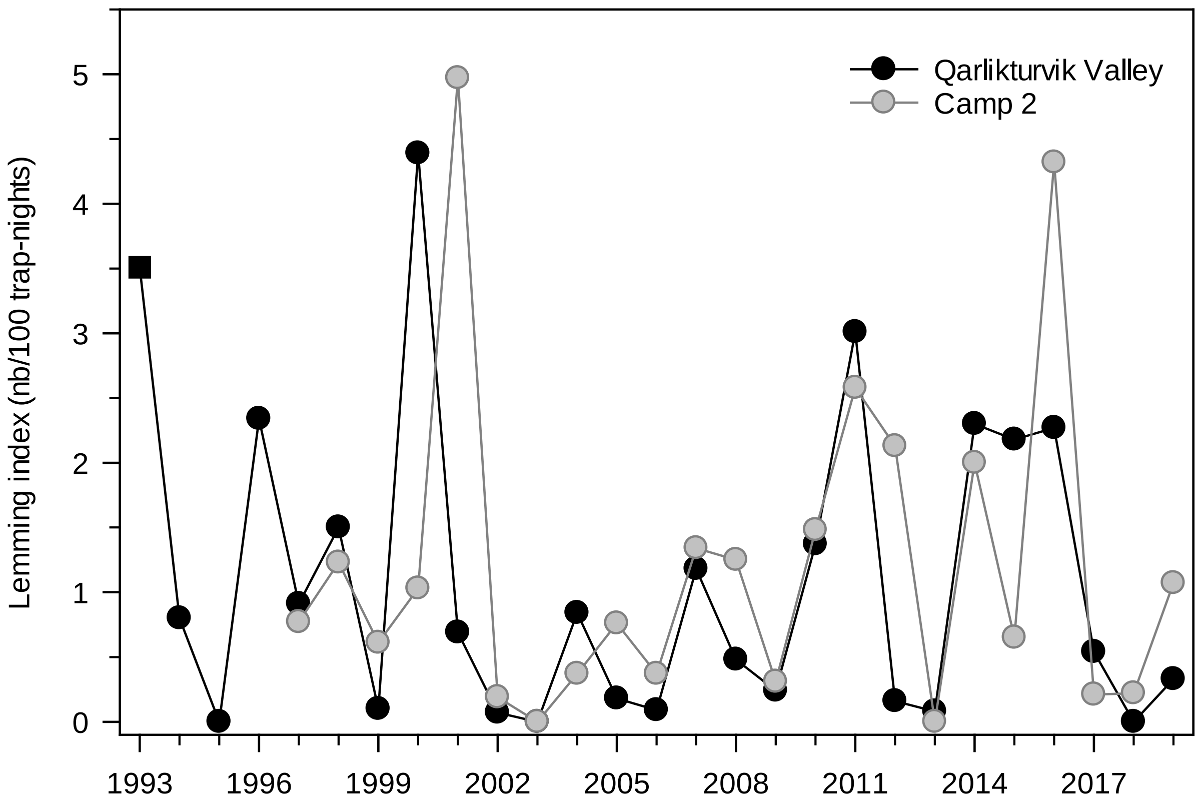

Figure 5. Annual index of lemming abundance in mid-July based on snap-trapping at two study areas (Qarlikturvik Valley and Camp 2) located 30 km apart on Bylot Island (see Fig. 1). Because the sampling protocol changed after 2006, the trapping effort was adjusted in the calculation (i.e. reduced from 3 to 2 traps per station) to make the data collected after 2006 comparable to the previous period.

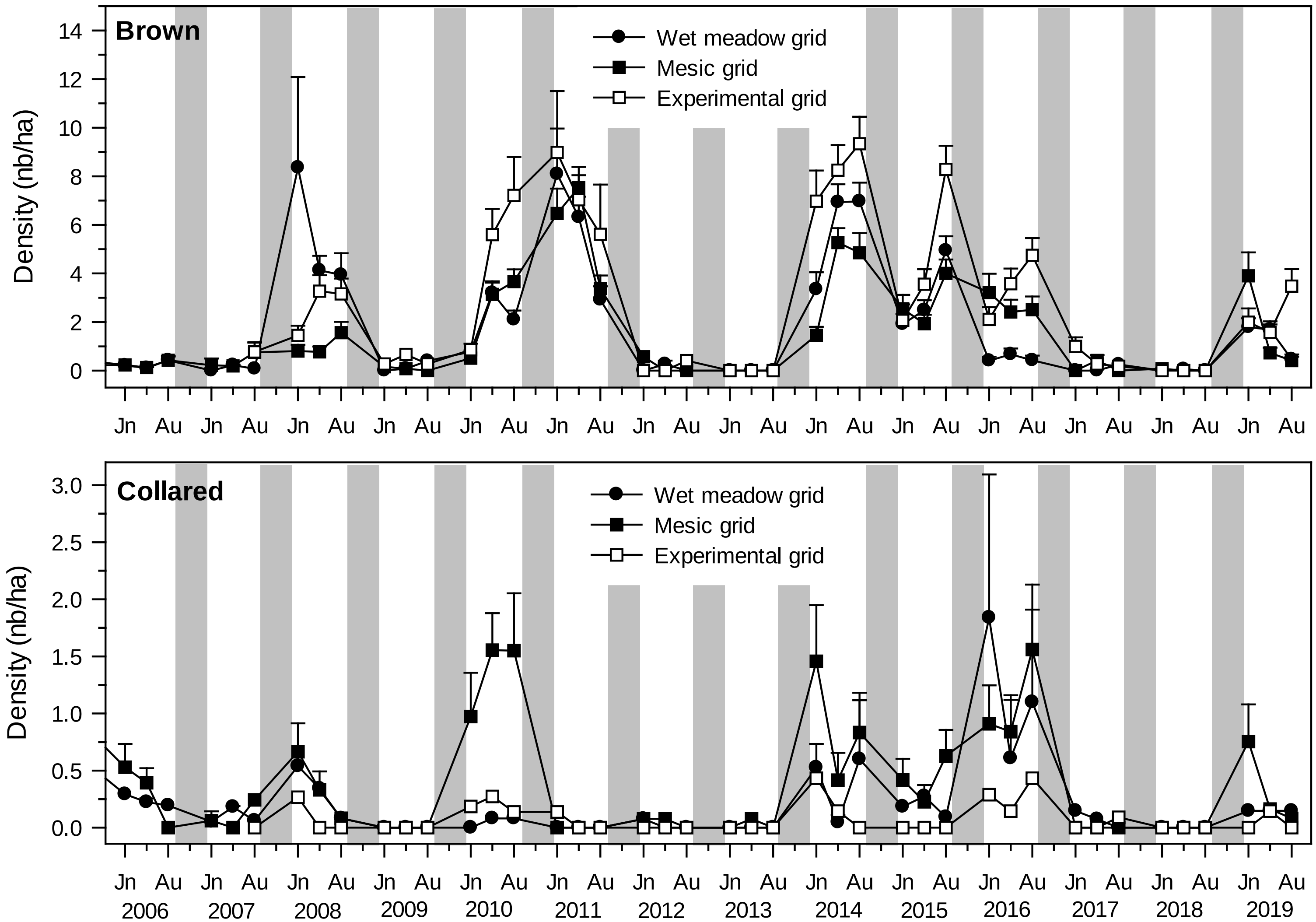

Figure 6. Annual summer density (+ SE) of Brown and Collared Lemmings on 3 trapping grids located in the Qarlikturvik Valley of Bylot Island over the past 14 years (snow cover was increased from 2008 to 2011 and predators were excluded from 2012 to 2019 on the experimental grid). The gray area indicates winter. Jn = mid-June, Au = mid-August.

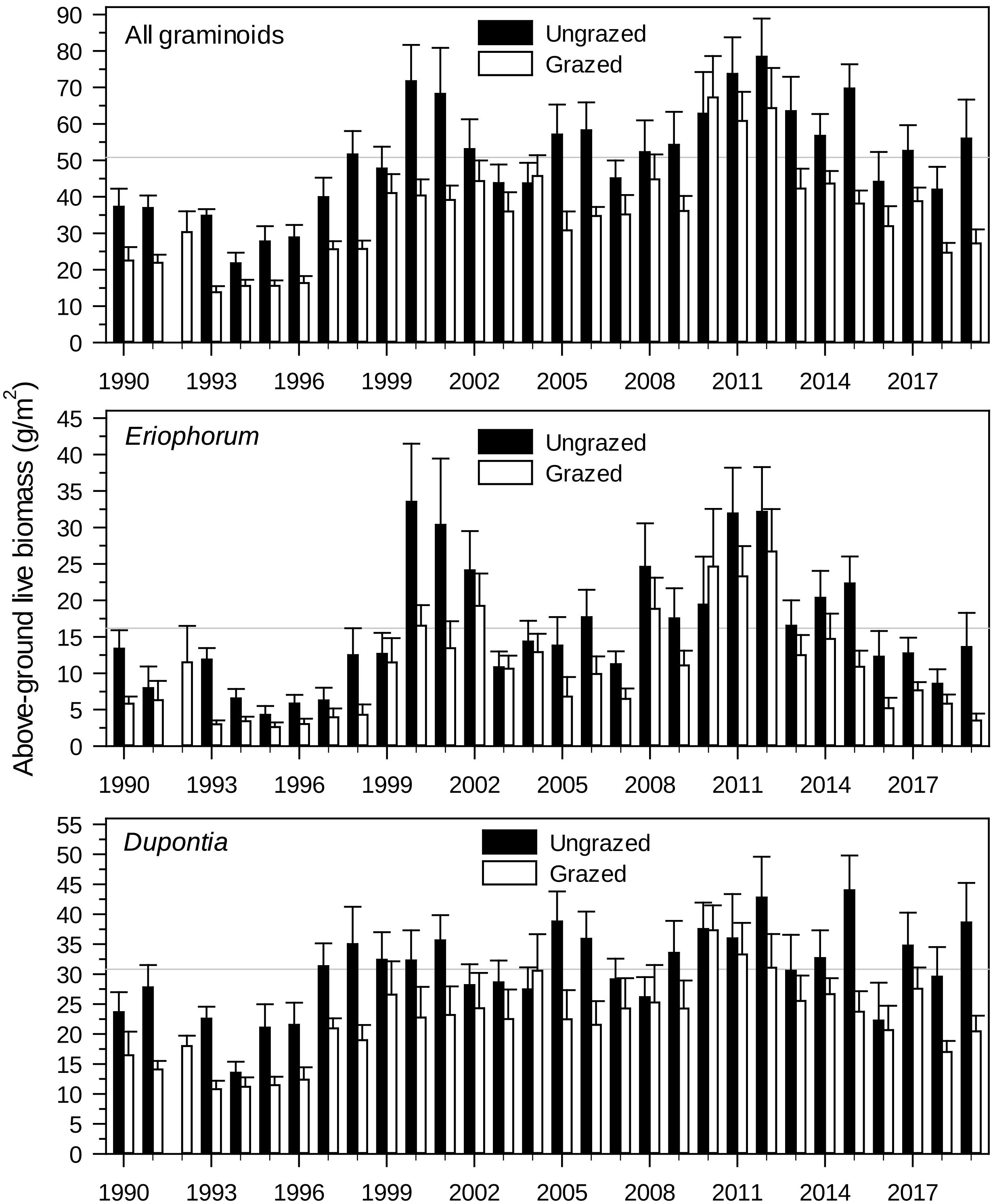

Figure 7. Live above-ground biomass (mean + SE, dry mass) of graminoids around 12 August in grazed and ungrazed wet meadows of the Qarlikturvik Valley, Bylot Island (*n* = 12, except in 2013, 2014 and 2016, *n* = 11). Total graminoids include *Eriophorum scheuchzeri*, *Dupontia fisheri* and *Carex aquatilis*. There is no data from ungrazed area in 1992. The solid gray line is the long-term average for ungrazed area.

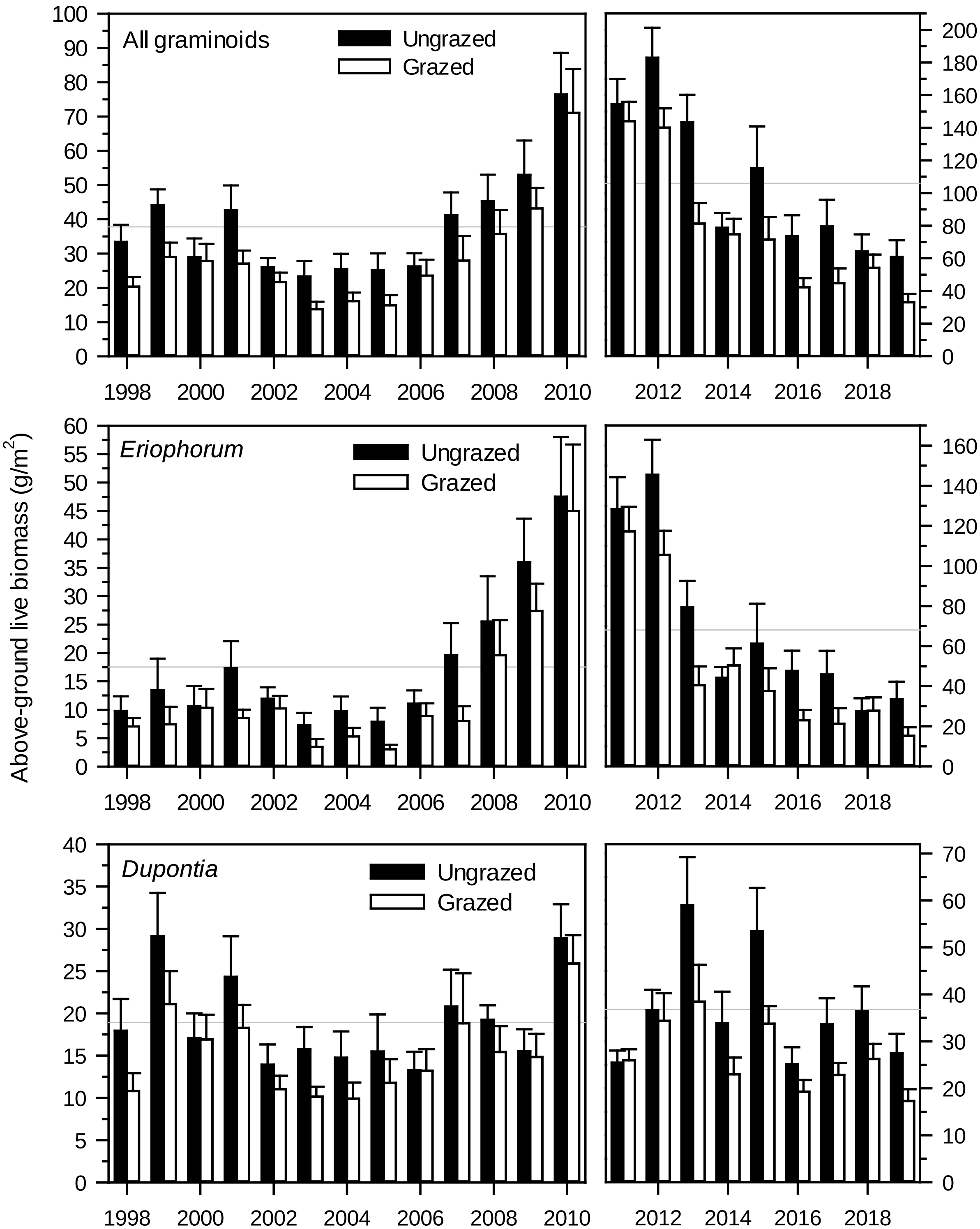

Figure 8. Live above-ground biomass (mean + SE, dry mass) of graminoids around 14 August in grazed and ungrazed wet meadows of the Camp 2 (goose colony), Bylot Island (n = 12, except in 2008 and 2014 n = 8, and 2012, 2013 and 2015 n = 10). Total graminoids include *Eriophorum scheuchzeri*, *Dupontia fisheri* and *Carex aquatilis*. Half of the exclosures had to be moved to a new site in 2011, which explains why the figure was split and the long-term average for ungrazed area (solid gray line) calculated separately before/after 2011.

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J.181. Weiser E.L., S.C. Brown, R.B. Lanctot, H.R. Gates, K. Abraham, R.L. Bentzen, J. Bêty et al. 2018. Life-history tradeoffs revealed by seasonal declines in reproductive traits of Arctic-breeding shorebirds. **Journal Avian Biology** 49:e01531.

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C.128. Fauchald, P., D. Ehrich, J. Schmidt, K. Klokov, F. S. I. Chapin, D. Berteaux & V. Hausner. 2012. The importance, management and status of harvested animals in the Arctic tundra ecosystems. *4th International Conference EcoSummit*, Columbus, OH.

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C.126. Fast, P.L.F., M. Doiron, G. Gauthier, J.A. Schmutz, D.C. Douglas, J. Madsen, J.Y. Takekawa, J. Yee & J. Bêty. 2012. Linking animal migration, spring weather and timing of breeding in an arctic herbivore. *International Polar Year Conference: From Knowledge to Action*. Montréal, QC.

C.125. McKinnon, L., C.A. Corkery, E. Bolduc, C. Juillet, J. Bêty & E. Nol. 2012. Assessing the vulnerability of Arctic-nesting shorebirds to climate induced changes in food resource peaks. *International Polar Year Conference: From Knowledge to Action*. Montréal, QC.

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C.123. Lai, S., D. Berteaux and J. Bêty 2012. Movement tactics and habitat selection of overwintering arctic foxes in the Canadian high Arctic. *International Polar Year Conference: From Knowledge to Action*. Montréal, QC.

C.122. Lamarre, J.-F., J. Bêty & G. Gauthier. 2012. Shorebird predation risk in the high-Arctic, do geese have a role to play? *International Polar Year Conference: From Knowledge to Action*. Montréal, QC.

C.121. Berteaux, D., G. Gauthier, J. Bêty, A. Franke & G. Gilchrist. 2012. Effects of climate change on the canadian arctic wildlife. *International Polar Year Conference: From Knowledge to Action*. Montréal, QC.

C.120. Therrien, J.-F., G. Gauthier & J. Bêty. 2011. Avian predators play a key role in population regulation and energy flux of the Arctic tundra food web. *Annual Meeting of the Raptor Research Foundation*, Duluth, MN.

C.119. Bêty, J. 2011. Sensitive Arctic birds under the spotlights: global change and recent discoveries. *Society of Canadian Ornithologists Annual Meeting*, Moncton, NB.

C.118. Legagneux, P., P. Fast, G. Gauthier & J. Bêty. 2011. Manipulating individual state during migration provides evidence for carry-over effects modulated by environmental conditions. *Society of Canadian Ornithologists Annual Meeting*, Moncton, NB.

C.117. Bêty, J. 2011. Ecology and evolution of arctic migrants: fundamental questions and recent results. *Royal Swedish Academy of Sciences and Wenner-Gren Foundations*, Sweden.

C.116. Gauthier, G. 2011. Lemmings: a keystone species of the tundra food web vulnerable to climate change. *6th Annual Meeting of the Canadian Society of Ecology and Evolution*, Banff, AB.

C.115. Tarroux, A., D. Berteaux & J. Bêty. 2011. The marine side of a terrestrial mammal: trophic niche and diet specialization of arctic foxes. *Estación Biológica de Doñana – CSIC*, Sevilla, Spain.

C.114. Gauthier, G. & M.-C. Cadieux. 2011. Goose-plant interactions on Bylot Island in the context of global warming. *Twelfth North American Arctic Goose Conference*, Portland, OR.

C.113. Legagneux, P., P. Fast, G. Gauthier & J. Bêty. 2011. Migratory connectivity in Greater Snow Geese: carry-over effects of a manipulation of spring body condition. *Twelfth North American Arctic Goose Conference*, Portland, OR.

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C.111. Doiron, M., G. Gauthier & E. Lévesque. 2011. Climate change and the ecological mismatch between Greater Snow Goose breeding and plant phenology. *Twelfth North American Arctic Goose Conference*, Portland, OR.

C.110. Desnoyers, M. & G. Gauthier. 2011. Travelling in greater snow goose flocks: do you know with whom you're travelling? *Twelfth North American Arctic Goose Conference*, Portland, OR.

C.109. Horrigan, E., R.L. Jefferies & G. Gauthier. 2011. Vegetation responses to simulated snow goose herbivory in two arctic ecosystems. *Twelfth North American Arctic Goose Conference*, Portland, OR.

C.108. Gauthier, G. & D. Berteaux. 2010. Is the tundra food web controlled by top predators? New evidence from the ArcticWOLVES project. *Seventh ArcticNet Scientific Meeting*, Ottawa, ON.

C.107. Bilodeau, F., G. Gauthier & D. Berteaux. 2010. Life under the snow: the effect of the snow cover on lemming population dynamics. *Seventh ArcticNet Scientific Meeting*, Ottawa, ON.

C.106. Chalifour, E., J. Bêty, M. Bélisle, J. Lefebvre & J.-F. Giroux. 2010. Molt migration of Greater Snow Geese. *Seventh ArcticNet Scientific Meeting*, Ottawa, ON.

C.105. Tarroux, A., D. Berteaux & J. Bêty. 2010. Surviving the arctic winter: insights into the foraging tactics of an arctic terrestrial predator. *Seventh ArcticNet Scientific Meeting*, Ottawa, ON.

C.104. Fast, P. 2010. Studies of migratory connectivity and nest choice in Arctic waterfowl. *Max Planck Institute for Ornithology*, Seewiesen, Germany.

C.103. Gauthier, G., J.-F. Therrien, J. Bêty, F. Doyle & D. Reid. 2010. Surprising migratory movements and site fidelity unraveled by satellite-tracking of snowy owls. *25th International Ornithological Conference*, Sao Paulo, Brazil.

C.102. Legagneux, P., G. Gauthier, D. Berteaux, J. Bêty, M.-C. Cadieux, G. Szor, F. Bilodeau, E. Bolduc, L. McKinnon, A. Tarroux, J.-F. Therrien, M.-A. Valiquette, L. Morissette & C.J. Krebs. 2010. Modeling temporal trophic dynamics of a terrestrial arctic ecosystem. *IPY Oslo Conference*, Oslo, Norway.

C.101. Doiron, M., G. Gauthier & E. Lévesque. 2010. Plant-herbivore interactions and climate change: the case of the Greater Snow Goose. *IPY Oslo Conference*, Oslo, Norway.

C.100. Legagneux, P., P. Fast, G. Gauthier & J. Bêty 2010. Effect of spring condition manipulation on reproductive success in the greater snow geese *Chen caerulescens*. *5th annual meeting of the Canadian Society of Ecology and Evolution*, Quebec, QC.

C.99. Therrien, J.-F., G. Gauthier & J. Bêty. 2010. The lemming buffet: is there anything left after owls and jaegers have eaten? *5th annual meeting of the Canadian Society of Ecology and Evolution*, Quebec, QC.

C.98. Desnoyers, M. & G. Gauthier. 2010. Le voyage organisé, un aspect inconnu du comportement grégaire de la grande oie des neiges *Chen caerulescens*. *5th annual meeting of the Canadian Society of Ecology and Evolution*, Quebec, QC.

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C.94. Reid, D., C.J. Krebs, G. Gauthier, A. Kenney, S. Gilbert, E. Hofer, D. Duchesne, M. Leung & F. Bilodeau. 2010. Snow depth and small mammal winter habitat choice: a tundra fencing experiment. *IPY Canada Early Results Workshop*, Ottawa, ON.

C.93. Lai, S., D. Berteaux & J. Bêty. 2009. From land to sea ice with the arctic fox, following the movements of a terrestrial mammal in the Canadian High Arctic. *Sixth ArcticNet Scientific Meeting*, Victoria, BC.

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C.91. Tarroux, A., D. Berteaux & J. Bêty. 2009. The marine side of a terrestrial mammal: trophic niche and diet specialization in arctic foxes. *Sixth ArcticNet Scientific Meeting*, Victoria, BC.

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C.88. Gauthier, G., C. Juillet, J. Bêty & M. Morrissette. 2009. Annual productivity in Greater Snow Geese: which fecundity parameter is the best predictor and why? *Meeting of the International Society of Ecological Modelling*, Quebec City, QC.

C.87. Legagneux, P., G. Gauthier & C.J. Krebs. 2009. Spatial and temporal trophic dynamics of terrestrial arctic ecosystems. *ECOPATH conference*, Vancouver, BC.

C.86. Gauthier, G. 2009. Impact of climate change on arctic terrestrial food webs: examples from the Bylot Island long term study. *Canadian Society of Ecology and Evolution Annual Meeting*, Halifax, NS.

C.85. Gauthier, G. & D. Berteaux. 2008. Arctic Wildlife Observatories Linking Vulnerable EcoSystems (ArcticWOLVES): A study of the impact of climate change on tundra food webs. *Arctic Change Conference*, Quebec City, QC.

C.84. Gauthier, G. & M.C. Cadieux. 2008. Impact of climate change on arctic terrestrial food webs: examples from the Bylot Island long term study. *Arctic Change Conference*, Quebec City, QC.

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C.81. Valiquette, M.A. & G. Gauthier. 2008. Numerical and functional responses of a generalist avian predator, the glaucous gull, to variations in lemming abundance in the Arctic. *Arctic Change Conference*, Quebec City, QC.

C.80. Juillet, C., M. Doiron, G. Gauthier & M.C. Cadieux. 2008. Importance of local and regional climatic effects on the reproduction of a migratory species, the Greater Snow Goose. *Arctic Change Conference*, Quebec City, QC.

C.79. Côté, G., R. Pienitz, G. Gauthier, D. Muir & B. Wolfe. 2008. Impacts of present-day and past animal populations on the nutrient and contamination status of freshwater lakes on Bylot Island, Nunavut (Canada). *Arctic Change Conference*, Quebec City, QC.

C.78. Pouliot, R., L. Rochefort, M. Marchand-Roy & G. Gauthier. 2008. Polygon fens and trophic interactions: 15 years of research on Bylot Island. 4th International Meeting on the Biology of Sphagnum, Juneau, Alaska.

C.77. Gauthier, G. & D. Berteaux. 2008. ArcticWOLVES: a study of the tundra food web. *International IPY conference on the Dynamics of Lemmings and Arctic foxes in the Circumpolar Tundra*, Salekhard, Russie.

C.76. Berteaux, D. & Gauthier, G. 2008. Dynamics of lemmings and arctic foxes on Bylot Island, Nunavut, Canada. *International IPY conference on the Dynamics of Lemmings and Arctic foxes in the Circumpolar Tundra*, Salekhard, Russie.

C.75. Duchesne, D., G. Gauthier & D. Berteaux. 2007. Characterization of the winter environment of lemmings in relation to the snow cover in the Arctic. *Fourth ArcticNet Scientific Meeting*, Collingwood, ON.

C.74. Doiron, M., G. Gauthier & E. Lévesque. 2007. Impacts of climate change on plant-herbivore interactions in the High Arctic. *Fourth ArcticNet Scientific Meeting*, Collingwood, ON.

C.73. Juillet, C., G. Gauthier, R. Pradel & Rémi Choquet. 2007. Use of mixture of information models to evaluate the effect of special conservation measures on survival in a hunted species, the Greater Snow Goose. *EURING-2007 meeting*, Otago, New Zealand.

C.72. Gauthier, G., K. Hobson & J. Bêty. 2006. Diet change inferred from stable-isotopes in spring-staging Greater Snow Geese. *XXIVth International Ornithological Congress*, Hamburg, Germany.

C.71. Gauthier, G. 2006. Application of capture-recapture methods to demographic analyses of bird populations: case studies with an emphasis on multistate models. Colloque *Capture 2006*, Université Laval, Québec, QC.

C.70. Dickey, M.-H. & G. Gauthier. 2005. Effect of climate variables on the phenology and reproductive success of Greater Snow Geese (*Chen caerulescens atlantica*). *Eleventh North American Arctic Goose Conference*, Reno, NV.

C.69. Lecomte, N., G. Gauthier, L. Bernatchez & J.-F. Giroux. 2005. Population structure of a Greater Snow Goose colony. *Eleventh North American Arctic Goose Conference*, Reno, NV.

C.68. Gauthier, G., A.M. Calvert & E.T. Reed. 2005. Impacts of special conservation measures on demographic parameters in Greater Snow Geese (*Chen caerulescens atlantica*). *Eleventh North American Arctic Goose Conference*, Reno, NV.

C.67. Mainguy, J., G. Gauthier, J.-F. Giroux & J. Bêty. 2005. Long distance brood movements in Greater Snow Geese: effects on goslings growth and survival. *Eleventh North American Arctic Goose Conference*, Reno, NV.

C.66. Ouellet, N., J. Larochelle & G. Gauthier. 2005. Effect of locomotion on growth in Greater Snow Goose goslings (*Chen caerulescens atlantica*). *Eleventh North American Arctic Goose Conference*, Reno, NV.

C.65. Lecomte, N., G. Gauthier & J.-F. Giroux. 2005. Habitat effects on nest predation risks: the case of the Greater Snow Goose. *Eleventh North American Arctic Goose Conference*, Reno, NV.

C.64. Audet, B., G. Gauthier & E. Lévesque. 2005. Feeding ecology of Greater Snow Goose (*Chen caerulescens atlantica*) goslings in upland tundra on Bylot Island, Nunavut. *Eleventh North American Arctic Goose Conference*, Reno, Nevada.

C.63. Bêty, J., J.-F. Giroux, & G. Gauthier. 2004 Individual variation in timing of migration: causes and reproductive consequences in greater snow geese. *122nd American Ornithologist Union Meeting*, Québec, Canada.

C.62. Calvert, A.M. & G. Gauthier. 2004. Exceptional conservation measures: how have they affected survival and hunting mortality in greater snow geese. *122nd American Ornithologist Union Meeting*, Québec, Canada.

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C.58. Giroux, J.-F., G. Gauthier, A. Béchet, M. Féret, J. Mainguy, J. Bêty & V. Lemoine. 2003. Controling overabundant bird populations: the case of the greater snow goose. Third International Wildlife Management Congress, 1-5 December 2003, Christchurch, New Zealand.

C.57. Gauthier, G. & J.D. Lebreton. 2003. Population models in Greater Snow Geese: a comparison of different approaches. *EURING-2003 meeting*, Radolfzell, Germany.

C.56. Reed, E., G. Gauthier & J.-F. Giroux. 2003. Effects of spring conditions on breeding propensity of greater snow goose females. *EURING-2003 meeting*, Radolfzell, Germany.

C.55. Calvert, A.M. & G. Gauthier. 2003. Applying band recovery models to an evaluation of the demographic impacts of exceptional conservation measures. *EURING-2003 meeting*, Radolfzell, Germany.

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C.52. Gauthier, G. 2002. Are Greater Snow Geese overabundant? A review of population Dynamics and management actions on this population in North America. *7th Annual Meeting of the Goose Specialist Group of Wetlands International*, El Rocio, Spain.

C.51. Gauthier, G., F. Fournier & J. Larochelle. 2002. The effect of environmental conditions on early growth in geese. *XXIIIrd International Ornithological Congress*, Beijing, China

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C.49. Bêty, J., G. Gauthier, E. Korpimäki & J.-F. Giroux. 2001. Shared predators and indirect trophic interactions: lemming cycles and arctic-nesting geese. *119th American Ornithologist Union Meeting*, Seattle, WA.

C.48. Bourguelat, G., G. Gauthier & R. Pradel. 2001. New analytical tools to study stopover length in birds : what can we learn from the greater snow goose example? *119th American Ornithologist Union Meeting*, Seattle, WA.

C.47. Gauthier, G. 2001. The effects of management actions on populations: greater snow goose. *Tenth North American Arctic Goose Conference*, Québec, QC.

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C.41. Righi, M. & G. Gauthier. 2001. Abundance and distribution of intestinal helminths in greater snow geese on the breeding colony, and during their fall and spring migration. *Tenth North American Arctic Goose Conference*, Québec, QC.

C.40. Renaud, M., G. Gauthier & J. Larochelle. 2001. Energetic cost of thermoregulation for greater snow goose goslings growing in a natural environment. *Tenth North American Arctic Goose Conference*, Québec, QC.

C.39. Féret M., G. Gauthier, J.-F. Giroux & K. Hobson. 2001. Impact of spring conservation hunt on nutrient storage of greater snow geese staging in Québec. *Tenth North American Arctic Goose Conference*, Québec, QC.

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C.37. Béchet, A. J.-F. Giroux & G. Gauthier. 2001. Impact of a spring hunt on the regional movements of staging greater snow geese. *Tenth North American Arctic Goose Conference*, Québec, QC.

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C.34. Duclos, I., E. Lévesque & L. Rochefort. 2001. Mesic habitats of the Greater Snow Goose (*Chen caerulescens atlantica*) on Bylot Island (Nunavut): characterization and feeding potential. *Tenth North American Arctic Goose Conference*, Québec, QC.

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C.30. Lévesque, E., C. Pineau, L. Rochefort & G. Gauthier. 1999. Combined influence of grazing and warming in a high arctic wet meadow. Abstract in *Plant response to climate change*, R.D. Hollister (ed), Proceedings from the *9th International Tundra Experiment Meeting,* East Lansing, MI.

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C.21. Reed, A. & G. Gauthier. 1997. Changes in demographic and physical parameters of greater snow geese during an extended population growth phase. *Symposium on Over-abundant goose population: an emerging challenge in wildlife conservation, Wildlife Society 4th annual conference,* Snowmass, Colorado.

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