

APPENDIX 1. Detailed discussion of the international scientific literature concerning the winter feeding ecology and distribution of arctic foxes (*Vulpes lagopus*), the relationship between arctic and red foxes (*Vulpes vulpes*), as well as the molting cycle, migration pattern and distribution and abundance of greater snow geese (*Chen caerulescens atlantica*). Since Bylot Island is a very important study site for the latter species, most literature reviewed pertains to the area of Mittimatalik, although references to other areas are also mentioned.

Arctic fox (*Vulpes lagopus*)

Winter feeding ecology and distribution

Arctic fox have a varied diet, opportunistically feeding on a variety of available food sources during the winter. Lemmings (*Dicrostonyx* and *Lemmus* spp.) and voles (*Microtus*) are the primary prey of arctic foxes occupying inland habitats (Macpherson 1964, Angerbjörn et al. 1999, Elmhagen et al. 2000). In winters with low small mammal abundance, or where rodents are mostly inexistent (e.g., Svalbard), arctic foxes feed on caribou carrion, arctic hares, ptarmigan, stored eggs (Macpherson 1964, Chesemore 1968, Fay and Stephenson 1989, Eide et al. 2005) or increase their consumption of marine food sources (Roth 2002). In areas close to human settlements, arctic foxes may also feed on garbage and sheep to complement their winter diet (Kapel 1999).

In coastal areas, the winter diet of arctic foxes consists mostly of sea mammal carrion, invertebrates, seaweed, shellfish and fish (Garrott and Eberhardt 1987, Fay and Stephenson 1989, Kapel 1999). Where bird colonies are found, arctic foxes may also feed on birds and eggs cached during summer (Fay and Stephenson 1989, Sklepkovych and Montevicchi 1996, Bantle and Alisauskas 1998). Arctic foxes have also been reported to follow polar bears on the sea ice to scavenge on the remains of kills (Hiruki and Stirling 1989, Roth 2002). During the late winter and spring, arctic foxes prey on ringed seal pups by entering their subnivean birth lairs (Smith 1976), a behaviour that has been observed in various sites across the Canadian Arctic (Smith 1976, Hammill and Smith 1991, Furgal et al. 1996), Alaska (Burns and Frost 1988, cited in Hammill and Smith 1991) and Spitzbergen (Lydersen and Gjertz 1987). Seal pups may therefore constitute an important food source for arctic foxes (Hiruki and Stirling 1989, Smith 1976), although predation rates vary both annually and regionally (Furgal et al. 1996). Furgal et al. (1996) recorded that at Admiralty Inlet, around 250 km west of Mittimatalik, arctic foxes were responsible for less than 1 % of all seal pup kills in the only year (over three) they recorded successful predation by arctic foxes.

Differences in the ecology of arctic foxes residing in coastal versus inland areas have been documented in Alaska, Svalbard, Iceland and Greenland (Chesemore 1967, Fay and Stephenson 1989, Angerbjörn et al. 1994, Eide et al. 2005). In Greenland, Braestrup (1941) suggested that fox populations were divided into non-rodent eating foxes, mainly the blue color phase and found in coastal areas, and the rodent eating foxes, more frequently the white phase and inhabiting inland areas. On a large scale (i.e., comparing

populations across countries), differences in feeding habits have been measured (Angerbjörn et al. 1994) between inland and coastal foxes. At a smaller scale, two distinctive summer feeding strategies have been documented in areas where arctic foxes occupying coastal areas have access to seabird cliffs (Fay and Stephenson 1989, Angerbjörn et al. 1994, Eide et al. 2005). It has been suggested that the two foraging options, one terrestrial and one marine, may also be adopted by different segments of an arctic fox population during the winter (Roth 2002), although this was not demonstrated.

Winter food may be a limiting factor for arctic foxes (Eide et al. 2005); it may regulate reproductive output (Angerbjörn et al. 1991, Elmhagen et al. 2000) and winter malnourishment can cause mortality (Macpherson 1964). Arctic fox may stay close to shorelines as they provide a variety of food sources throughout the year (West and Rudd 1983, cited in Garrot and Eberhardt 1987). In Alaska, foxes occupying inland areas have been observed to move towards the coast and sea ice during the fall, returning to inland denning sites in spring; however, in some inland areas arctic foxes may remain in their summer range throughout the winter (Eberhardt et al. 1983). Winter food shortages associated with severe rodent declines are also believed to stimulate fox movements or dispersal, and arctic foxes have been documented to have traveled hundreds to thousands of kilometers (Chesemore 1968, Wrigley and Hatch 1976, Eberhardt 1978).

Relationship between arctic and red foxes

Over the last century, a northward expansion in the distribution of the red fox has been observed in North America, Europe and Eurasia (Macpherson 1964, Chirkova 1968). Coinciding with this northward spread of the red fox, the arctic fox has shown a reduction in abundance and distribution throughout its circumpolar range (Chirkova 1968, Angerbjörn et al. 1994), and currently the distribution of these species overlaps extensively (Angerbjörn et al. 1994). Due to their larger size and increased aggression, the red fox tends to outcompete the arctic fox for resources (Rudzinski et al. 1982, Korhonen et al. 1997), and can even be its predator (Hersteinsson et al. 1989). Red foxes may also exclude arctic foxes from highly productive feeding habitats (Elmhagen et al. 2002). When selecting denning sites, arctic foxes tend to avoid areas occupied by red foxes (Tannerfeldt and Angerbjörn 1998). It has been suggested that red foxes may gradually limit the southern distribution of the arctic fox (Angerbjörn et al. 1994). Currently in North America, the possible impacts of the red foxes' northward expansion on arctic fox populations have not been studied (Szor et al. 2008).

Locations and characteristics of arctic and red fox denning areas

From 2003 to 2005, research has been performed on the south plain of Bylot Island to identify the characteristics used by arctic foxes when selecting reproductive and non-reproductive dens (Szor et al. 2008). During an extensive survey performed in summer 2003, 83 arctic fox dens were identified in a study area of approximately 425 km². Analyses of local environmental characteristics of the 83 dens revealed that dens were usually excavated on mounds or steep slopes, most often southerly exposed, in the proximity of streams and on a sandy substrate (Szor et al. 2008). Dens were also preferentially located at sites with high ground temperature, high depth to permafrost and

low snow cover in spring (Szor et al. 2008). Of the 83 dens identified, 27 were used at least once as reproductive dens between 2003 and 2005 (Szor et al. 2008). Resource selection analysis applied to the reproductive dens revealed that proximity to food resources positively influenced the selection of reproductive dens, while proximity to neighbouring dens negatively influenced likelihood of use as a reproductive den (Szor et al. 2008).

Similar characteristics of arctic fox dens have also been found in other arctic regions (Szor et al. 2008). In Svalbard, Eide et al. (2001) showed that dens were more generally located in moderately rugged terrain, likely due to higher ground temperature and early snowmelt. Selection of south-facing slopes for den sites by arctic foxes has similarly occurred due to warmer microclimate and earlier melting of snow and permafrost (Chesemore 1969, Garrott et al. 1983, Prestrud 1992). In the Canadian Arctic, Macpherson (1969) observed that arctic fox seemed to prefer to build dens on sandy and well drained soil, as well as in sites overlooking large valleys or river flats. High ground temperatures, low snow cover and depth to permafrost were also identified as being preferred by arctic foxes when selecting denning sites (Prestrud 1992, Smits et al. 1988, Chesemore 1969). Tannerfeldt et al. (2002) showed that arctic fox also tend to avoid areas with red fox when selecting breeding dens.

Greater snow goose (*Chen caerulescens atlantica*)

Molting cycle

There is no published quantitative data regarding timing of molt for breeding, non-breeding, and failed-nesting snow geese on Bylot Island. Based on unpublished observations and studies performed elsewhere, nesting geese start to molt two to three weeks after goslings have hatched (G. Gauthier, personal communication, Mowbray et al. 2000) and lasts for about three weeks (Mowbray et al. 2000). Based on the average hatching date of 9 July for geese breeding on Bylot Island (Gagnon et al. 2004), breeding geese should start to molt around 31 July, regaining their flight around 20 August. However, this depends on the timing of reproduction, which varies annually (Bêty et al. 2003). Data are available that could allow quantifying the molt timing of adult geese breeding on Bylot Island more precisely. Indeed, measures of the 9th primary feathers taken while banding geese each August, combined with information on feather growth, could allow to quantifying when feather growth was initiated and when it would cease; but deriving this information would take time and has not yet been performed (G. Gauthier, *personal communication*).

Data on radio-collared non-breeding and failed-nesting female snow geese revealed that around 90% of tracked birds departed Bylot Island between the end of June and the middle of July to molt at other locations (Reed et al. 2003). There are few large water bodies providing protection against predators on Bylot Island (Reed et al. 2003). Large concentrations of molting geese (most of which were non-breeders or failed nesters) were observed in 1993, 2006, 2007 and 2008 in an area located about 200 km south of Bylot

Island, encompassing several large lakes (A. Reed and M. R. Evans, *personal communication*). , Although this area is along the spring migratory path of geese that nest on Bylot Island (see below), it is not known whether these molting birds came from Bylot Island or not (G. Gauthier, *personal communication*).

Approximately 700 geese were observed molting on Bylot Island on 15 July 1999 (Reed et al. 2003). No breeding females were observed to have started molting at that time, therefore the authors suggested that these geese were likely non-breeders or failed nesters. The authors also reported that 5 non-breeding radio-collared females molted on Bylot Island and had completed their molt between 31 July and 8 August. This pattern of non-breeding geese molting earlier than the breeders has been mentioned elsewhere in the literature (Mowbray et al. 2000).

Migration pattern

For geese nesting in the High Arctic, the only scientific information available regarding the timing of the fall migration and migration routes is based on five reproductive geese tracked by satellite telemetry from their breeding ground on Bylot Island to their wintering grounds on the Atlantic U.S.A. coast (G. Gauthier, *personal communication*). The tracked birds left Bylot Island between 28 August and 3 September and spent a few days on the north coast of Baffin Island (nearby Milne Inlet) (Blouin 1996). From there, the geese appeared to have made a direct flight across Foxe Basin until they reached the Ungava Peninsula where they spent nearly a month; they then flew inland over the boreal forest and reached their staging area in the St-Lawrence estuary in early to mid October, then left for their wintering grounds in New Jersey and Delaware (Mowbray et al. 2000). Surveys performed in the North Baffin area in summer 2006, 2007 and 2008 suggest that during the spring migrations, the area of Steen Bay, along north Foxe Basin (around 250 km south of Bylot Island), may be an important stopover for geese migrating to Bylot Island (M. R. Evans, *personal communication*).

Trends in population numbers and distribution

Spring surveys conducted at staging areas in the St-Lawrence estuary (Québec, Canada) show a pronounced increase in the greater snow goose population (Reed et al. 1998), from < 40,000 birds in the mid 1960s to nearly 700,000 birds in 1997 (Reed et al. 1998). The primary cause of this population expansion is thought to be due to extensive use of agricultural food resources during the winter, thus increasing survival rates of adults and yearling geese (Gauthier et al. 2005).

Starting in 1983, surveys were performed at five-year intervals during the brood-rearing period on Bylot Island (late July). These surveys also show an increase in the number of geese present on Bylot Island, with the number of adult geese increasing from 25,500 in 1983 to 69,500 in 1993, a year of exceptional reproductive success. The estimated adult population size has declined slightly over that last 10 years, with 60,700 in 1998 (Reed et al. 2002) and 47,800 adult geese estimated in 2003 (J. Lefebvre, *unpublished data*). The same trend has been observed for goslings. Their numbers increased from 26,500 to 86,500 from 1983-1993 and then decreased to 59,100 and 58,000 in 1998 and 2003,

respectively (Reed et al. 2002, J. Lefebvre, *unpublished data*). Failed-nesters and non-nesting geese are reported to leave Bylot Island prior late July (Reed et al. 2003), and therefore would not influence these population estimates. Therefore, variations in the number of geese spending the summer on Bylot Island is likely strongly influenced by their breeding success, which in turn is dictated by spring climatic conditions (Reed et al. 2004) and predator pressure (Bêty et al. 2002).

As the population increased on Bylot, brood densities and distribution of snow geese has varied on the island. The average brood density in 1983 was 5 broods/km², increasing three fold to reach 17 broods/km² in 1993 and decline to 12 brood/km² in 1998 and 2003. During seasons with fewer breeding females (1983 and 1988), broods were distributed among a few areas of high and moderate brood densities and one large area of low density (Reed et al. 2002). As the number of geese increased, areas of high to moderate densities expanded, increasing brood densities within areas which had previously low densities (mostly located on upland sites) (Reed et al. 2002).

During the last 20 years of extensive scientific research performed on Bylot Island, there has been no evidence of consistent changes in the location of greater snow goose nesting sites (G. Gauthier, *personal communication*). Although in some years the distribution of nesting geese has changed, this was likely due to very late spring snow melts or the presence of many nesting snowy owls (*Bubo scandiacus*), with whom geese nest near in peak lemming years. These changes in distribution were always short-lived (one year), and geese resumed their normal nesting pattern in the following year. However, some unpublished information dating back almost 40 years is presently being re-analyzed, and may show some changes over this longer period (A. Reed, *personal communication*). There is no information available regarding changes in numbers and distribution of greater snow geese elsewhere in the Arctic.

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