MONITORING THE ENVIRONMENTAL AND ECOLOGICAL IMPACTS OF CLIMATE CHANGE ON BYLOT ISLAND, SIRMILIK NATIONAL PARK

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by

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INTRODUCTION

Global climatic change caused in part by the greenhouse gases released due to human activities is a major challenge faced by the earth ecosystems in this century. However, nowhere else on earth are these effects more threatening than in the Arctic. Indeed, all models predict that warming trends will be strongest in the Polar Regions as Arctic temperatures should increase by as much as 4° to 7°C over the course of the XXIst century (ACIA 2004). Precipitation is also expected to increase from 10 to 20%, as well as daily and seasonal variability in both temperature and precipitation, leading to more frequent climatic extremes. Recent analyses indicate that temperatures in the Arctic have been increasing steadily for the last three decades, and the extent and thickness of sea ice has been reduced considerably (Moritz et al. 2002, ACIA 2004).

Several long-term studies in different parts of the globe have detected ecological changes due to climate warming, such as alterations in geographical and breeding ranges, flowering dates, breeding dates, and migration schedules (reviewed by McCarty 2001, ACIA 2004, Berteaux et al. 2004). Impacts of climatic changes on arctic ecosystems are expected to be particularly strong because community structure is increasingly dominated by abiotic factors as we move closer to the poles and the climate becomes harsher (Hansell et al. 1998). Disruption of close ecological linkages, such as trophic interactions among plants-herbivores and herbivores-predators, will affect a significant proportion of the species assemblages in these depauperate communities (Gauthier et al. 2004). Thus, the simple ecological communities of the arctic may be at great risk.

Yet, evidences of these changes and of their impacts on biological communities are still scarce in the Arctic, mainly because few sites have adequate long-term data sets to address these questions. Our ongoing, long-term ecological research program on Bylot Island, Sirmilik National Park, Nunavut has been running for 18 years and has become one of the longest, most comprehensive, and rigorous long-term biological monitoring program in Nunavut. We have been monitoring the abundance and reproduction of several key species of birds, mammals, and plants. In addition, we have been continuously recording the most significant climatic variables through a network of automated weather stations. Hence, this program offers an exceptional opportunity to fill important knowledge gaps on climate/ecosystem status and may help to improve future ecological monitoring programs at other sites in the Arctic.

OBJECTIVES

The overall aim of our project is to measure changes occurring in Arctic ecosystems, analyse temporal trends, and evaluate to what extent these changes are driven by climate warming. This is achieved by continuing and expanding for the period 2004-2008 the climatic and ecological monitoring already in place on Bylot Island, and involving local communities into our research activities. Our specific objectives during that period are as follows:

1) Continue the climate monitoring of Bylot Island and examine temporal trends.
2) Continue the monitoring of breeding activities of key bird species and expand it to shorebirds and avian predators.
3) Continue the monitoring of lemming populations.
4) Continue the monitoring of the breeding activities of Arctic and Red Foxes.
5) Continue the monitoring of plant production in wetland communities and expand it to plant phenology and goose grazing impact.
6) Expand the monitoring of goose grazing impact to mesic communities.
7) Develop an Inuit Knowledge Component to our monitoring program in order to get a more complete understanding of the ecosystem and of the ecological impacts of climate change.
8) Hold an annual community workshop in Pond Inlet to discuss the project findings and future work.
9) Present study results to high school students in Pond Inlet.
10) Maintain the project English-French-Inuktitut web site.
11) Hire and train individuals from local communities.

METHODS

STUDY AREA

All field work is conducted on the south plain of Bylot Island at the northern tip of Baffin Island (Fig. 1). The island is a Migratory Bird Sanctuary and is also included in the Sirmilik National Park. Our activities are conducted primarily at two sites on the island, the Qarlikturvik Valley (73° 08' N; 80° 00' W) and the main goose nesting colony (72° 53' N, 79° 55' W; Fig. 1). At both sites, lowlands are covered by a mixture of wetlands and mesic tundra, and uplands are largely dominated by mesic tundra (Gagnon et al. 2004).

CLIMATIC DATA

We have 7 automated environmental monitoring stations at our study site. Our network includes 3 full climatic stations that record data on an hourly basis, year-round. One is in operation since 1994 (elevation: 20 m ASL), another one since 2001 (340m ASL) and the most recent one since 2004 (21 m ASL). The two oldest stations are 3-m high towers that record air temperature and humidity (at 2 m), soil temperature (at 2, 5 and 10 cm), wind speed and direction (at 3 m), and snow depth. The newest one is a 10-m meteorological tower that hosts more recording instruments and over a greater height range above the ground. In compliance with recognized standards, we record air temperature (at 5 m), wind speed and direction (at 10 m), full solar radiation (i.e. far infrared, photosynthetic active radiation, albedo, net solar radiation, and UV-B radiation), barometric pressure, soil temperature (at 5 and 10 cm; two sites each), snow depth and air humidity. A fourth station monitors ground surface temperature (at 2 cm) at five paired sites (each pair has a site protected from goose grazing by an exclosure and a nearby site exposed to grazing). Finally, three additional stations record permafrost temperature at various depths down to 3 m (two sites) or 11 m (one site). All automated stations were visited during the summer 2006 to download data and were found to be operating normally. A few damaged sensors (especially those recording ground temperatures) were replaced.

Daily precipitation is recorded manually during the summer (1 June to 20 August) using a pluviometer. Snowmelt is monitored from 1 June until snow disappearance using 2 methods: 1) by measuring snow depth at 50 stations along two 250-m transects at 2-day intervals and 2) by visually estimating the proportion of snow cover on the study area every 2-3 days.

BIOLOGICAL DATA

Birds

Greater Snow Geese.— We monitor the reproduction of Greater Snow Geese (*Chen caerulescens atlantica*) annually on Bylot Island since 1989. Goose nests are searched extensively in the Qarlikturvik Valley and at the main goose nesting colony where several thousands geese nest every year. All nests monitored are positioned with a GPS receiver. Each nest, are visited several times during the nesting period. On every visit we determine the number of eggs and/or goslings (dead or alive) and from these data we are able to determine the following parameters: total clutch laid (total number of egg laid by the female during nesting), clutch size at hatch, number of goslings leaving nest, laying and hatching dates, and nesting success.

Avian predators. — We systematically monitor the reproduction of Snowy Owls (*Nyctea scandiaca*) since 1993, and of jaegers (*Stercorarius* spp.) and Glaucous Gulls (*Larus hyperboreus*) since 2004 (before then, data on gulls and jaegers were taken opportunistically). Every year, we search systematically for nests of these species in our two study areas (Qarlikturvik Valley and the main goose nesting colony). The position of all nests found is recorded with a GPS receiver and nests are revisited periodically to determine laying and hatching dates, total clutch laid, and nesting success.

Other bird species. — We have been monitoring the reproductive activity of Lapland Longspurs (*Calcarius lapponicus*) since 1995. Longspur nests are found in the Qarlikturvik Valley only while walking throughout the study area for other activities, often when females are flushed from their nest. Starting in 2005, systematic searches of shorebirds nests have also been conducted in the Qarlikturvik Valley. Species include White-rumped Sandpiper (*Calidris fuscicollis*), Baird's Sandpiper (*Calidris bairdii*), American Golden Plover (*Pluvialis dominica*), Black-bellied Plover (*Pluvialis squatarola*), Common Ringed Plover (*Charadrius hiaticula*), Red Phalarope (*Phalaropus fulicarius*), Purple Sandpiper (*Caladris maritime*), Pectoral Sandpiper (*Calidris melanotos*), Buff-breasted Sandpiper (*Tryngites subruficollis*) and Ruddy Turnstone (*Arenaria interpres*). The position of all nests found is recorded with a GPS receiver and nests are revisited periodically to determine laying and hatching dates, total clutch laid, and nesting success. Since 1996, information on the reproductive activity of other bird species is also collected opportunistically, mostly for Sandhill Cranes (*Grus canadensis*), King Eiders (*Somateria spectabilis*) and Long-tailed Ducks (*Clangula hyemalis*).

Mammals

Lemmings.— We monitor the populations of Collared (*Dicrostonyx groenlandicus*) and Brown Lemmings (*Lemmus sibiricus*) using two techniques: deadly trapping, which has been conducted at two sites since 1994, and live trapping, a new sampling program that we developed in 2004. The deadly trapping monitoring takes place in July and follows the protocol of the small mammal survey coordinated across the Northwest Territories and Nunavut by the Northwest Territories Renewable Resources office in Yellowknife (Shank 1993). This trapping is carried out in two study plots of the Qarlikturvik Valley (one in wetlands, one in mesic tundra) since 1994, and at a third study plot in mixed wetland/mesic tundra at the main goose nesting colony since 1997. We use Museum Special® traps baited with peanut butter and rolled oats. At each site, we use 50 traps set at 10-m intervals along two parallel transect lines 100 m apart (25 traps/transect) and left open for a period of 10 days for a total of ~500 trap-nights (50 traps × 10 nights) per plot. Traps are checked daily; all lemmings caught are identified at the species and sprung traps are reset.

Our sampling program based on live-trapping of lemmings uses two permanent grids laid out in the Qarlikturvik Valley (one in wetlands and one in mesic tundra). 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 use Longworth® traps baited with apples and set at each grid intersection every 30-m. We trapped during four 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).

Arctic and Red Foxes.— We monitor the breeding activity of Arctic (*Alopex lagopus*) and Red Foxes (*Vulpes vulpes*) at dens annually since 1993. Until 2002, den monitoring only occurred in the Qarlikturvik Valley and the vicinity of the main goose nesting colony (about 100 km^2). Dens were found opportunistically and their position recorded with a GPS receiver. The number of dens found thus gradually increased from 1993 to 2002. We have been expanding the covered area since 2003 and in 2006 it covered about 475 km^2 where we conduct a systematic survey of fox dens, which considerably increased the number of known dens. All dens are visited at least once in June or early July and any signs of fox activity is noted (e.g. fresh digging, new hairs, fresh prey). Dens showing signs of activity are re-visited later in the summer to determine the presence of a litter and the number of pups in each litter. Litter size data are the minimum number of pups observed at dens, which may sometimes be lower than the true number of pups present. All observations of adults near dens are also noted, and the species of fox identified.

Plant monitoring

Plant production and goose grazing impact in wetland communities.— We monitor the annual plant production in wetlands and the impact of goose grazing at three sites on Bylot Island (see Fig. 1): the Qarlikturvik Valley (monitored since 1990), the main goose nesting colony (monitored since 1998), and north of Pointe Dufour (monitored since 1998). At each site, 12 exclosures (1 × 1 m fenced areas built with chicken wire to keep geese off plots) are installed in late June. At the end of the plant-growing season (i.e. mid-August), we sample the vegetation inside and outside the exclosures (i.e. ungrazed and grazed areas, respectively). All live above-ground plant biomass is cut, sorted out into sedges (*Eriophorum scheuchzeri* or *Carex aquatilis*), grasses (mostly *Dupontia fisheri*) and forbs, dried, and weighed. Above-ground biomass of vascular plants includes all green material and white basal stems buried in mosses. Live above-ground biomass in mid-August is a good measure of annual graminoid production (Gauthier et al. 1995).

Plant phenology in wetland communities. — In 2005, we expanded our monitoring to the plant phenology of *C. aquatilis*, *E. scheuchzeri* and *D. fisheri* in the Qarlikturvik Valley. Inside each exclosure, a permanent quadrat of 25 × 25 cm was delimited and every two weeks the number of shoots of each species was determined as well as their phenological stages, i.e. green leaves only, buds emergence, stigmas visible (*C. aquatilis* only), anthers visible, yellowing leaves (*C. aquatilis* only), fruits formed (*E. scheuchzeri* and *D. Fisheri* only), seeds dispersal. In 2006, we were able to start our monitoring earlier than last year, which enable us to add another sampling period (i.e. five periods instead of four in 2005).

Grazing impact in mesic communities.— In 2002 we established an experimental set-up of long-term exclosures in two dominant mesic habitats used by geese (mesic meadows on the hills and mesic polygons in the lowlands; see Fig. 1). This experiment includes, in each community, three treatments: goose exclosure (3 × 2 m surrounded by chicken wire 0.45 m high, 2.5-cm mesh), goose+lemming exclosure (3 × 2 m surrounded by welded wire 0.45 m high inserted 0.15 m into the ground, 1.25-cm mesh) and control (unfenced plots receiving normal grazing pressure) in four replicated blocks (each with three groups of exclosures and a control) for a total of 24 groups of exclosures.

In 2003, 2004 and 2005, we monitored the grazing impact in mesic habitat using this experimental set up. To quantify the plants grazed by geese and lemmings, each treatment (see above) was sampled with two marked contiguous 70 × 70 cm quadrats early (prior to massive goose arrival in the valley) and late in season (mid-August). All inflorescences (and the phenological stage) and marks of grazing and/or grubbing (mostly on leaves and shoots) were counted. It was possible to distinguish and exclude grazing by invertebrates (mostly insects). To assess use by geese, permanent 1 × 20 m feces transects were marked and the number of feces were counted at each visit (early and late summer). After three years of sampling grazing marks, the long term exclosure experiment in the mesic habitats was not sampled in 2006 to minimize disturbance. The exclosures were simply visited and repaired where necessary. We plan to sample vegetation changes in 2008.

INUIT TRADITIONAL ECOLOGICAL KNOWLEDGE

In spring and summer 2006, we were in the second phase of the Inuit Traditional Ecological Knowledge (TEK) gathering, with the following goals: 1) organise and participate to an Elder-Youth camp and 2) verify and investigate more deeply the TEK collected in 2005 using semi-directives interviews. In order to fulfill these goals, MSc student Catherine Gagnon resided in Pond Inlet from May to July 2006.

Since the beginning of the Inuit TEK project, elders and hunters who participated to the knowledge gathering expressed their desire that the knowledge collected be transmitted to youth of the community. Therefore, we came with the idea of organising an Elder-Youth Camp that would serve that purpose, as well as provide an occasion for meaningful exchanges between elders, youth and scientists. Following this idea, we submitted the project to the community, which expressed great support. We applied for funding to Parks Canada, Polar Continental Shelf Project and the Department of Culture, Language, Elders and Youth (government of Nunavut) to help cover the camp expenses (e.g. translator fees, honoraria for participating elders and hunters, transportation, food, gas, oil). In May 2006, once funding was secured, Catherine Gagnon met with the Pond Inlet Elder’s committee to select the camp participants (elders and youth). Then she met with the selected participants and together they organised the final details of the camp: activities, transportation, location and food.

From May to June 2006, Catherine Gagnon also hired a local research assistant to help her verify parts of the 2005 interviews that were unclear. They also validated the preliminary interpretation of results and insured that Inuktitut names of places were accurate. When further explanations were required, they contacted the interviewees and conducted more interviews and consulted elders. In June, focus groups were organised to clarify and discuss our interpretations of TEK collected.

In fall and winter 2006-2007, we coded all segments of the transcripts according to the topic they covered (e.g. arctic fox denning areas, geese nesting areas, etc.). Using a geographic information system (GIS) software, we digitalised and georeferenced all the spatial information in order to produce comprehensive maps according to topics and/or informant.

PRESENTATIONS AND COMMUNITY WORKSHOP

We organized a full day workshop on ecological monitoring on Bylot Island with representatives from the community of Pond Inlet on 16 January 2007. Invited representatives were from the Joint Park Management Committee (JPMC Pond Inlet members), the Hamlet of Pond Inlet, the Mittimatalik Hunters and Trappers Organization (HTO), the Government of Nunavut, the Nattinak Center of Pond Inlet, the Elders of Pond Inlet, the Inuit Knowledge Working Group of Pond Inlet, the Parks Canada Office (Pond Inlet an Iqaluit), the Wildlife Office and the RCMP. The workshop was organized by Joël Bêty, with support from the local Parks Canada Office, and held in the conference room of the Nattinak Visitor Centre, Pond Inlet. One researcher (Joël Bêty) and one student (Ludovic Jolicoeur) from a southern university (Université du Québec à Rimouski) attended the meeting. The workshop was followed by an evening public presentation (16 January) at the Nattinak Center, Pond Inlet. Everybody from the community was invited to attend the public meeting through announcements made on the local radio. Simultaneous Inuktitut/English translation was available during the workshops and public meeting. On the morning and afternoon of 17 January, Joël Bêty and Ludovic Jolicoeur gave talks to the students of the Pond Inlet Nassivik High School. The school principal organized the schedule of these talks.

RESULTS

CLIMATIC DATA

The data retrieved from our automated environmental stations in 2006 spanned the period from summer 2005 to summer 2006. All data were compiled, validated (e.g. missing or erroneous values were excluded), and archived. We present here an overview of the most important climatic variables during the last year, and an update of long-term trends.

Air temperature

The year 2005 (the last year for which we have a complete record) was the third warmest year of the past 11 years on Bylot Island (mean annual temperature: -14.0°C, which is 0.5°C above the long-term average). However, there is no detectable trend yet in annual air temperature (Fig. 2). Seasonal temperatures since fall 2005 have been above average. There was no trend observed in temperature for any of the seasons at Bylot Island (Fig. 3). The temperature during the period of egg-laying of Greater Snow Geese (i.e. 1-15 June) was relatively cold with an average temperature of 0.97°C (0.12°C below the long-term average for this period; Fig. 4) while the second part of June (16-30 June) was warmer with an average temperature of 4.05°C (0.03°C above the long-term average for this period). The number of thawing degree-days (TDD) was above the long-term average in 2004-2005, both on an annual and seasonal basis (Fig. 5).

Snow cover and precipitations

The snow pack in spring 2006 was near normal with an average snow depth of 28.8 cm on 1 June compared to a long-term average of 31.3 cm. Snow depth varied greatly among years, but no trends were detected (Fig. 6). The percentage of snow cover recorded in the lowlands of the Qarlikturvik Valley on 5 June was 70%, slightly above the long-term average. Snow cover varied similarly to snow depth, with no evidence of a temporal trend (Fig. 7). Despite the thinner snow pack in 2006 compared to 2005, snow-melt was similar in both years (Fig. 8). Again, there were large inter-annual differences in the speed of snowmelt, and no temporal trend was found.

Rainfall received during the summer 2006 on Bylot Island was close to normal, with 95 mm of rainfall compared to a long-term average of 97 mm. Although we found no evidence of a temporal trend in total summer rainfall, rainfall during the month of July showed a positive temporal trend, with an increase of 41.4 mm of rain over the last 10 years (Fig. 9).

Wind speed

The long-term average of the annual wind speed on Bylot Island is 1.9 m s^{-1} (Fig. 10). Fall 2005, winter 2005-2006 and spring 2006 wind speeds were near average while summer 2005 was below average. Summer wind speed showed a weak negative temporal trend, with a decrease of 0.4 m s^{-1} in wind speeds over the last 10 years (Fig. 11).

BIOLOGICAL DATA

Birds

Greater Snow Geese.— Overall, the median date that the first egg was laid in goose nests (i.e. egg-laying date) in 2006 was 14 June (n = 260), which is later than the long-term average (12 June). Mean egg-laying date showed relatively large inter-annual variations (from 6 to 20 June but analyses revealed no temporal trend in egg-laying dates; Fig. 12A). Because incubation has a set time length in birds (23-24 days in snow geese), egg hatching dates followed annual trends similar to laying dates. In 2006, hatching date was 10 July (n = 119), which is slightly later than the long-term average (9 July). There was no detectable long-term trend in hatching date (Fig. 12B).

The mean number of eggs per nest (i.e. total clutch laid) was 3.68 ± 0.09 eggs (n = 176) in 2006, very close to the long-term average (3.70; Fig. 13). We did not find any temporal trends in clutch size. Nesting success (proportion of nests hatching at least one egg) in 2006 was low (42%, n = 279) and lower than the long-term average (63%; Fig. 14). We did not find any temporal trends in nesting success.

Avian predators.— Snowy Owls only nest in peak lemming years, which occur every 3-4 years on Bylot Island (see below). Owl nests were thus previously found in 1989, 1993, 1996, 2000 and 2004. In 2006, no Snowy Owls were found nesting in our study area.

In 2006, we found 12 nests of Glaucous Gulls in the Qarlikturvik Valley and 4 at the goose colony, 3 nests of Long-tailed Jaegers at each study site and 1 nest of Parasitic Jaeger at the goose colony (Table 1). Mean egg laying date of gull nests was 18 June, mean hatching date was 17 July and mean clutch size was 2.1 (data were insufficient for jaegers). Nesting success of gulls was 38% while all jaeger nests were predated. This is the lowest nesting success ever recorded for avian predators.

Shorebirds.— Our monitoring of shorebird species was successful again in 2006. Among the ten species monitored, six of them were found nesting, mostly in the Qarlikturvik Valley

(Table 2). The most abundant shorebirds were the White-rumped Sandpiper (20 nests) and the Baird's Sandpiper (33 nests). American Golden Plovers (6 nests), Pectoral Sandpipers (2 nests), Common Ringed Plovers (1 nest), Red Phalaropes (1 nest), Black-bellied Plovers, Purple Sandpipers, Buff-breasted Sandpiper and Ruddy Turnstone were also observed on the island during the summer. Clutch size of all shorebird nests monitored was 4.0 eggs. Mean laying and hatching dates were between 11 and 15 June, and 4 and 13 July, respectively (Table 2). Overall, American Golden Plovers had a nesting success similar to last year (20% compared to 19% in 2005) but White-rumped Sandpipers and Baird's Sandpipers had a very low nesting success (1% and 2%, respectively compared to 11% and 25% in 2005).

***Lapland Longspurs and other bird species*.—** In 2006, we found a record number of Lapland Longspur nests (89, Table 3). Large annual variations in number of nests found in part reflect variations in sampling effort, which increased in the past 2 years. Egg-laying and hatching dates of longspurs in 2006 were 18 June (n = 39; long-term average: 18 June) and 6 July (n = 15; long-term average: 3 July), respectively. No temporal trends were detected for both laying and hatching dates. The clutch size was 5.1 ± 0.1 eggs (n = 71), slightly below the long-term average (5.3; Table 3) and no temporal trend was detected. Nesting success was very low (9%, n = 79) and below the long-term average (48%).

We also found 3 nests of Sandhill Cranes, 3 of King Eiders and 4 of Long-tailed Ducks in 2006 (Table 3).

Mammals

***Lemmings*.—** As commonly observed in the Arctic, lemming populations have been going through marked cycles of abundance on Bylot Island. Our longest record in the Qarlikturvik Valley indicated that cycles lasted 3 to 4 years, with peak abundance occurring in 1993, 1996, 2000 and 2004 (Fig. 15). Trapping conducted at the main goose colony suggested that the two sites generally fluctuated either in synchrony or possibly with a 1-year time lag in the main goose colony for the peak years of lemming abundance (Fig. 15).

The relative abundance of the two lemming species generally differed between the two sites (Fig. 16). In the Qarlikturvik Valley, the site with the highest density of wetlands, Brown Lemmings were typically more abundant than Collared, whereas at the main goose colony, where mesic tundra is most abundant, the reverse was true, except during the 2001 lemming peak. In 2006, abundance of Brown Lemmings was very low at both sites whereas the one of Collared

Lemmings was low at both sites. The large annual fluctuations in lemming abundance precluded the examination of long-term trend in abundance.

For the third year of our live-trapping monitoring program for lemming populations, we captured a total of 47 lemming individuals, of which 25 were recaptured more than once (Table 4). 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 14 Brown Lemmings and 10 Collared Lemmings in wetlands, and 12 Brown Lemmings and 11 Collared Lemmings in mesic tundra. This provides further evidence that lemming abundance was very low in 2006.

Arctic and Red Foxes.— In 2006, we visited 97 dens during the summer and we detected signs of activity (fresh digging and/or footprints) at 29 of them. The breeding activity of foxes was low as we found only 2 litters (2% of known denning sites with a different litter) of Arctic Foxes and none of Red Foxes. This level of use is lower than last year (9%; Fig. 17) but typical of the proportion of fox dens used in years of low lemming abundance (~5%). Minimum litter sizes were 1 and 5 (mean of 3.0 pups). This value is lower than the long-term average litter size (Arctic Fox: 6.4 pups; Table 5). No temporal trend was detected in the litter size of Arctic Foxes since 1996 (not enough data are available for a similar analysis in Red Fox). No temporal trend was detected in the percentage of dens used by Arctic Foxes since 1996 ($P = 0.111$, Fig. 17; number of dens monitored before this date is too small for statistical analysis).

Plant monitoring

Plant production in wetlands.— Wetland communities on Bylot Island are largely dominated by graminoid plants (i.e. >90 % by sedges and grasses), and thus only these plants are considered here. Among the three sites where wetland plants are monitored on Bylot Island, the longest time series comes from the Qarlikturvik Valley, a major brood-rearing site for geese (Fig. 1). Above-ground biomass of graminoid plants in the valley reached 58.3 ± 7.6 g m^{-2} in ungrazed areas in mid-August 2006, which is much higher than the long-term average (45.2 g m^{-2}) for the second year in a row (Fig. 18). *Dupontia fisheri* accounted for 62 % of the graminoid biomass, i.e. 35.9 ± 4.6 g m^{-2} in ungrazed areas (long-term average: 28.5 g m^{-2}) while *Eriophorum scheuchzeri* represented 30% with a production of 17.7 ± 3.8 g m^{-2} in ungrazed plots (long-term average: 14.1 g m^{-2}). Since 1990, the biomasses of all graminoids, *Eriophorum* and *Dupontia* have showed significant increasing trends in the Qarlikturvik Valley. Average production of all graminoid plants has increased by 1.9 g m^{-2} yr^{-1} (R^2 = 0.120, df = 190, *P* < 0.001), *Eriophorum* by 0.8 g m^{-2} yr^{-1} (R^2 = 0.053, df = 190, *P* = 0.001) and *Dupontia* by 0.9 g m^{-2} yr^{-1} (R^2 = 0.081, df = 190, *P* < 0.001) since 1990.

Wetland plant monitoring at the two other sites (main goose nesting colony and Pointe Dufour) has been conducted since 1998 only. The above-ground biomass of graminoids at the end of the summer was 26.2 ± 3.9 g m^{-2} in ungrazed areas of the main goose nesting colony, which is lower than the long-term average (30.6 g m^{-2}; Fig. 19). Graminoid biomass was also dominated by *Dupontia fisheri*, with an annual production of 13.3 ± 2.2 g m^{-2} (i.e. 51% of the total biomass, long-term average: 18.0 g m^{-2}) followed by *Eriophorum scheuchzeri* with 11.1 ± 2.3 g m^{-2} (i.e. 42% of the total biomass, long-term average: 11.0 g m^{-2}). Since 1998, average production of graminoids plants has decreased significantly at the main goose colony. We observed a decrease of 1.9 g m^{-2} $yr^{-1}$for all graminoids (R^2 = 0.076, df = 107, *P* = 0.004) and 1.2 g m^{-2} yr^{-1} for *Dupontia* (R^2 = 0.063, df = 107, *P* = 0.009). No significant trends were observed for *Eriophorum* (*P* = 0.360). Graminoid plants production at Pointe Dufour was 56.5 ± 9.3 g m^{-2} at the end of summer 2006 which is above the long-term average recorded since 1998 (50.3 g m^{-2}; Fig. 20). *Dupontia* represented 68% of the graminoid biomass, i.e. 38.5 ± 10.4 g m^{-2} (long-term average: 22.9 g m^{-2}) while *Eriophorum* accounted for 17%, i.e. 9.8 ± 3.4 g m^{-2} (long-term average: 13.1 g m^{-2}). We found a significant temporal trend in *Dupontia*'s annual production at Pointe Dufour with an increase of 2.4 g m^{-2} yr^{-1} (R^2 = 0.080, df = 80, *P* = 0.011) but no temporal trends were detected in the total annual plant production (i.e. all graminoids, *P* = 0.605) or in *Eriophorum*'s annual production (*P* = 0.530). Over the period 1998-2006 when sampling was carried out at the 3 sites, we note that plant production was comparable in the Qarlikturvik Valley (55.0 g m^{-2}) and Pointe Dufour (50.3 g m^{-2}) but lower at the main goose colony (30.6 g m^{-2}).

Goose grazing impact in wetlands. — Goose grazing was relatively high in the wet meadows of the Qarlikturvik Valley where geese removed 40% of the above-ground biomass by mid-August 2006 (Fig. 18). Geese removed 44% of the total annual production of *Eriophorum* and 40% of *Dupontia*. We found significant temporal trends in goose grazing impact in the Qarlikturvik Valley. Since 1990, grazing impact by geese on total graminoid plants decreased by 1.0% yr^{-1} (R^2 = 0.042, df = 190, *P* = 0.004), 1.0% yr^{-1} on *Eriophorum* (R^2 = 0.020, df = 188, *P* = 0.054) and 0.8% yr^{-1} on *Dupontia* (R^2 = 0.026, df = 190, *P* = 0.027).

At the main colony, the grazing impact was much lower with only 10% of the graminoid biomass (19% of *Eriophorum* and <1% of *Dupontia*) removed by geese (Fig. 19). Since 1998, goose impact on *Eriophorum* has increased by 3.1% yr^{-1} at the goose colony ($R^2 = 0.056$, df = 100, $P = 0.017$) but there was no temporal trends on total graminoids ($P = 0.918$) and *Dupontia* ($P = 0.318$).

Similarly, at Pointe Dufour geese removed 19% of the total biomass (11% of *Eriophorum* and 17% of *Dupontia*; Fig. 20). From 1998 to 2006, the proportion of total biomass removed by geese at Pointe Dufour increased by 2.5% yr^{-1} ($R^2 = 0.094$, df = 80, $P = 0.005$). This was mainly due to an increase of grazing impact on *Eriophorum* ($R^2 = 0.123$, df = 76, $P = 0.002$). No temporal trends were detected for *Dupontia* ($P = 0.294$).

***Plant phenology in wetlands.* —** This year was the second season of our new sampling program for the phenology of graminoid plants in wetlands. *E. scheuchzeri* was the first to start their reproductive cycle with buds emerging around 6 to 19 July, whereas most of *D. fisheri* buds appeared only in late July (Fig. 21). Contrary to last year, flowering parts (i.e. anthers or male spikes) of both species were not recorded because, by 1 August, they were at the fruiting stage. This suggests that the flowering stage was very short-lived (<2 weeks) this year and occurred between 19 July and 1 August. *E. scheuchzeri* and *D. fisheri* passed from the fruiting stage in early August to seed dispersal in mid-August. Senescence (i.e. yellowing of leaves) of both species had not yet started in mid-August, when we left the study site. On the contrary *C. aquatilis* did not seem to have produced any buds in 2006. Half of its shoots had started their senescence in early August while shoots were still showing male spikes (i.e. anthers) at that same period in 2005.

INUIT TRADITIONAL ECOLOGICAL KNOWLEDGE

The Elder-Youth Camp was highly successful, with a total of 17 participants, of which five were elders and/or hunters, ten young people, one interpreter, and one researcher (Catherine Gagnon). Dominique Berteaux also visited the camp during the week. The camp lasted seven days (from June 10 to June 17) and was located at a site called Ikpiugalik, on Bylot Island. Activities performed during the camp included goose hunting and traditional egg picking, story telling and teaching (e.g. land survival skill, old fox trapping techniques). On 13 June, all participating young, elders and hunters visited one of the researcher camps on Bylot Island. During that visit, researchers explained to Elders, hunters and youg the goal of their studies as well as what type of field work is involved. Participants had the chance to become acquainted with some field equipment and research techniques. Joël Bêty and Dominique Berteaux, two of the principal investigators, made small presentations about their work. Later during the week, all participants went seal hunting and learned how to prepare seal meat to be cached. On the last day of the camp, helicopter hours granted by the Continental Shelf Project allowed camp participants, as well as Elder Cornelius Nutaraq (brought from town by helicopter) and Dominique Berteaux, to visit the archaeological site of Nunguvik, located on Baffin Island. The presence of M. Nutaraq was most appreciated since he assisted archaeological diggings in Nunguvik during the 1970s and 1980s and was able to provide valuable information about the site. The Elder-Youth Camp was also reported as a special feature article in the Nunatsiaq News of 7 July 2006 (see Appendix 1). We are also finishing editing a short movie about the camp that will be made available to the community. The DVD will include small clips pertaining to particular subjects such as egg picking, storytelling, preparing seal meat for caches, sowing goose wings and the visit to Nunguvik.

The focus groups held in June 2006 was useful to clarify the timing of arrival of Red Foxes in the North Baffin area and the consequences it had on Arctic Foxes, the wintering strategies of Arctic Foxes, the locations where foxes can be observed or trapped, the various color morphs observed in the area, the moulting cycle of foxes and their winter feeding ecology. We also discussed goose ecology, changes that have been observed in the environment as well as areas that are considered sensitive. These areas are either important sites for specific animals, important archaeological sites or important sites for subsistence activities. The sea as a whole, especially the one between Bylot Island and Baffin Island, was considered very sensitive to one informant. Areas that posed concern due to potential industrial development were also denoted

Final results have now been compiled and maps have been produced. The main point that emerges from this project component is that Inuit TEK provides us with a perspective that extends the spatial and temporal scales of our actual knowledge of the ecosystem of Bylot Island. For example, Inuit TEK provided very useful information on Arctic and Red Foxes denning locations outside the south plain of the island (Fig. 22), goose migratory routes and stopovers (Fig. 23), and areas considered sensitive (Fig. 24). TEK also provided information about temporal changes in goose distribution since the 1960s. According to Inuit TEK, geese are more scattered than they use to be and they are seen in new locations. According to informants, geese have also moved towards the western side of the south plain of Bylot Island and are no longer nesting in the areas of Bylot Island located in front of Pond Inlet. TEK also provided information about fox winter distribution and feeding habits. On a temporal scale, Inuit TEK allowed us to draw the annual moulting cycle of foxes and provided information on the timing of goose migration, local changes in the abundance of geese and other animals, the timing of the arrival of Red Foxes in the area and, finally, areas where changes were observed in the environment.

Results have been presented at two conferences: the 31st annual meeting of the *Société Québécoise pour l'Étude de la Biologie et du Comportement* (Université du Québec à Montréal Montréal, QC, November 2006) and the Third ArcticNet Annual Scientific Meeting (Victoria, BC, December 2006). Final results will also be entered into the Parks Canada Inuit Knowledge Project database that will be made available to the community. Copy of interviews, focus groups and maps will also be sent to every informant as well as to the Pond Inlet Hamlet Office and Parks Canada office. We also intend to produce visual materials such as posters for the community.

COMMUNITY WORKSHOP

The workshop was very successful, with 16 participants (twelve from Pond Inlet and two from Iqaluit) attending it on 16 January (the list of participants and their affiliation are given in Appendix 2). Five presentations were planned (three by Joël Bêty, one by Ludovic Jolicoeur, both from Université du Québec à Romouski, and one by Jane Chisholm from Parks Canada; see schedule in Appendix 3). However, due to flight cancellation by First Air, the meeting started two hours later than expected and Jane Chisholm had to cancel her presentation. All presentations were supported by visual material (Power Point presentations are available upon request). Following these presentations, considerable time was devoted to questions and discussions with participants. The purpose of the workshop was to 1) inform the community about the ecological monitoring activities performed on Bylot Island, with a special focus this year on studies related to arctic birds and insects, 2) present the proposed monitoring activities in the coming years, seeking suggestion and advices, especially those associated to the International Polar Year. During the workshop, a pamphlet that summarizes the shorebirds studies performed on Bylot Island was distributed. The pamphlet is bilingual (Inuktitut-English) and copies were distributed to all participants (see Appendix 4). During the afternoon, procedures and equipment for shorebirds and insects monitoring were presented.

The evening consultation with the general public was also very successful with 11 local persons attending. The activity had been publicised in the community (on the community radio). Talks were given by Joël Bêty and Ludovic Jolicoeur, followed by presentations of shorebirds and insects monitoring procedures. Collections of insects captured on Bylot Island were presented and generated lots of interests. Shorebird pamphlets were also distributed during the consultation. It was followed by snacks and coffee, which allowed people to discuss in a more informal way.

The morning and early afternoon of 17 January was dedicated to talks given at the high school (grades 7, 8 and 9). Joël Bêty and Ludovic Jolicoeur presented their research, with a special focus on shorebirds and insects monitoring, and showed collection of insects captured on Bylot Island. They prepared a 30-minute talk supported by visual material (Power Point). During the presentations, Joël Bêty advertised the possibility for students to get summer jobs with the researchers. Students and teachers enjoyed the talks and our presentation generated several questions from the students. Overall, the interaction between researchers and students was very positive and very stimulating for everybody.

HIRING AND TRAINING OF INDIVIDUALS FROM LOCAL COMMUNITIES

We hired 4 persons from the Pond Inlet community to work with us in the field for various lengths of time (1-2 weeks each) during the summer 2006: Ivan Koonoo, Joasie Otoovak, Enook Muktar and Bernie Kilukishak. All these people received valuable training in environmental studies while working with us. We also hired 4 additional people for the TEK component: Titus Arnakallak, Lucy Quasa and Rachel Ootoova worked as translators and Leslie Pewatoalook assisted Catherine Gagnon in different aspects of her study.

PRELIMINARY CONCLUSIONS

So far, few temporal trends were observed in the climatic data collected on Bylot Island over the last decade. Air temperatures has varied greatly from year to year and no trend were detected either on an annual or seasonal basis. The weak decreasing trend in the spring thawing degree-days (TDD) is entirely due to the extremely high TDD value recorded in 1994, a year with virtually no snow cover during the winter. The absence of temporal trends in air temperatures on Bylot Island is likely related to our short time series (i.e. 13 years) as Gagnon et al. (2004) were able to detect warming trends in the summer, spring and fall temperatures of Pond Inlet and Nanisivik over the past 3 decades. Interestingly, our data suggests some trends in summer precipitation with an increase in mid summer (July) and a seasonal decrease in summer wind speeds.

Even though Snow Geese nested at later dates in 2006, they were able to have normal clutch sizes but their reproductive effort was low (i.e. low nesting density). Despite the low abundance of breeding foxes and jaegers, egg predation was high this year and resulted in a low nesting success, probably due to the very low abundance of lemmings in the study area. Even though goose data provided our longest record of environmental monitoring, we did not find evidence for long-term trends so far.

Our long-term data on lemming abundance show that the population dynamics of the two lemming species found on Bylot Island differ. Indeed, the population of Brown Lemmings has been going through much deeper cycles than the one of Collared Lemmings at our two study sites. During peak years, abundance of Brown Lemmings was several times higher than Collared Lemmings, but in low years that species was equally scarce (in the Qarlikturvik Valley) or rarer (at the nesting colony) than Collared Lemmings. Although population cycles were much more obvious in Brown than Collared Lemmings, the abundance of both species tended to fluctuate synchronously. The recent MSc thesis of Nicolas Gruyer (2007) presents a detailed analysis of these patterns. Results from our 2006 dead and live-trapping surveys indicated that lemming abundance had decline and was lower than last year. The numbers of foxes that produced a litter was also at its lowest since the last lemming peak in 2004. Furthermore, jaegers and gulls also seem to be affected by the low abundance of lemmings in 2006. Both the reproductive effort (number of nests) and nesting success of jaegers have declined gradually and are at their lowest since 2004. Gulls on the other hand were able to maintain their reproductive effort but their nesting success was nonetheless half of that of last year.

Of all our long-term monitoring, it is the plant production in wetlands that show the strongest evidences of long-term changes. At the two brood-rearing sites (Qarlikturvik Valley and Dufour Point), we found evidence of a long-term positive trend in plant production. The trend is strongest at the former site, which has the longest record (17 years). Over that period, annual plant production in wetlands was lower than the long-term average during the first eight years, and is above during seven of the last nine years. Over the full period, plant production increased by 30 g m^{-2}, or 100%, on average, a very large increase. This change is possibly a consequence of the long-term increase in summer temperature reported by Gagnon et al. (2004) during this period as Dickey (2006) has shown that plant production in wetlands is positively related to summer temperature on Bylot Island. Such positive trend was not detected at the main goose colony site where plant production is only 60% of the level found at the other sites. This relatively low production, and the weak decreasing trend observed at the site may be a consequence of the high grazing pressure occurring there due to the very density of nesting geese.

We are highly satisfied with the success of our TEK project. Support from the community was very high and many positive feedbacks were expressed from community members throughout the project. The success of the Elder-Youth Camp conducted in June 2006 was certainly one of the highlights of this project since it provided a great platform for exchanges between scientists and community members, as well as between Elders and young people.

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Table 1. Data on the reproduction of Snowy Owls, Jaegers (mostly Long-tailed) and Glaucous Gulls on Bylot Island, from 1993 to 2006. Mean values are provided for each parameter except for number of nests (total).

Species		1993	1994	1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Snowy Owl	N of nests [a]	12 / -	0 / 0	0 / 0	7 / 3	0 / 0	0 / 0	0 / 0	12 / 1	0 / 0	0 / 0	0 / 0	13 / 9	0 / 0	0 / 0
	Laying date	21 May	- [b]	-	16 May	-	-	-	29 May	-	-	-	18 May	-	-
	Hatching date	22 June	-	-	17 June	-	-	-	30 June	-	-	-	19 June	-	-
	Clutch size	7.6	-	-	7.9	-	-	-	6.4	-	-	-	7.1	-	-
	Nesting success	-	-	-	-	-	-	-	85%	-	-	-	95%	-	-
Long-tailed Jaeger	N of nests	-	-	-	-	6	3	0	9	9	0	0	17 / 6	9 / 9	3 / 4 [c]
	Laying date	-	-	-	-	-	-	-	-	-	-	-	15 June	16 June	-
	Hatching date	-	-	-	-	-	-	-	-	-	-	-	10 July	11 July	-
	Clutch size	-	-	-	-	-	-	-	-	-	-	-	1.8	1.8	-
	Nesting success	-	-	-	-	-	-	-	-	-	-	-	86%	8%	0%
Glaucous Gull	N of nests	-	-	-	-	3	5	7	5	4	1	-	5 / 5	11 / 1	12 / 4
	Laying date	-	-	-	-	-	-	-	-	-	-	-	-	13 June	18 June
	Hatching date	-	-	-	-	-	-	-	-	-	-	-	-	10 July	17 July
	Clutch size	-	-	-	-	-	-	-	-	-	-	-	2.3	2.9	2.1
	Nesting success	-	-	-	-	-	-	-	-	-	-	-	-	80%	38%

[a] Qarlikturvik Valley / main goose nesting colony; otherwise, number of nests combines both sites.
[b] No data available.
[c] 1 nest of Parasitic Jaeger and 3 of Long-tailed Jaegers

Table 2. Data on the reproduction of shorebirds species on Bylot Island, from 2004 to 2006. Mean values are provided for each parameter except for number of nests (total).

Species		2004	2005	2006
White-rumped Sandpiper	N of nests [a]	- [b]	36 / 3	17 / 3
	Laying date	-	13 June	15 June
	Hatching date	-	8 July	10 July
	Clutch size	-	4.0	4.0
	Nesting success	-	11%	1%
Baird's Sandpiper	N of nests	5 / 0	20 / 0	32 / 1
	Laying date	-	10 June	11 June
	Hatching date	-	4 July	4 July
	Clutch size	4.0	4.0	4.0
	Nesting success	-	25%	2%
American Golden Plover	N of nests	-	6 / 0	5 / 1
	Laying date	-	17 June	15 June
	Hatching date	-	13 July	13 July
	Clutch size	-	4.0	4.0
	Nesting success	-	19%	20%
Black-bellied Plover	N of nests	-	1 / 0	0 / 0
	Laying date	-	18 June	-
	Hatching date	-	18 July	-
	Clutch size	-	4.0	-
	Nesting success	-	-	-
Red Phalarope	N of nests	-	1 / 0	0 / 1
	Laying date	-	-	-
	Hatching date	-	-	-
	Clutch size	-	4.0	-
	Nesting success	-	-	-
Common Ringed Plover	N of nests	-	-	0 / 1
	Laying date	-	-	-
	Hatching date	-	-	-
	Clutch size	-	-	-
	Nesting success	-	-	-
Pectoral Sandpiper	N of nests	-	-	2 / 0
	Laying date	-	-	-
	Hatching date	-	-	-
	Clutch size	-	-	-
	Nesting success	-	-	-

[a] Qarlikturvik Valley / main goose nesting colony.
[b] No data available.

Table 3. Data on the reproduction of Lapland Longspurs, Sandhill Cranes, King Eiders and Long-tailed Ducks on Bylot Island, from 1995 to 2006. Mean values are provided for each parameter except for number of nests (total).

Species		1995	1996	1997	1998	1999	2000	2001	2002	2003	2004	2005	2006
Lapland Longspur	N of nests [a]	23	5	13	18	7	22	18	13	18	27	68	89
	Laying date	16 June	13 June	23 June	13 June	22 June	19 June	16 June	16 June	7 June	24 June	21 June	18 June
	Hatching date	1 July	29 June	9 July	30 June	8 July	4 July	2 July	1 July	23 June	9 July	3 July	6 July
	Clutch size	5.7	5.2	4.7	5.6	5.3	5.6	5.1	5.8	5.5	5.2	5.1	5.1
	Nesting success	75%	40%	40%	38%	50%	82%	- [b]	50%	-	75%	19%	9%
Sandhill Crane	N of nests	-	2	1	1	2	3	1	0	1	2 / 0	1 / 0	3 / 0
	Clutch size	-	-	-	-	-	-	-	-	-	2.0	2.0	2.0
King Eider	N of nests	-	-	-	2	2	7	3	1	2	2 / 2	5 / 0	3 / 0
	Clutch size	-	-	-	-	-	-	-	-	-	-	5.0	3.7
Long-tailed Duck	N of nests	-	-	-	1	-	5	1	-	-	1 / 1	4 / 0	4 / 0
	Clutch size	-	-	-	-	-	-	-	-	-	-	4.8	3.8

[a] Qarlikturvik Valley / main goose nesting colony; otherwise, number of nests combines both sites (except for Lapland Longspurs, Qarlikturvik Valley only).
[b] No data available.

Table 4. Number of Brown and Collared Lemmings captured and recaptured during the live-trapping program on Bylot Island from 2004 to 2006.

Year		Wetlands		Mesic tundra		Total
		Brown Lemming	Collared Lemming	Brown Lemming	Collared Lemming	
2004	Number captured	84	1	58	26	169
	Number recaptured[1]	55	0	33	9	97
2005	Number captured	12	13	16	14	55
	Number recaptured	7	5	10	6	28
2006	Number captured	14	10	12	11	47
	Number recaptured	6	8	6	5	25

[1] Number of individual recaptured more than once.

Table 5. Average minimum litter size of Arctic and Red Foxes on Bylot Island from 1993 to 2006.

Year	Average minimum litter size	
	Arctic Fox	Red Fox
1993	2.0	-[a]
1994	-	-
1995	-	-
1996	5.6	6.0
1997	5.0	-
1998	2.9	2.0
1999	2.0	4.0
2000	3.2	5.0
2001	3.3	5.0
2002	-	-
2003	4.3	-
2004	5.1	6.0
2005	6.9	-
2006	3.0	-
Long-term average	6.4	4.7

[a] No data available.

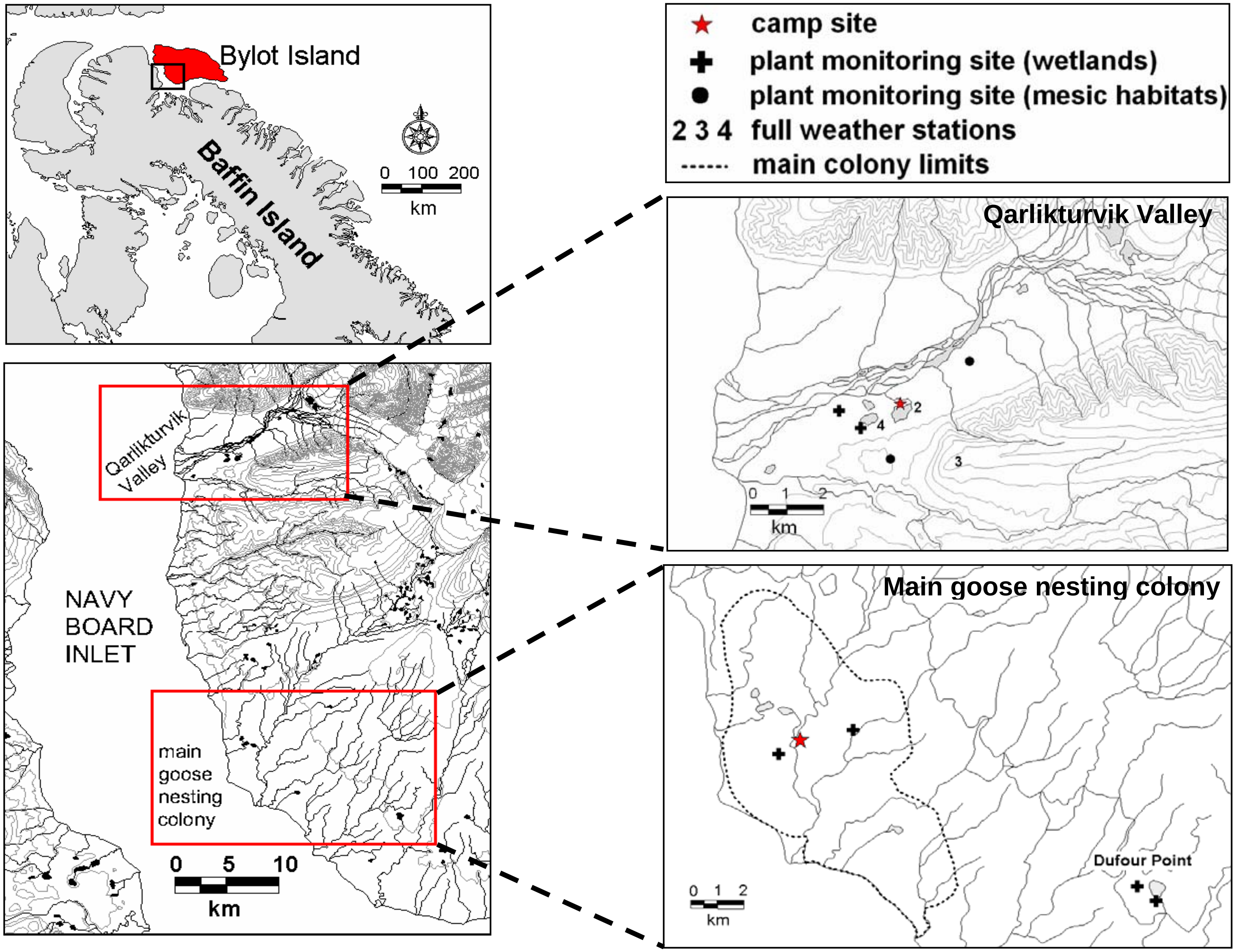

Figure 1. General location of the study area, Bylot Island, Nunavut, and of the two main study sites (Qarlikturvik Valley and the main goose nesting colony) on the South plain of the island. Enlarged maps on the right present these study sites in more details, including camp locations, sampling sites and our three full weather stations.

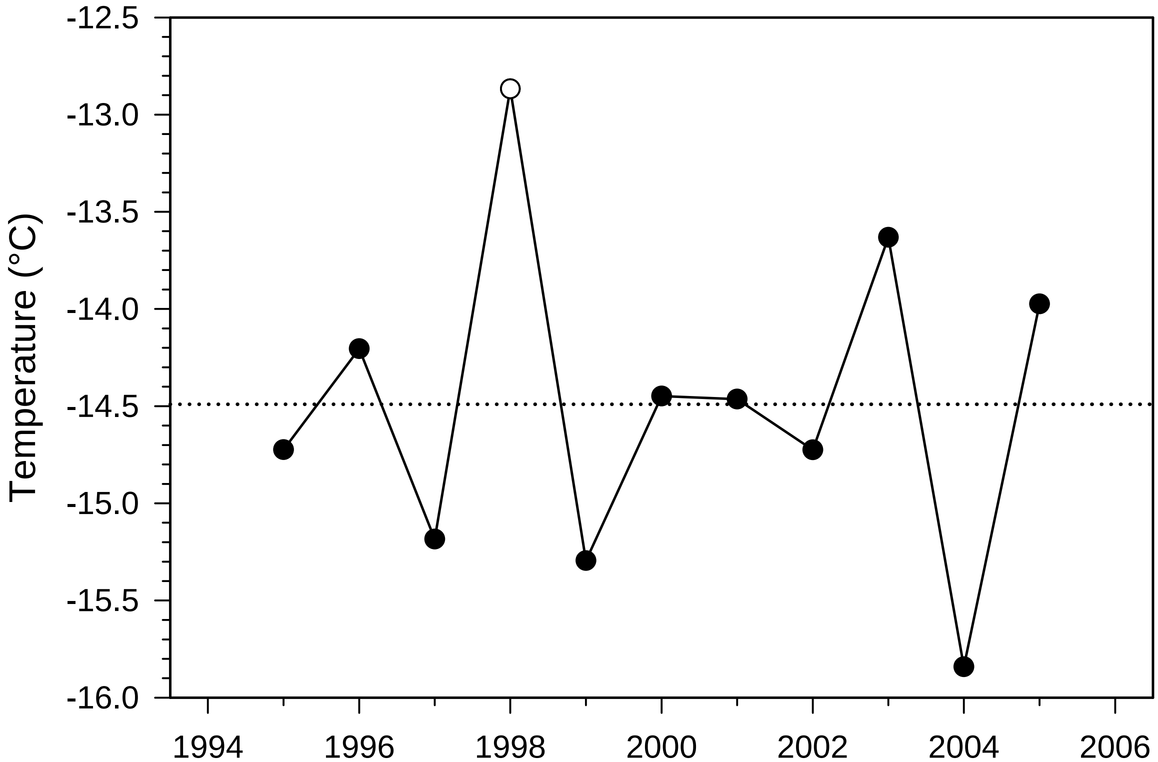

Figure 2. Average annual air temperature in the Qarlikturvik Valley lowlands of Bylot Island from 1995 to 2005. The dotted line shows the mean for the whole period. Air temperature for 1998 is represented by a white circle as it was extrapolated for part of the year from the relation between the air temperatures at Bylot Island and Pond Inlet due to missing values.

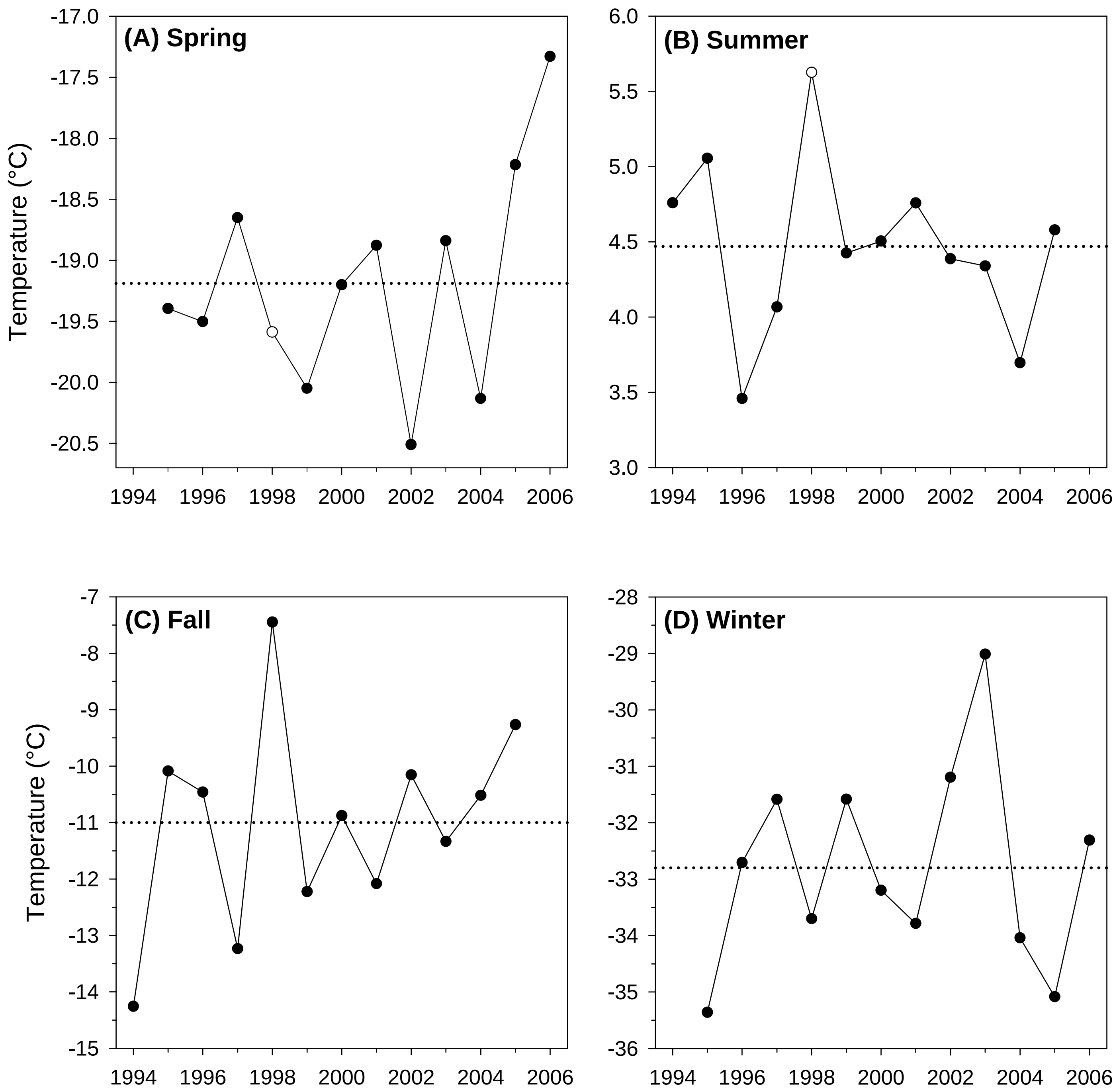

Figure 3. Average air temperature in the Qarlikturvik Valley lowlands of Bylot Island from 1994 to 2006 for (A) spring (March to May), (B) summer (June to August), (C) fall (September to November) and (D) winter (December to February). The dotted line shows the mean for the whole period. Air temperature for the spring and summer 1998 is represented by a white circle as it was extrapolated from the relation between the air temperatures at Bylot Island and Pond Inlet.

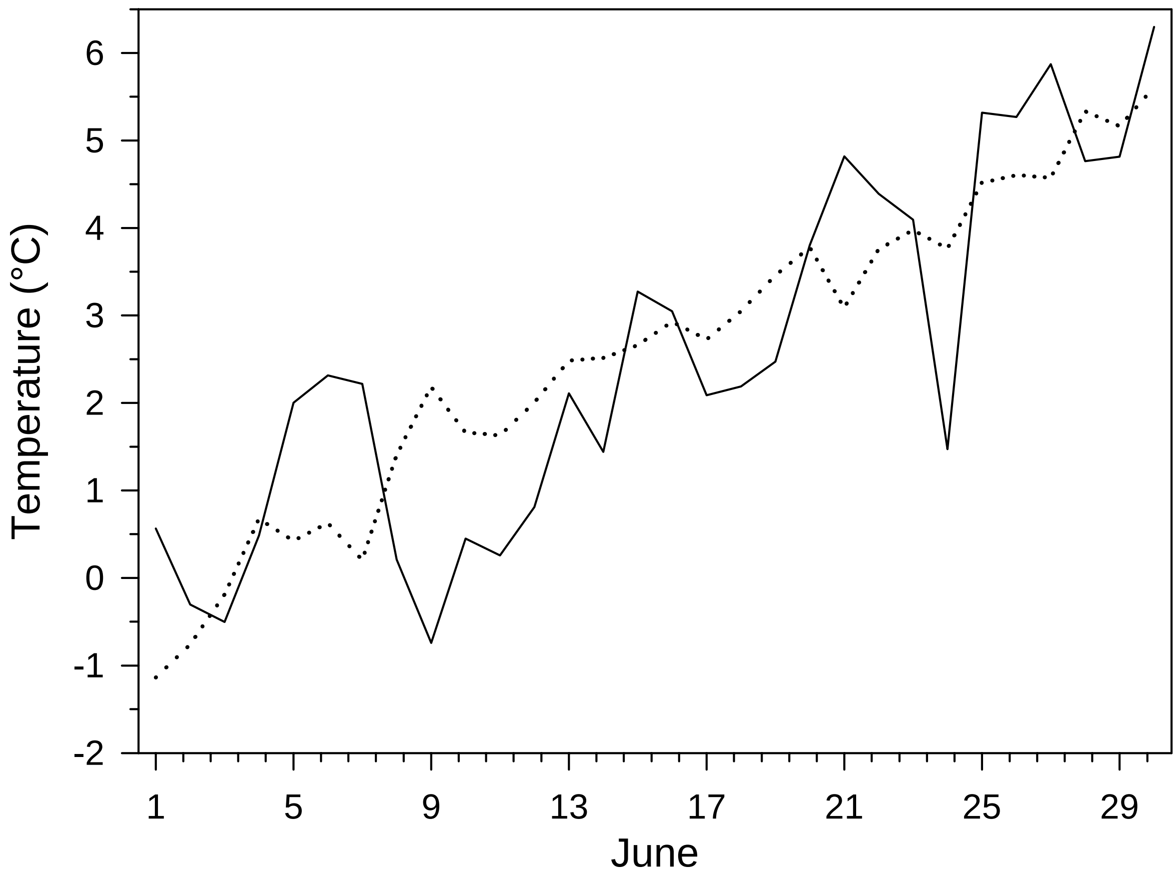

Figure 4. Average air temperature in the Qarlikturvik Valley lowlands of Bylot Island in June 2006. The solid line represents the 2006 data while the dotted line shows the long-term average from 1994 to 2006. Air temperature for June 1998 is excluded from the long-term average due to missing values.

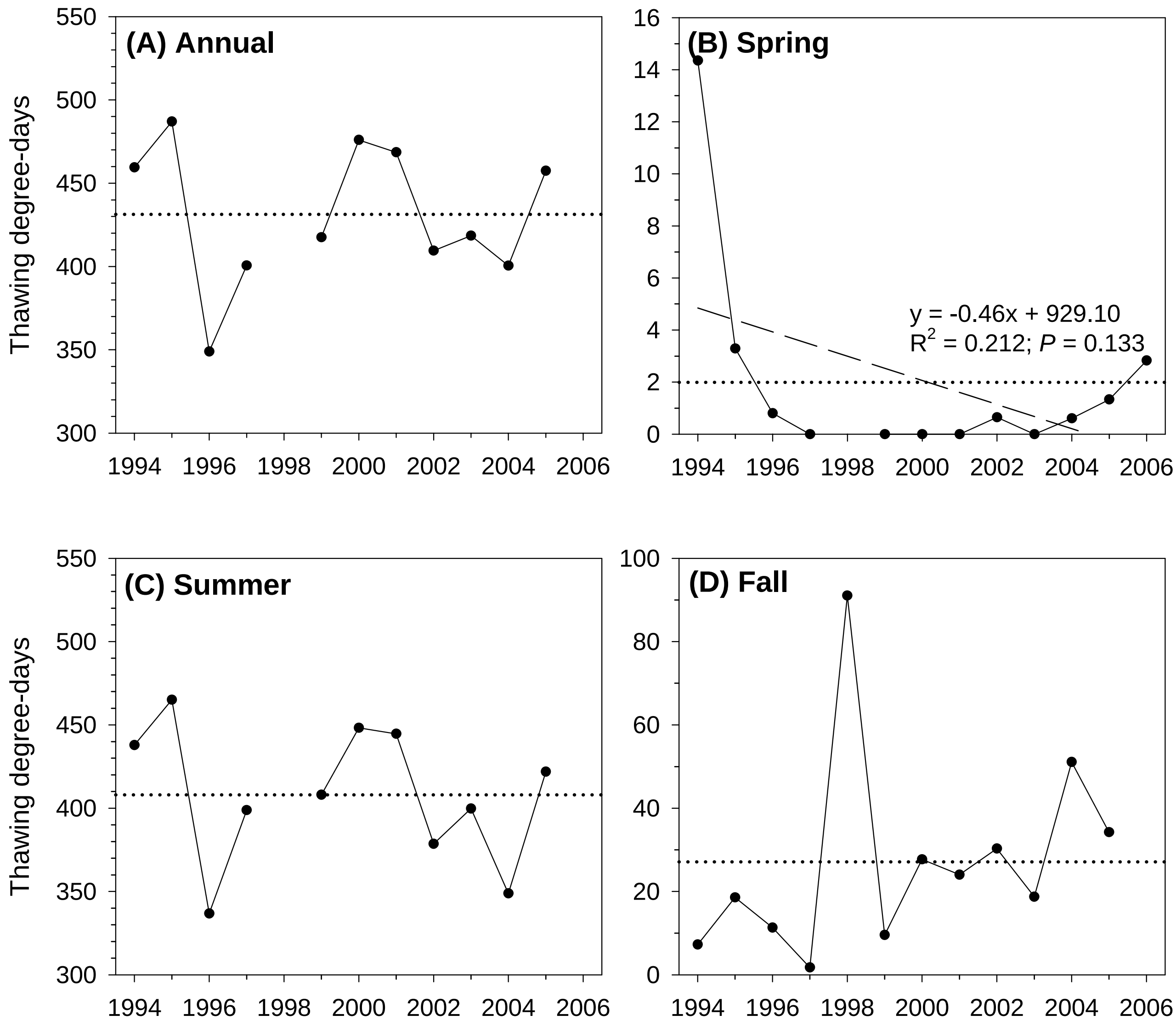

Figure 5. Number of thawing degree-days in the Qarlikturvik Valley lowlands of Bylot Island from 1994 to 2006 for (A) entire year, (B) spring (March to May), (C), summer (June to August) and (D) fall (September to November). Temporal trends are represented by a dashed line when approaching significance ($0.05 < P < 0.15$). The dotted line shows the mean for the whole period.

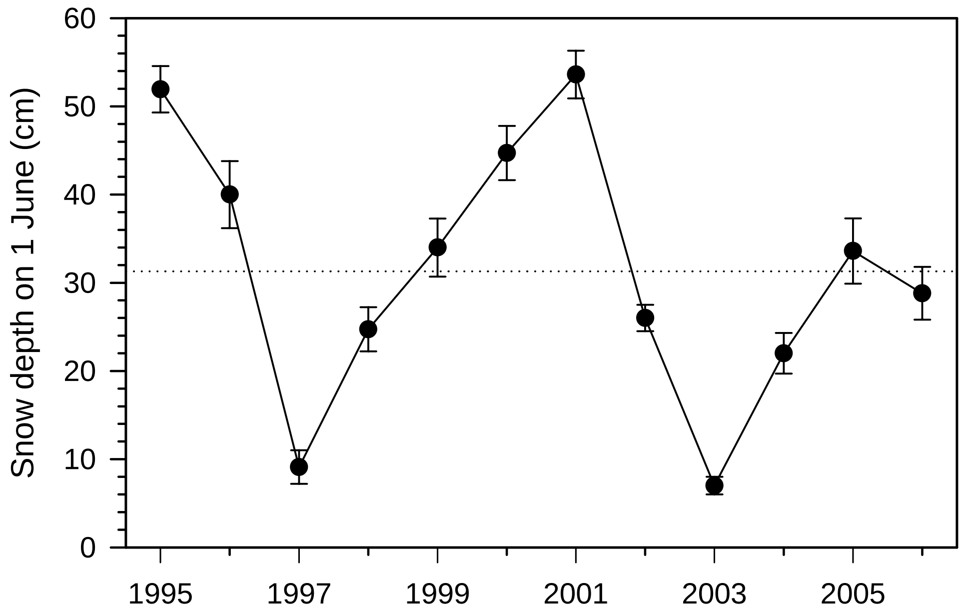

Figure 6. Average snow depth (mean ± SE) on the ground on 1 June in the Qarlikturvik Valley lowlands of Bylot Island from 1995 to 2006. The dotted line shows the mean for the whole period.

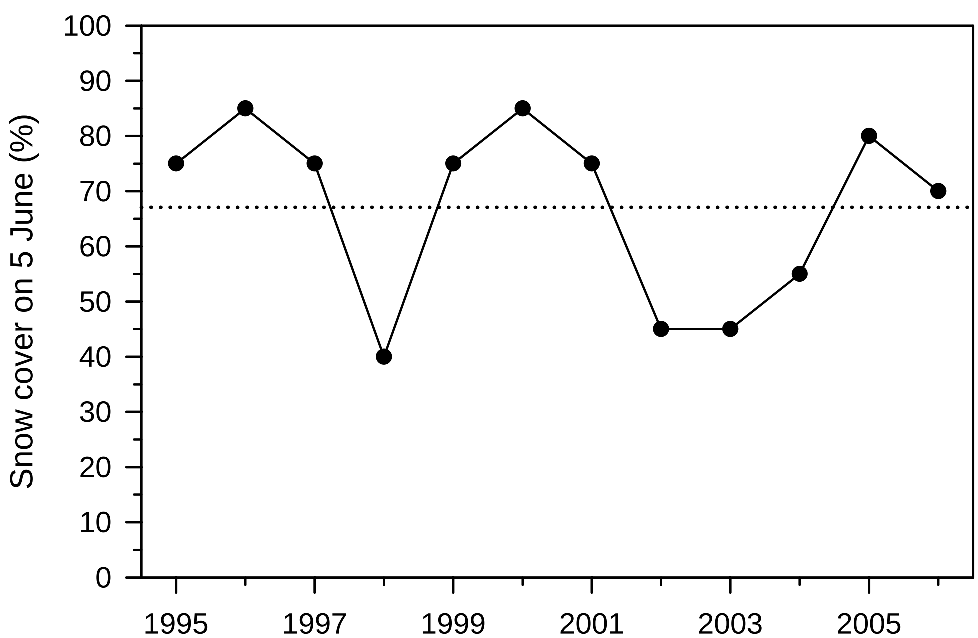

Figure 7. Average percentage of snow cover on the ground on 5 June in the Qarlikturvik Valley lowlands of Bylot Island from 1995 to 2006. The dotted line shows the mean for the whole period.

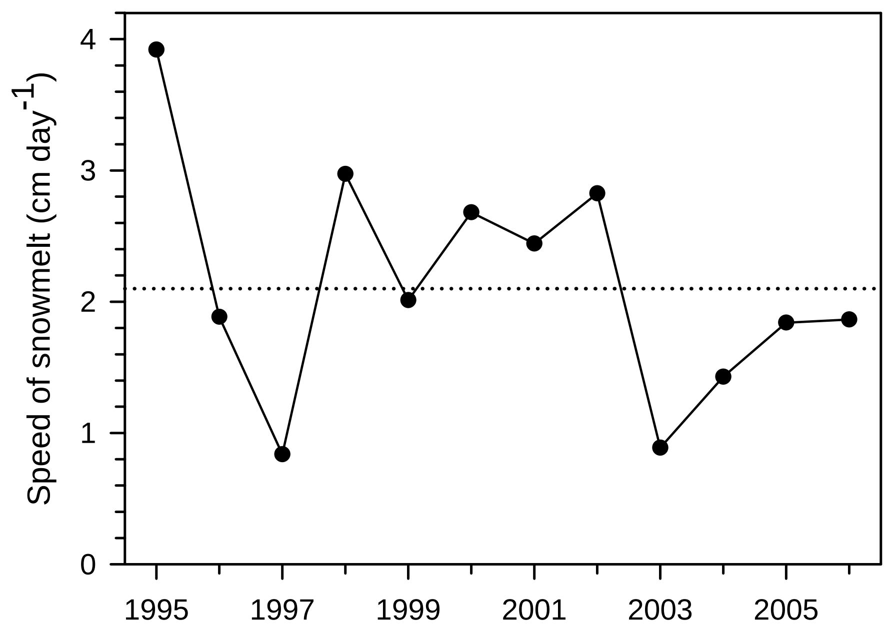

Figure 8. Average speed of snowmelt during the month of June in the Qarlikturvik Valley lowlands of Bylot Island from 1995 to 2006. The dotted line shows the mean for the whole period.

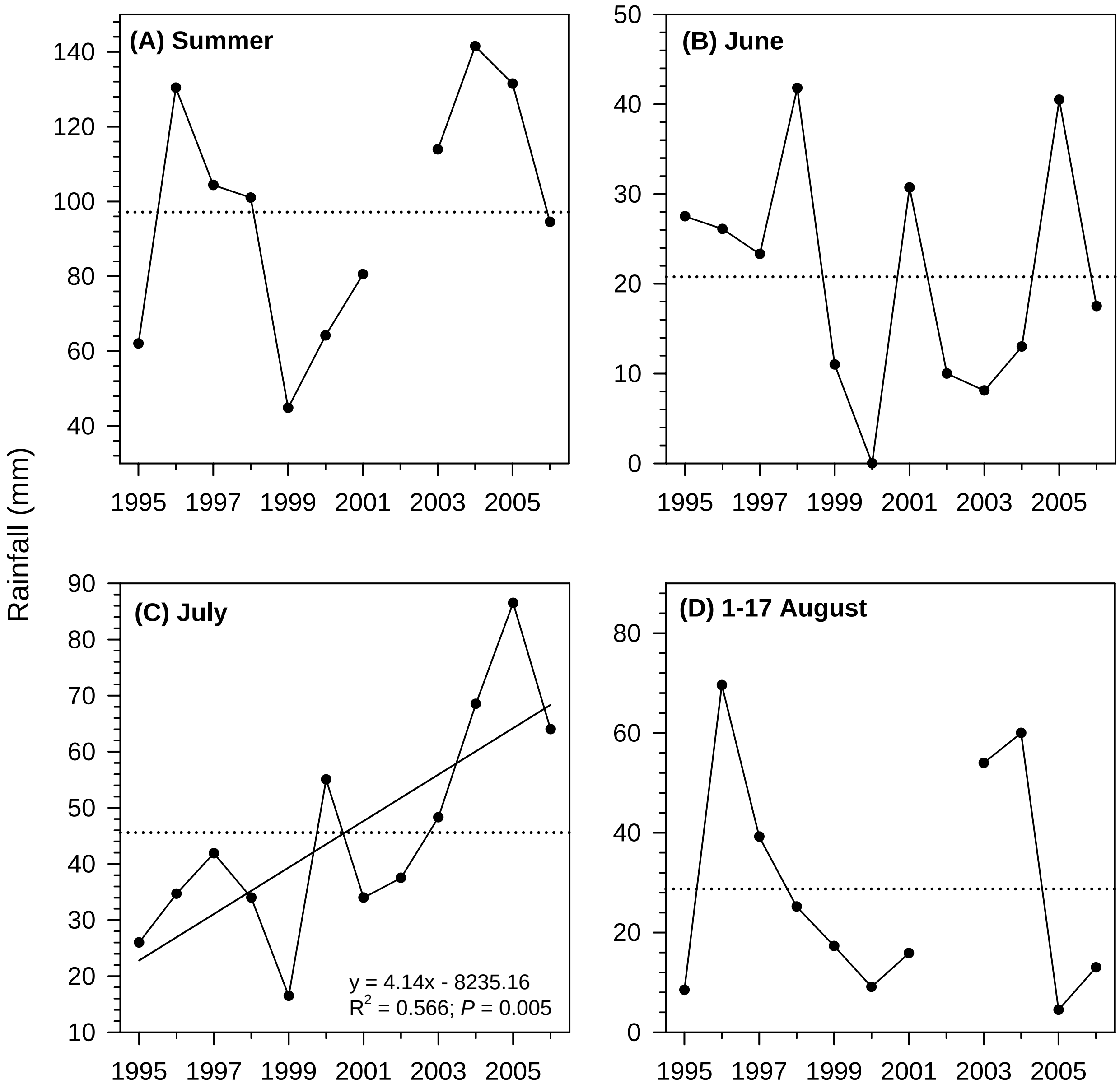

Figure 9. Average summer and monthly rainfall in the Qarlikturvik Valley lowlands of Bylot Island from 1995 to 2006 for (A) summer (1 June to 17 August), (B) June, (C) July and (D) August (1-17). Temporal trends are represented by a solid line when significant ($P < 0.05$). The dotted line shows the mean for the whole period.

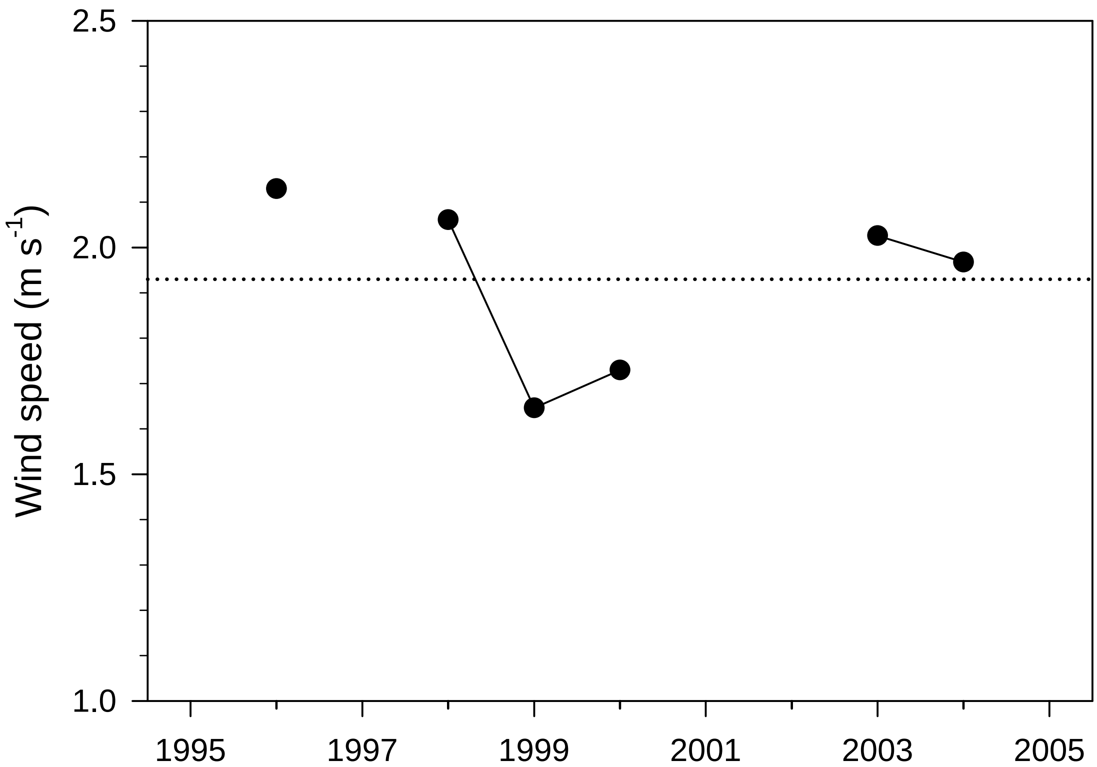

Figure 10. Average annual wind speed in the Qarlikturvik Valley lowlands of Bylot Island from 1995 to 2005. The dotted line shows the mean for the whole period.

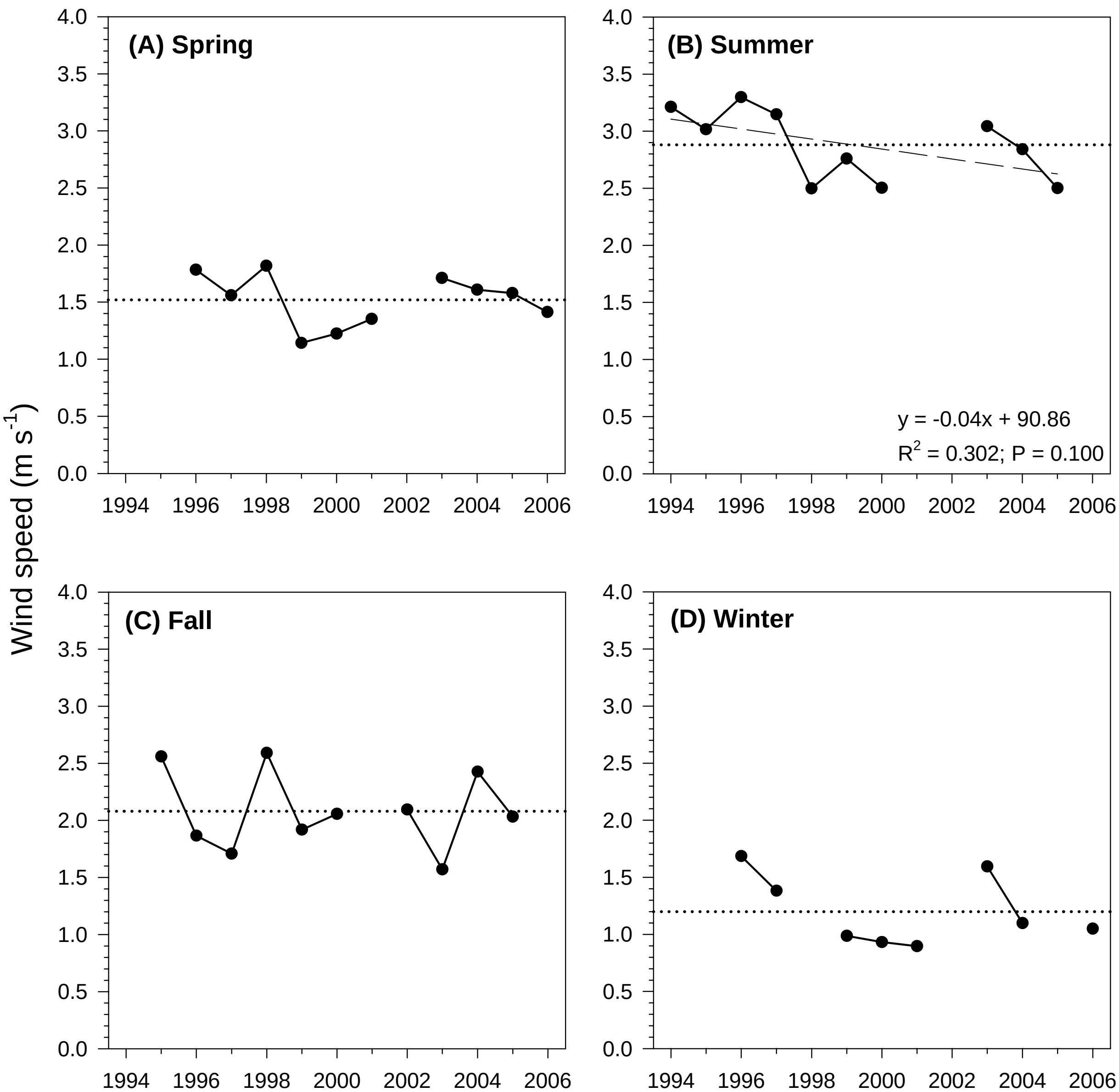

Figure 11. Average wind speed in the Qarlikturvik Valley lowlands of Bylot Island, from 1994 to 2006 for (A) spring (March to May), (B) summer (June to August), (C) fall (September to November) and (D) winter (December to February). The dotted line shows the mean for the whole period.

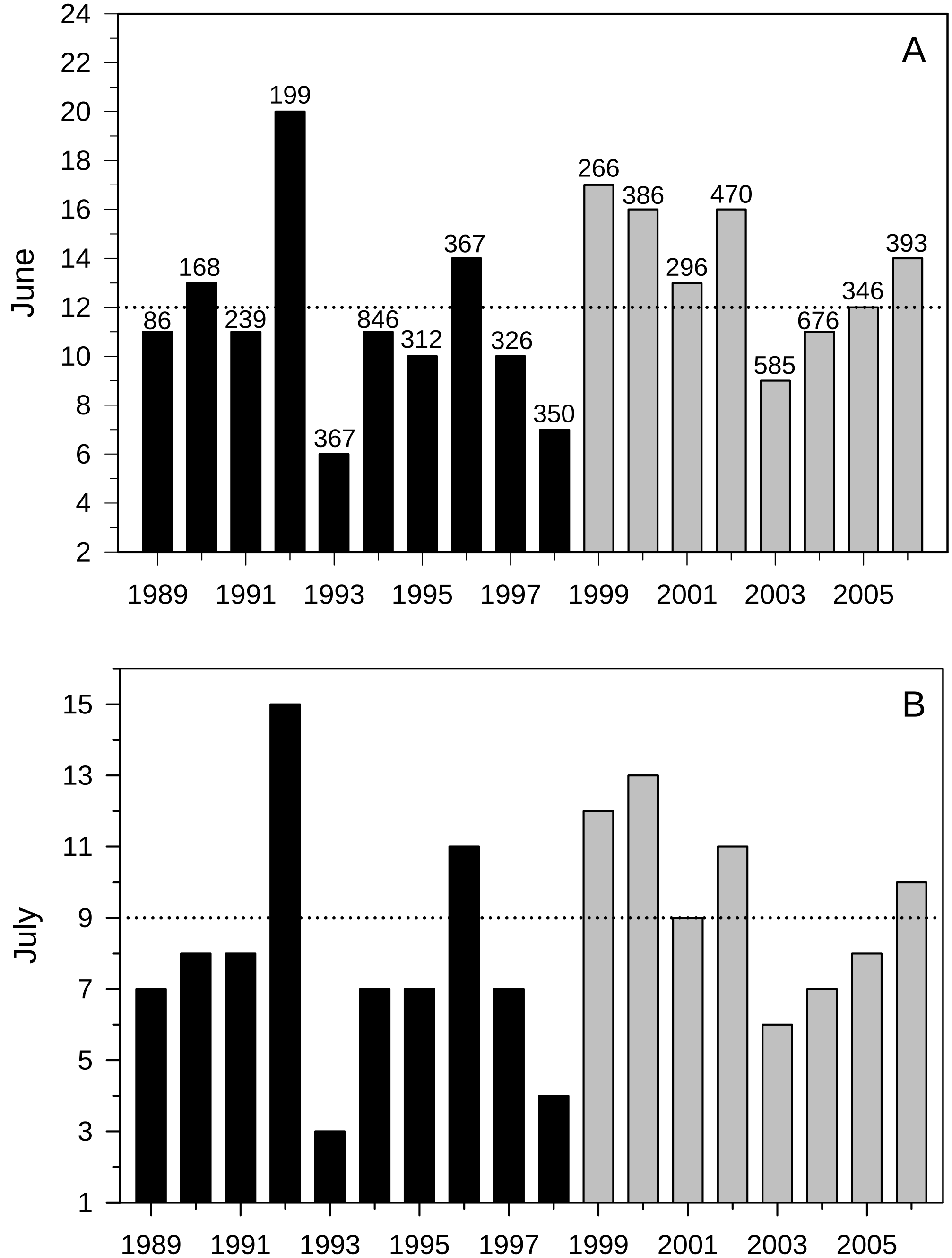

Figure 12. Median annual (A) egg-laying dates and (B) egg-hatching dates of Greater Snow Geese on Bylot Island from 1989 to 2006. Grey columns represents years during which a spring hunt occurred in Quebec. The dotted line shows the mean for the whole period. Numbers on top of bars in panel A indicate the number of nests monitored each year.

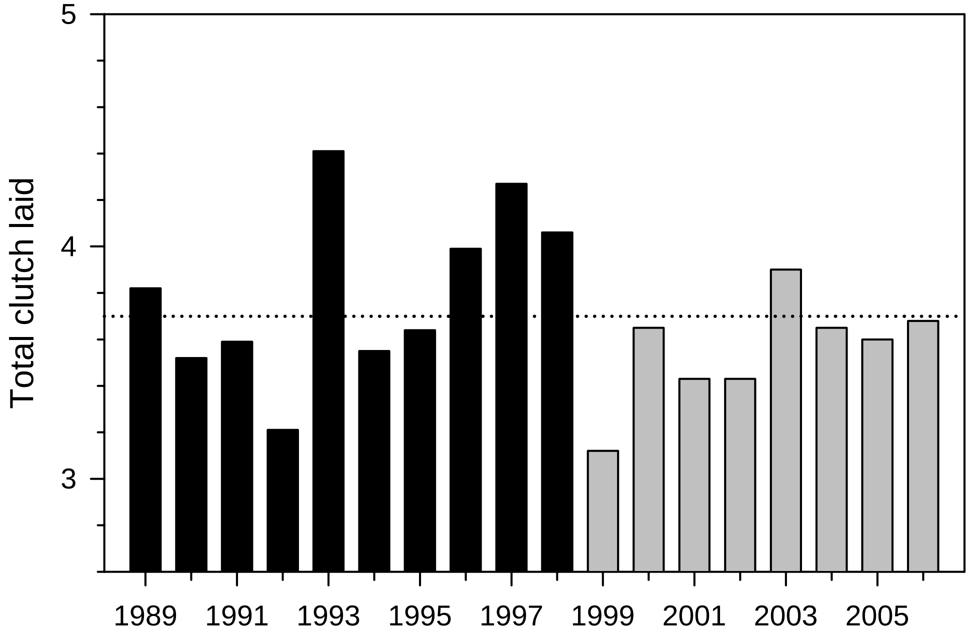

Figure 13. Annual total clutch laid of Greater Snow Geese on Bylot Island from 1989 to 2006. Grey columns represents years during which a spring hunt occurred in Quebec. The dotted line shows the mean for the whole period.

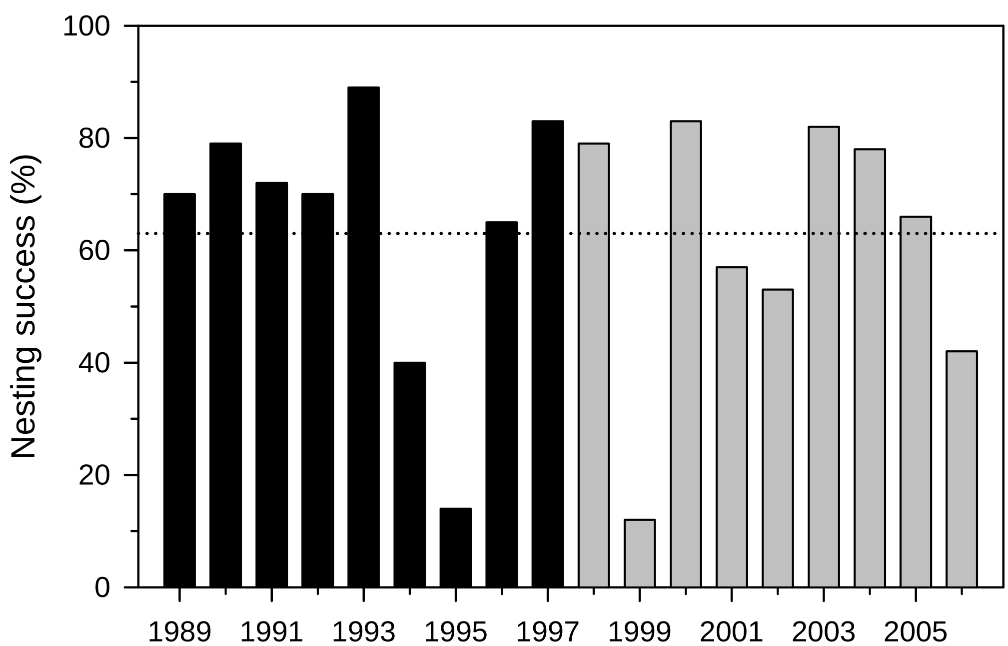

Figure 14. Annual nesting success (percentage of nests where at least one egg hatched) of Greater Snow Geese on Bylot Island from 1989 to 2006. Grey columns represents years during which a spring hunt occurred in Quebec. The dotted line shows the mean for the whole period.

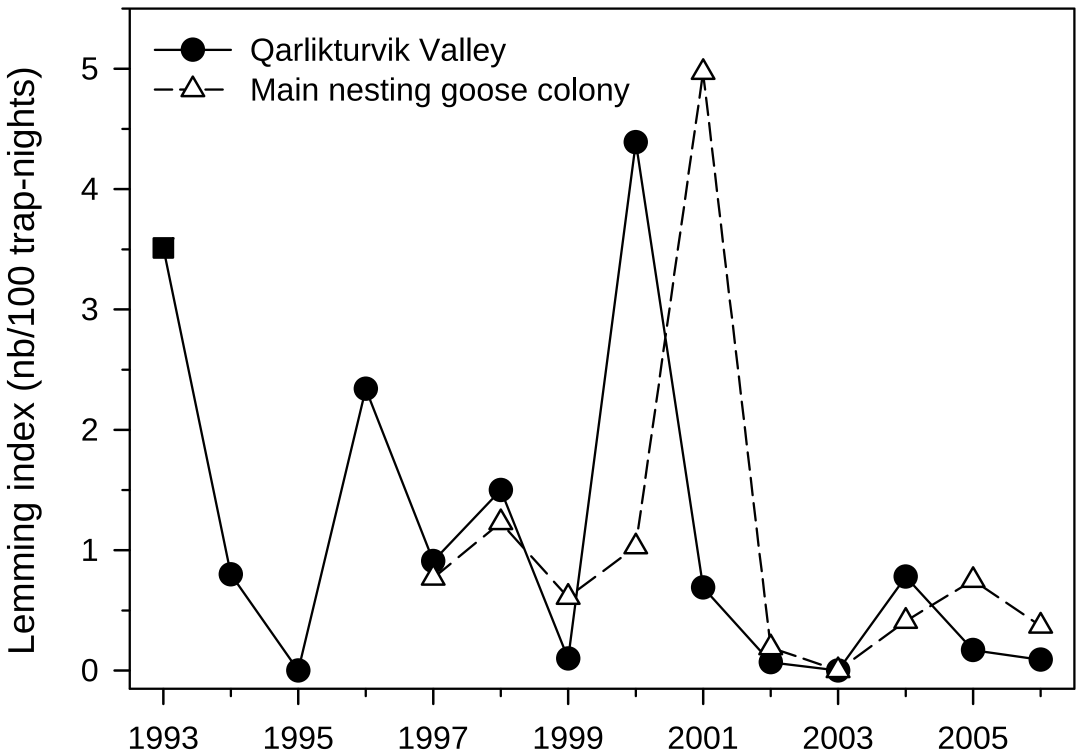

Figure 15. Index of lemming abundance (number caught per 100 trap-nights) in the Qarlikturvik Valley and the main goose nesting colony of Bylot Island from 1993 to 2006. Although no lemmings were trapped in 1993, an estimate was derived based on a winter nest survey.

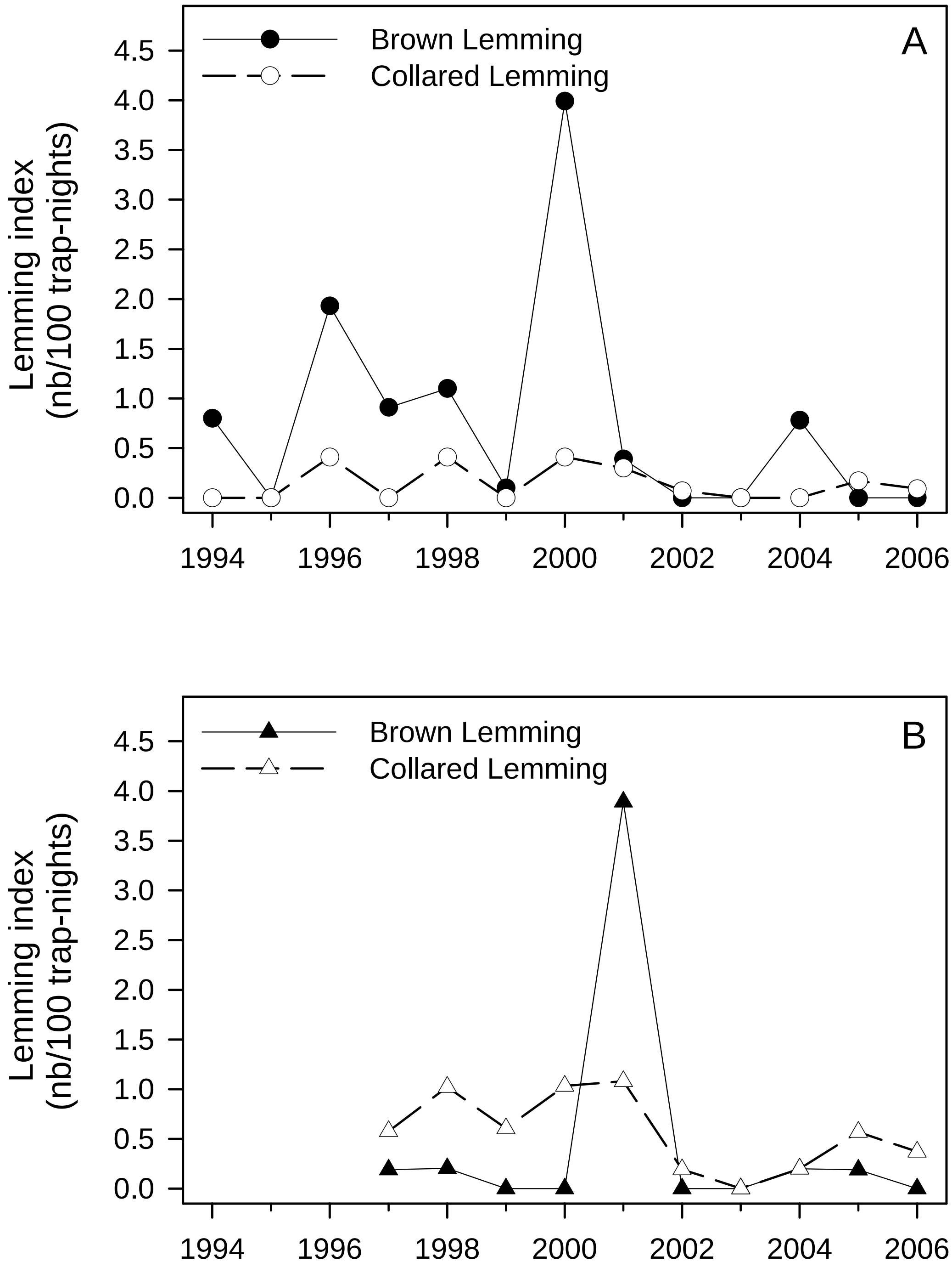

Figure 16. Index of Brown and Collared Lemmings abundance (number caught per 100 trap-nights) in (A) the Qarlikturvik Valley and (B) the main goose nesting colony of Bylot Island from 1994 to 2006.

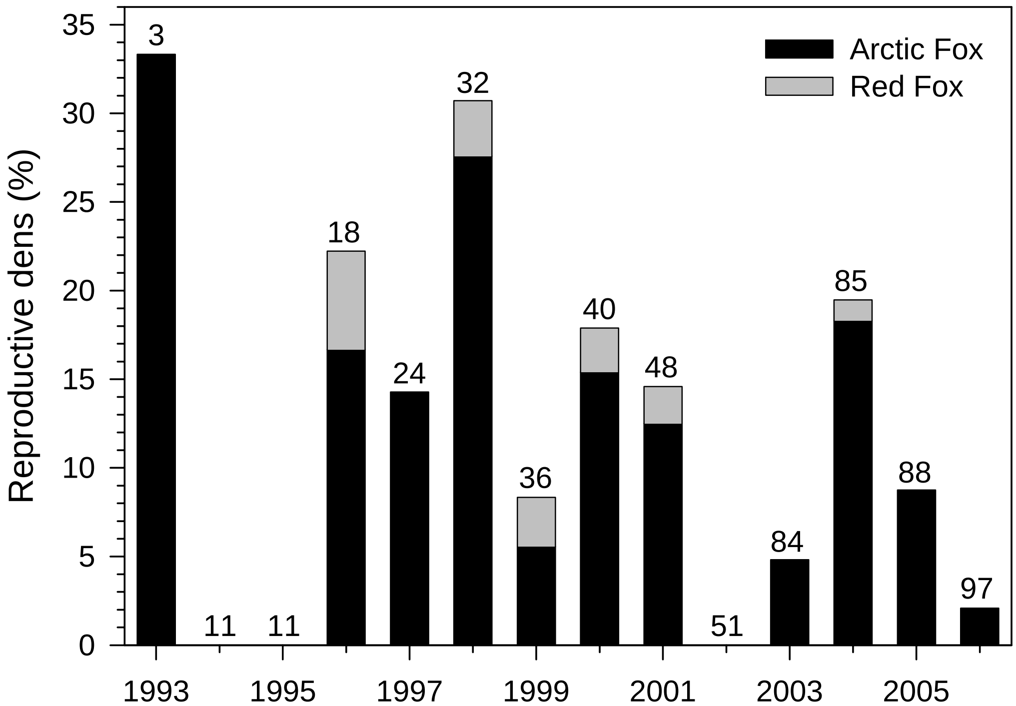

Figure 17. Annual percentage of Arctic and Red Fox dens with presence of pups on Bylot Island from 1993 to 2006. Numbers on top of bars indicate the number of dens monitored each year.

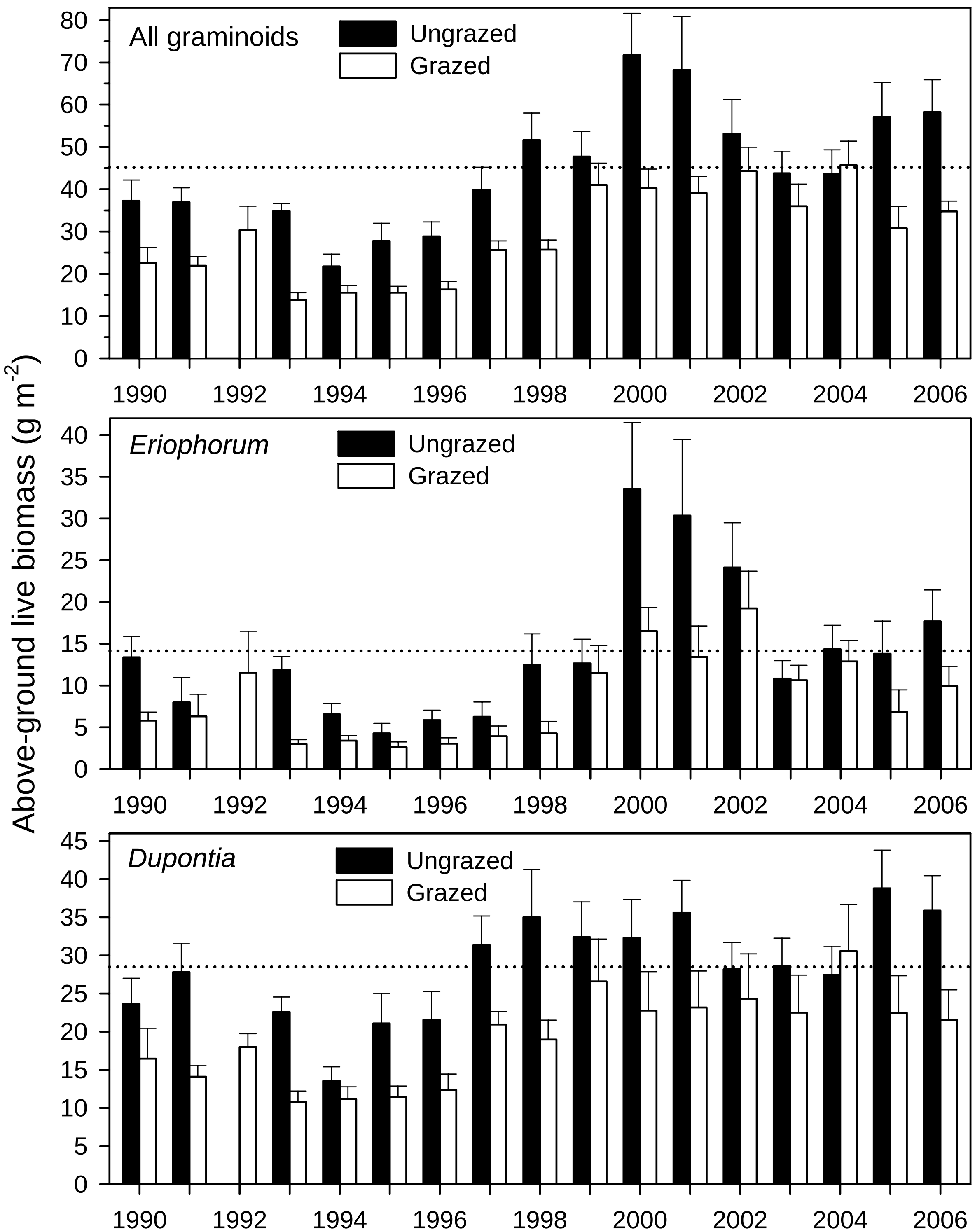

Figure 18. Live above-ground biomass (mean ± SE, dry mass) of (A) all graminoids, (B) *Eriophorum scheuchzeri* and (C) *Dupontia fisheri* on 12 August in grazed and ungrazed wet meadows of the Qarlikturvik Valley, Bylot Island, from 1990 to 2006 (n = 12 each year). There is no data from ungrazed area in 1992. The dotted line shows the mean plant production for the whole period.

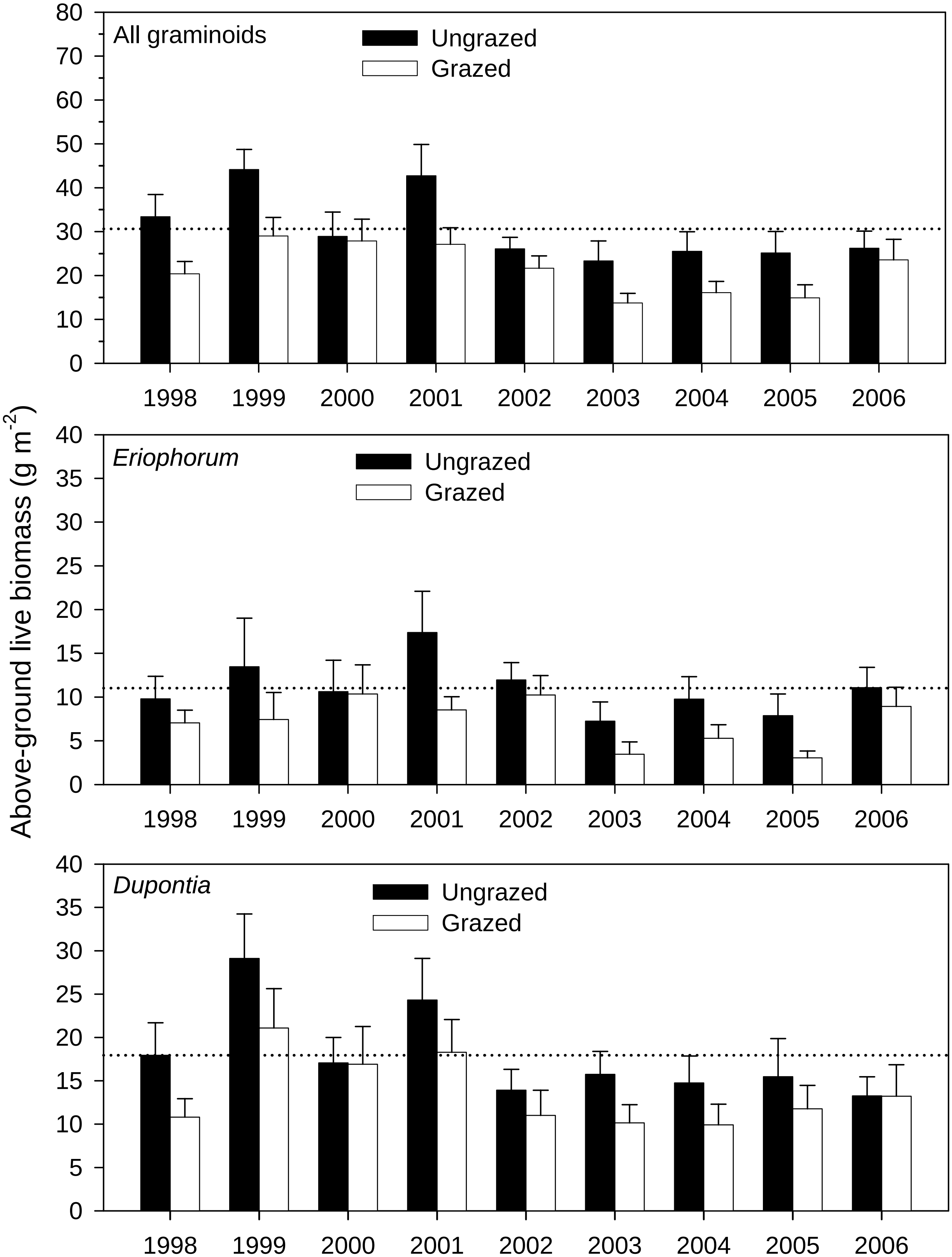

Figure 19. Live above-ground biomass (mean ± SE, dry mass) of (A) all graminoids (B) *Eriophorum scheuchzeri* and (C) *Dupontia fisheri* on 13 August in grazed and ungrazed wet meadows of the main nesting goose colony, Bylot Island, from 1998 to 2006 (n = 12 each year). The dotted line shows the mean plant production for the whole period.

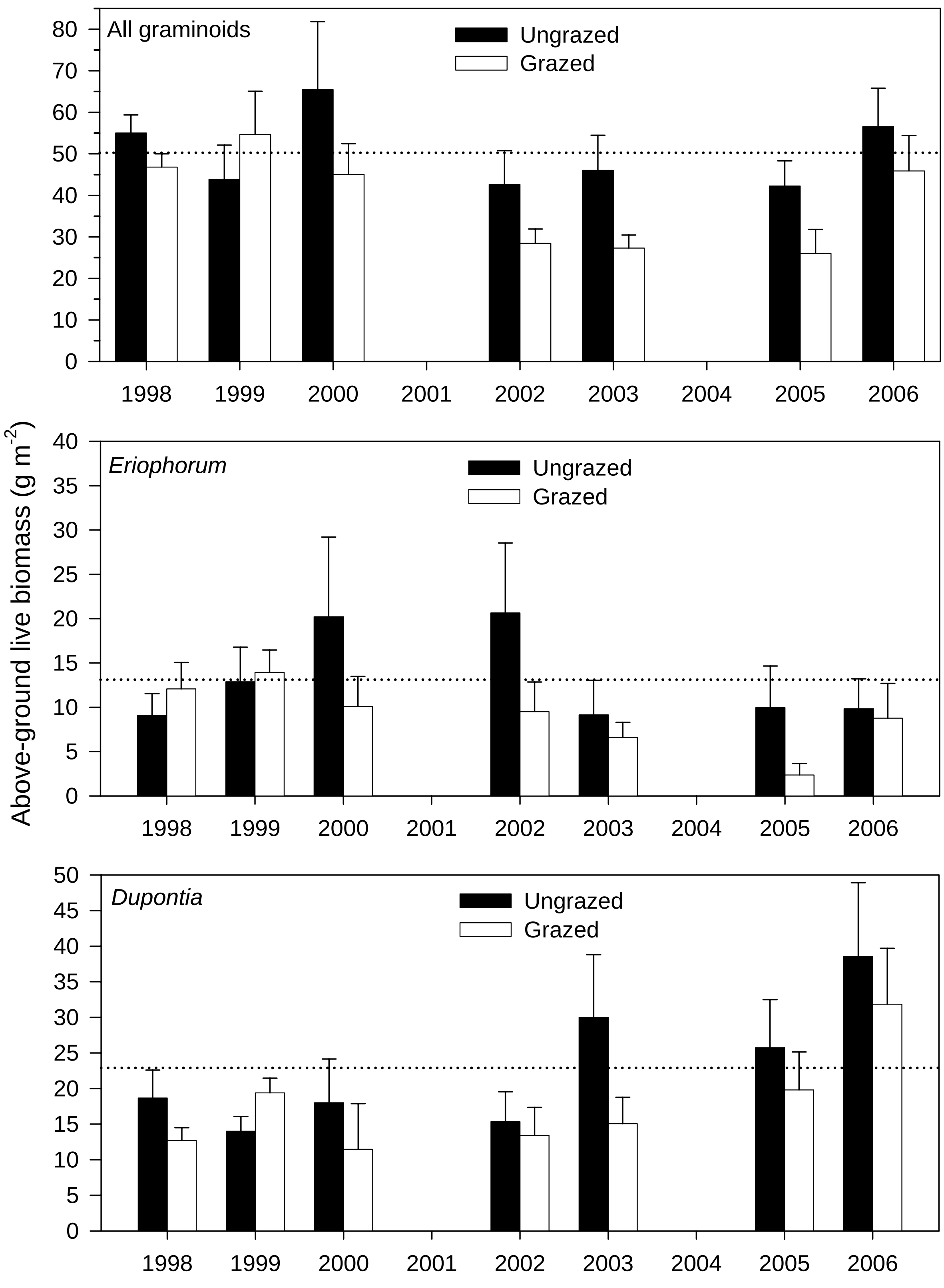

Figure 20. Live above-ground biomass (mean ± SE, dry mass) of (A) all graminoids (B) *Eriophorum scheuchzeri* and (C) *Dupontia fisheri* on 13 and 14 August in grazed and ungrazed wet meadows of Pointe Dufour, Bylot Island, from 1998 to 2006 (n = 12 each year). No sampling took place in 2001 and 2004. The dotted line shows the mean plant production for the whole period.

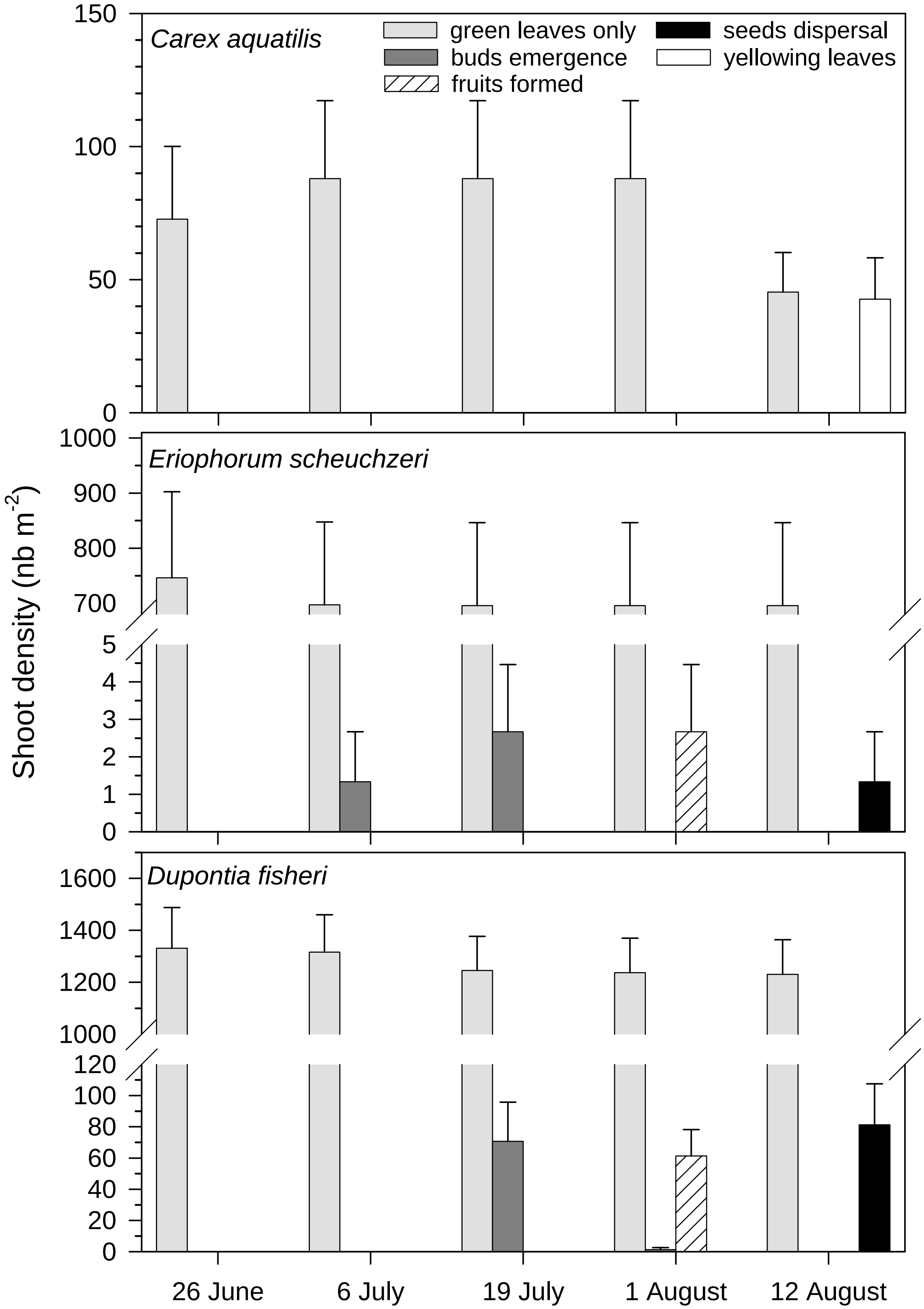

Figure 21. Plant phenology of (A) *Carex aquatilis*, (B) *Eriophorum scheuchzeri* and (C) *Dupontia fisheri* in ungrazed wet meadows of the Qarlikturvik Valley, Bylot Island, in 2006 (n = 12 for each sampling date).

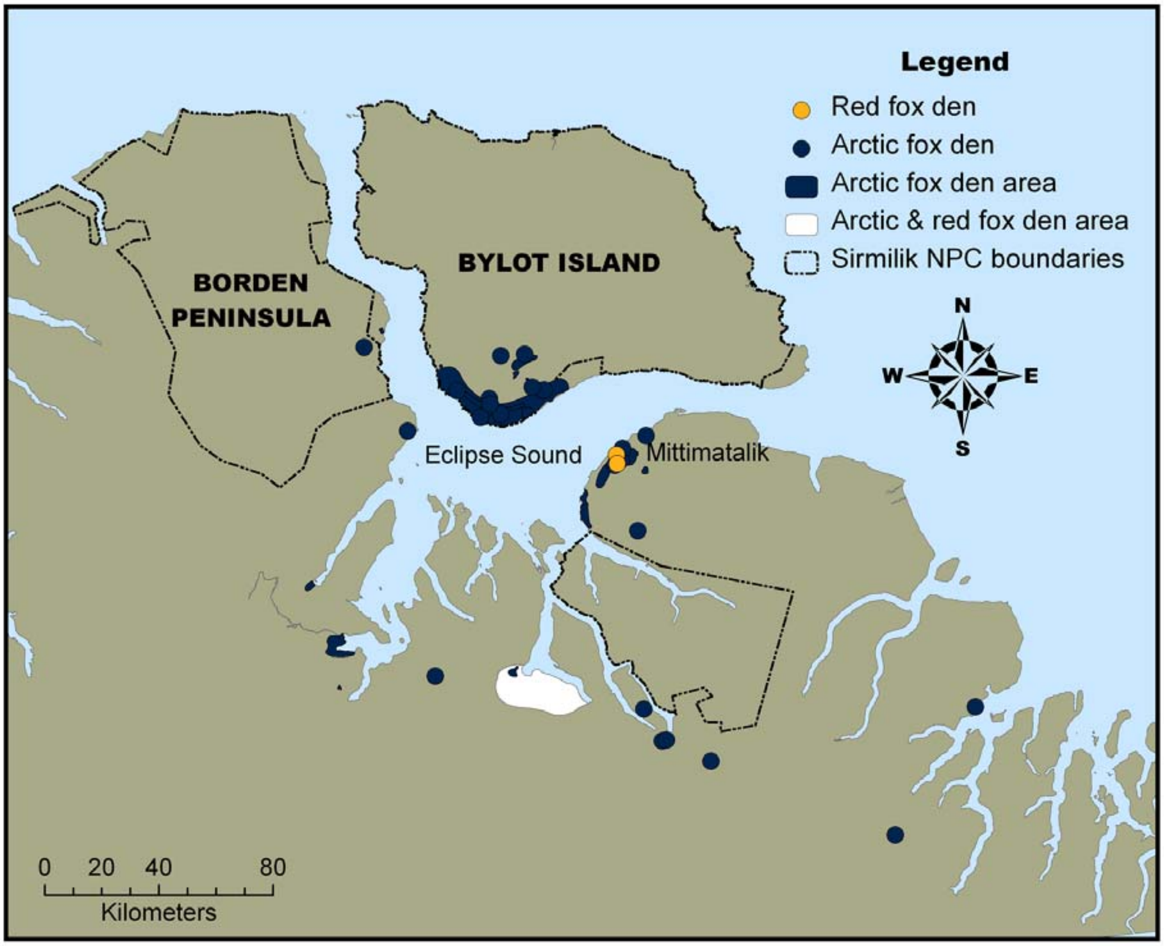

Figure 22. Locations of Arctic and Red Foxes dens and denning areas, as reported by local experts from Pond Inlet.

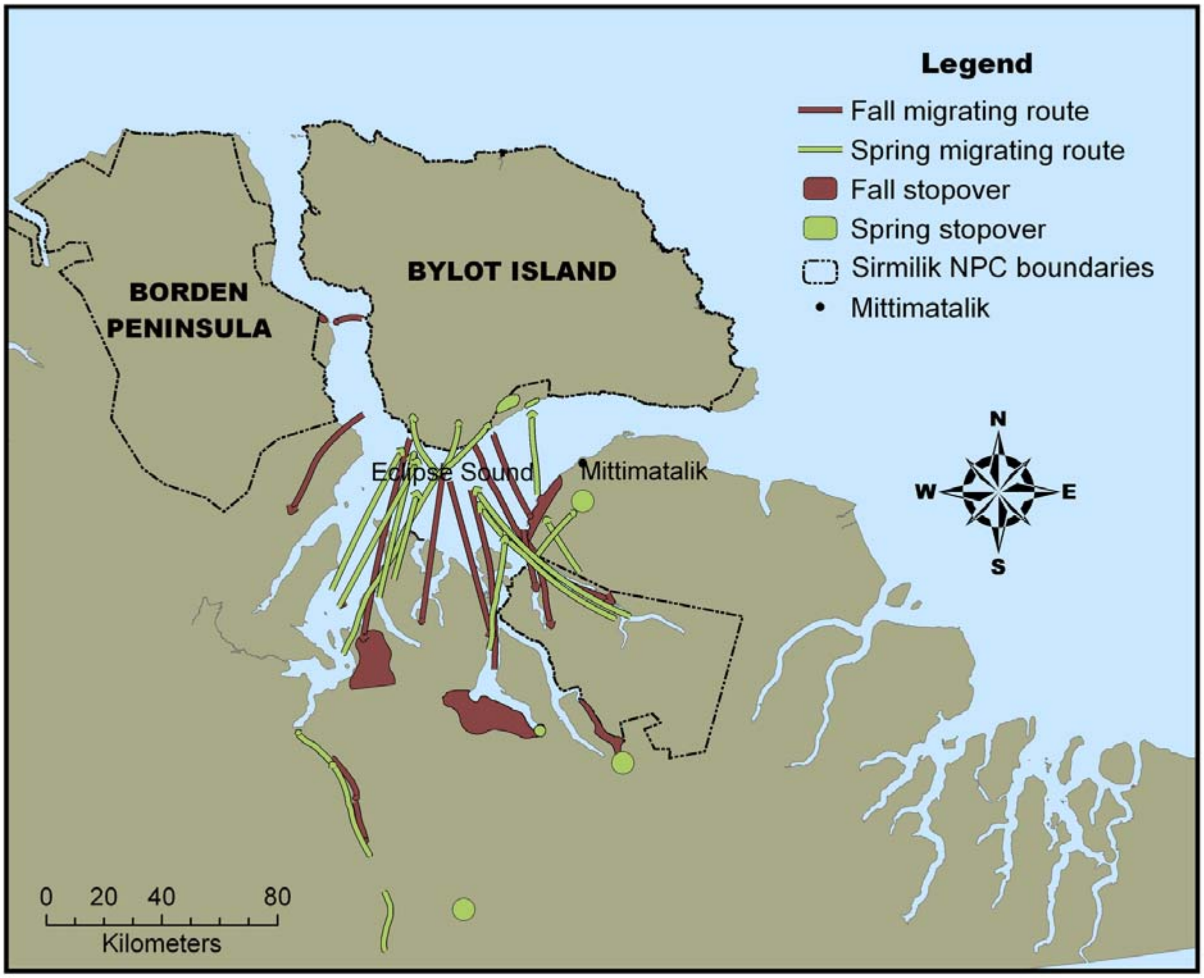

Figure 23. Spring and fall migrating routes of Greater Snow Geese, as reported by local experts from Pond Inlet.

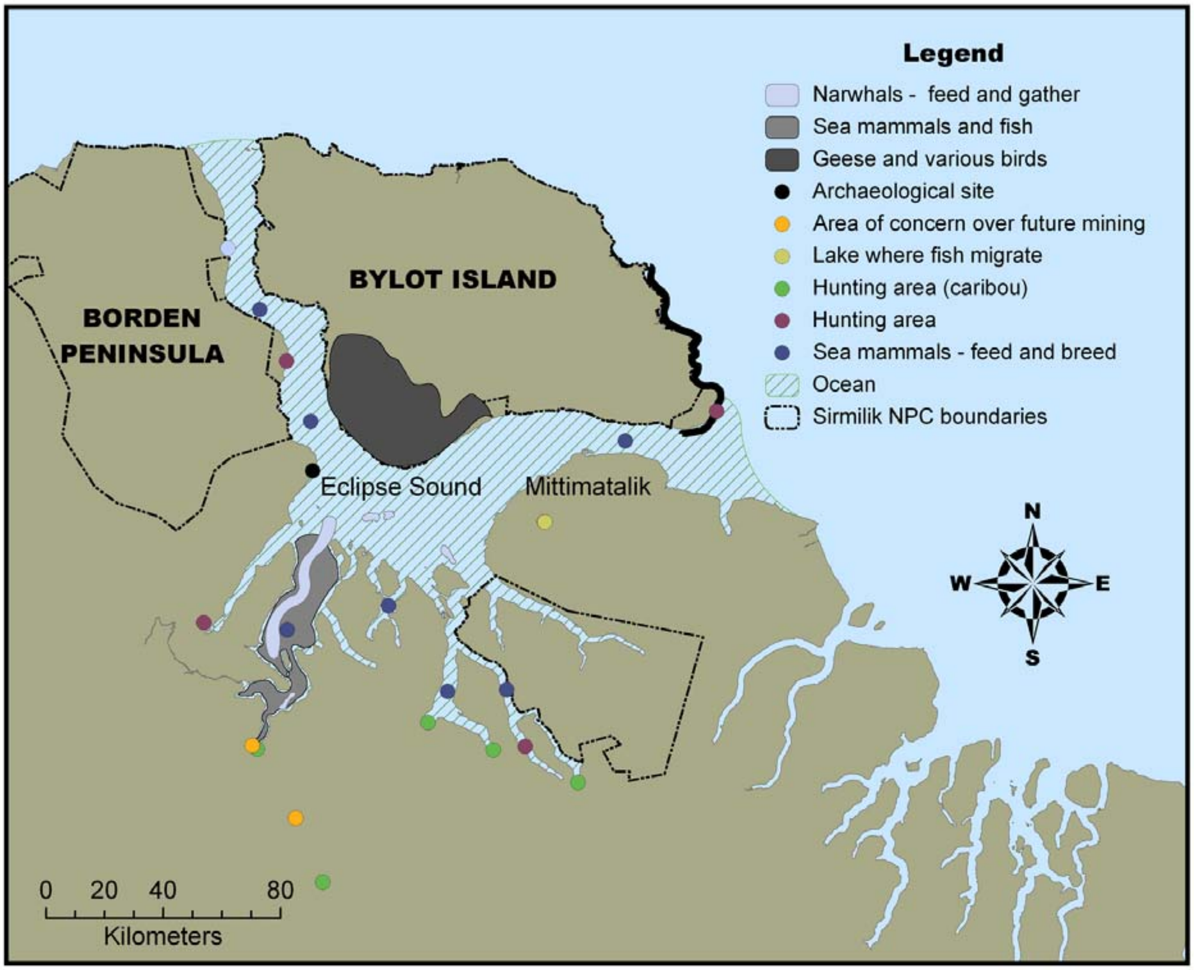

Figure 24. Locations of ecological or cultural sensitive areas, as reported by local experts from Pond Inlet.

APPENDIX 1. Article from the *Nunatsiaq News* featuring the Elder-Youth Camp held on Bylot Island in June 2006.

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NUNATSIAQ NEWS

July 7, 2006

Bylot's gigantic gaggle of geese

"You could hear them from one mile away"

Each June about 60,000 greater snow geese descend on the southwestern corner of Bylot Island, turning one patch of tundra into the largest colony of the geese in the Arctic.

Mathias Qaunaq, left, and Simon Sangoya carefully pack goose eggs for the trip from Bylot Island back to Pond Inlet. For a few weeks, Bylot Island hosts the largest colony of Greater Snow Geese in the Arctic. (PHOTOS COURTESY OF CATHERINE GAGNON)

That many birds make quite a squawk. And this year, their presence gave a group of elders and youth from Pond Inlet and visiting scientists an opportunity to chatter about what they know of the geese and other wildlife.

"You could hear them from one mile away," said Simon Sangoya, 19.

He was the eldest of about 10 youth who camped out on the beach with elders and scientists earlier this month, from June 11 to 17, in Sirmilik National Park, about 15 kilometres from the geese colony.

The trip aimed to bring new understanding between scientists who have studied the ecosystem of Bylot Island for several years, and elders who have witnessed changes occur over a far longer period of time.

The project was started by Catherine Gagnon, a masters student in natural resource management at the Université du Québec in Rimouski.

One big change is a growing number of geese, fuelled by the growth of the agriculture industry in Quebec, where the migrating geese spend part of the year.

Further down the migration path, along the St. Lawrence River, the number of greater snow geese counted during a census in the spring leaped from 417,000 in 1993 to 957,600 in 2004.

Pond Inlet elder Annie Paingut Peterloosie sews goose wings together for decoration during a land trip to Bylot Island this month.

That population boom has led to geese destroying the tundra in other parts of the North. Researchers want to know if that will happen on Bylot Island, too.

But so far there's no sign of that happening at the Bylot colony - just plenty of birds, which meant there was plenty of eggs and goose flesh for the campers to eat.

That food brought back memories for elders of how those animals were once hunted.

Greater snow geese spend several weeks on Bylot Island breeding and moulting - a stage of their lives when they shed their feathers and are unable to fly. That's when a group of hunters would circle the birds and herd them.

Usually hunters would herd the birds to a convenient frozen lake. But the group heard that in the past, hunters herded the birds all the way across the straight to Baffin Island and back to their camp near Pond Inlet.

Rachel Panipakoocho looks into a box carefully packed with goose eggs, just after egg picking.

When the birds tired, hunters would pick the geese up and carry them.

The cuddly moments would end when they reached their destination, however, where Inuit would spear or club the birds. It's food, after all.

Elders also spoke of how to trap foxes on the ice, by digging a hole and covering it with a thin sheet of ice covered with frozen blood.

And they spoke of how foxes venture out onto the sea ice in March and April each year.

That's of interest to researchers such as Dominique Berteaux, who has studied the population of about 110 fox on Bylot Island during the summer since 2003. Previously he had believed fox spent their whole winter on the ice.

To put this to the test, scientists have attached radio collars to fox this year, to follow their annual movements throughout the year.

Berteaux counts the number of red fox on Bylot Island, which have appeared more frequently over the last few decades.

"The elders, they all tell us that 50 years ago, they saw the first red fox," Berteaux said.

Rachel Ootoova, left, and Moses Amarualik relax at camp. Behind them, Elijah Panipakoocho builds a box to carry goose eggs back to Pond Inlet.

It could be one of many species to venture further north if the climate continues to warm, he said.

That could be one threat to the arctic fox population. But there could be other, more complicated, pressures at work as well.

In Scandinavian countries such as Sweden, Norway and Finland, red foxes threaten to squeeze out the arctic foxes.

In those countries, one reason for the decline in arctic foxes could be, oddly enough, reindeer husbandry.

That's because the reindeer industry in those countries has taken its toll on the tundra, and shrunken the habitat for lemmings.

Lemmings are an important food source for arctic foxes. So when reindeer push out the lemmings, the fox populations take a dive, too.

The spread of rabies through the fox populations also likely plays a role.

Elder Gamailie Kilukishak explains the old seal hunting technique of mimicking the seal, allowing him to sneak close enough to kill it with a harpoon. Elders also shared their knowledge of Bylot Island's fox population, which researchers will test by tracking the movement of the animals with radio collars this winter.

These are the sort of complex relationships between different animals and plants that the researchers on Bylot Island hope to chart out in the years to come, Berteaux said.

"We're trying to understand how the tundra ecosystem works."

Other researchers are studying various shorebirds, such as plovers, tiny birds with long legs. These birds are declining in population across North America. "No one knows why," Berteaux said.

The campers also visited a Dorset archeological site called Ikpiugalik, and learned how elders used to stalk seals. Evenings were passed with Gagnon, the group's leader, playing the fiddle, accompanied by an elder on the accordion.

The project received support from the Government of Nunavut's Department of Culture, Language, Elders and Youth, the Continental Polar Shelf Project, the Nunavut Wildlife Management Board, Parks Canada, Arctic Net and Polar Sea Adventures.

APPENDIX 2. List of attendees to the Bylot Island Research and Monitoring Workshop and public consultation on 16 January 2007 at the conference room of the Nattinak Visitor Center, Pond Inlet.

Name	Affiliation	Workshop	Public meeting
Carey Elverum	Parks Canada – Pond Inlet	X	
Samson Erkloo	Parks Canada – Pond Inlet	X	
Brian Koonoo	Parks Canada – Pond Inlet	X	
Israel Mablick	Parks Canada – Pond Inlet	(*morning only*)	
Jane Chisolm	Parks Canada - Iqaluit	X	
Jane Devlin	Parks Canada - Iqaluit	X	
Andrew Maher	Parks Canada – Pond Inlet	X	
Andrew Arreak	Parks Canada – Pond Inlet	X	
Geesoonie Killiktee	JPMC – Pond Inlet	X	
George Koonoo	Wildlife Officer	X	
Shelly Elverum	Inuit Knowledge Working Group	X	
Gregor Hope	Dept Environ GN – Pond Inlet	X	
Isidore Quasa	Inuit knowledge research assistant	X	
Lucy Quasa	Nattinak Visitor Centre	X	X
Joël Bêty	Professor, University Quebec Rimouski	X	X
Ludovic Jolicoeur	Student, University Quebec Rimouski	X	X
Philip Panneak	Inuit Qikiktani Association, translator	X	X
Abby Ootoova			X
Nancy Kadloo			X
Katelin Kadloo			X
Rhoda Koonoo			X
Ezekiel Mucktar			X
Aileen Kadloo			X
Katherina Kubloo			X
David Erkloo			X
Morgan Arnakallak			X
group of 5 students			(*short presence*)

APPENDIX 3. Schedule of the workshop on ecological monitoring on Bylot Island, Sirmilik National Park, Pond Inlet, 16 January 2007.

WORKSHOP ON ECOLOGICAL MONITORING ON BYLOT ISLAND, SIRMILIK NATIONAL PARK

POND INLET, 16 January 2007 – Nattinak Visitor Centre

TUESDAY, 16 January	
9:00-10:00	**Joël Bêty (Université du Québec à Rimouski)** Welcome word – Why doing some ecological research on Bylot Island Research on arctic birds on Bylot Island
10:00-10:20	Coffee Break
10:20-10:50	**Ludovic Jolicoeur (Université du Québec à Rimouski)** Research on insects on Bylot Island
10:50-11:20	**Joël Bêty** New research initiatives on Bylot Island
11:20-11:50	**Jane Chisholm (Parks Canada)** Research and conservation at Sirmilik National Park
12:00-13:30	LUNCH TIME
13:30-15:00	**Joël Bêty & Ludovic Jolicoeur** Presentation of procedures and equipment for birds and insects monitoring Presentation of insects collected on Bylot
15:00-15:20	Coffee Break
15:20-17:00	Meeting between researchers, JPMC members, Parks Canada people, HTO members and other people interested to discuss specific issues/topics related to the Bylot Island ecological monitoring (All to be confirmed. According to individual preferences and constraints)

19:00 – 19:10	**Joël Bêty & Ludovic Jolicoeur** Welcome word to the public evening session
19:10 – 21:00	Public presentation of research performed on Bylot Island Why doing some ecological research on Bylot Island Research on Arctic birds and insects on Bylot Island Presentation of procedures and equipment for birds and insects monitoring Presentation of insects collected on Bylot Island

APPENDIX 4

Pamphlet on shorebird studies on Bylot Island, Sirmilik National Park distributed to the participants at the workshop

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Why Study Shorebirds?

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Shorebirds exhibit one of the most impressive migrations, traveling up to 15,000 km from wintering areas in the south to breed in the Arctic. They are the most diverse group of arctic breeding birds (50 species). Unfortunately, most North American shorebird populations are declining, the reasons for which are poorly understood.

Questions? Please contact us!

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Université du Québec à Rimouski
joel_bety@uqar.qc.ca
(418) 723-1986 ext. 1701

Laura McKinnon:
laura.mckinnon@uqar.qc.ca
(418) 723-1986 ext. 1634

d/8Nù4 **THANK YOU!**

Parks Canada Parcs Canada
ArcticNet
CRSNG NSERC
BioNord
Fonds de recherche sur la nature et les technologies Québec
Canadian Wildlife Service Service canadien de la faune
UQAR
Canada Indian and Northern Affairs Canada

n8 i Dts2 er6b z i wms2 yN i t1ux5

Bylot Island Shorebirds

w3 i s3tQ i q8k5 x?toEJ5

Reproductive Ecology

k o s i q8k5

Breeding Ecology

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kNu WD6g5 s7mD3=4n z i WxC=x q5
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i v9 l 6bsv9MA8N3m5 yMs2 Wsy z
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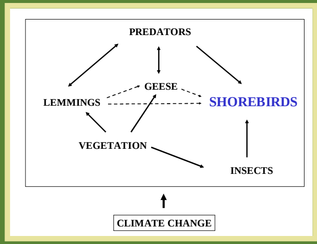
During the breeding season, shorebirds must synchronize hatching with peak insect abundance in order for chicks to survive. Arctic insect abundance is highly correlated with temperature. Rapid climate changes could disrupt this synchrony, negatively affecting shorebird reproduction.

x?b i kN6vt c3 i q5



Community Ecology

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w3 i s l xax3 i q5 cspm/s1m5
x4gx i cha i z k5 x=8z cosuN3 i z k5
x7m l WNh4bsosu i E/q8k5. bwm8N
i vN6gu t Q i q5 bm4f k z
w4W1 i 6t bsnCw8 i q8k5
t t C6bs l x6ym q7m5 xuxovw5
sx1N z i .

Shorebird breeding success is known to be linked to lemming cycles via predators. The vulnerability of different species of shorebirds to predation and the relative importance of predators is virtually undocumented in North America.

y3uo4 vNbomu u3aw6y3= z i m8N cspn6bsJ5

Current Research in Sirmilik National Park

1) cspm/sQx c5b6g5 wms2
yN i usbsJ5 t1ux5 w?}=q5
t t C6bs?9oxQ9 l t4 cz4f5 m8 i q8 i
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2) W=sc5bE9 l t4 dW3DDJw5
x4gx i c3m`z5 cspQx6bs i x3m5 cz4f5
koso6X9oxc5b3 i q5 bm4f x
s7mD6X9oxoC z u4.
3) x0pos6bs?9oxc5b3 l t4
W/sNh1 i q5 x0posDt Cb4f5 bm4f x
WNh4t Q?4b q5 N l Nw6g6bs5 t x3 i x3mb.

1) Monitor shorebird nests to record nest success and timing of breeding
2) Sample insects to compare timing of shorebird breeding with insect availability.
3) Record predation events using remote camera systems to identify predators.