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Sensitive Areas and Periods of the Greenland White-fronted Goose in West Greenland

Spring staging and moult as important bottleneck periods in the annual cycle of the goose subspecies

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Abstract: In the thesis the different nutritional bottlenecks in the annual cycle of the Greenland White-fronted Goose are discussed, and special emphasis is placed on the spring staging and moulting periods in West Greenland. Eight important spring staging areas were found in central West Greenland in a study that combined early snow-free areas on satellite images and aerial surveys. On a specific spring staging area the female goose fed for almost 80% of the activity budget during a 17 days period. A satellite tracking study with the purpose of identifying spring staging areas in Greenland and Iceland was initiated on the wintering grounds in Ireland. The behaviour of transmitter-fitted geese were studied and an effective harness type was found. The number and distribution of moulting Greenland White-fronted Geese in West Greenland were censused from the air in two years and 25-30% of the winter ing population was accounted for. It is concluded that at present human impacts on the population are small while it is in Greenland because of mineral and hunting regulations, but in the future more staging and moulting areas should be designated.

Keywords: Greenland White-fronted Goose, *Anser albifrons flavirostris*, West Greenland, spring staging, moult, aerial survey, satellite imagery, satellite tracking, behaviour, sensitivity

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Preface

The idea of this Ph.D. study evolved in the former Greenland Environmental Research Institute (since 1995 National Environmental Research Institute, Dept. of Arctic Environment) which assesses the environmental impact of exploration and exploitation of mineral resources in Greenland. In the early 1990s the institution initiated mapping of "Areas Important to Wildlife" in Greenland. The purpose was to regulate mineral activities in order to eliminate or mitigate negative impacts on the wildlife in certain sensitive areas and periods. The work resulted in the production of 16 maps including important areas, protection periods and specific regulations for land and marine mammals, seabirds, ducks and geese (MRA 1996).

In the initial phase of the study different gaps were discovered, among these the lack of information on spring staging and moulting areas of the Greenland White-fronted Goose *Anser albifrons flavirostris*. This Ph.D. study describes the work done to fill in some of these gaps and the study encompasses the period from 1992 to 1998; the study was supported by National Environmental Research Institute, Dept. of Arctic Environment, and the Danish Research Academy.

The study was performed at Zoological Museum, Dept. of Vertebrates, University of Copenhagen with professor Jon Fjeldså as supervisor. The Ph.D. defence took place at the University of Copenhagen on 22 March 1999. The assessment committee consisted of Dr. Jesper Madsen, National Environmental Research Institute, Dept. of Coastal Zone Ecology, Denmark, Dr. Barwolt S. Ebbinge, Institute for Forestry and Nature Research (DLO-IBN), Wageningen, Netherlands, and assoc. prof. Jørgen Rabøl, University of Copenhagen, Dept. of Population Biology.

The four publications of this Ph.D. thesis are referred to by their chapter number in Contents. The status of the publications is the following:

8: *Arctic*, 52 (3) 1999, *in print*,
9: Manuscript (December 1998),
10: *Wildfowl* 1997, 48: 88-97,
11: Manuscript (August 1998).

1 Introduction

The management of *Anatidae*, i.e., the family of ducks, geese and swans, has in North America since the 1977s been performed through flyway management plans. Among these are the plans for the Pacific population of Brent Goose *Branta bernicla*, and the population of Greater Snow Goose *Anser caerulescens atlanticus* (Stroud 1992). Such flyway plans are under way for Eurasian/African populations of especially waterfowl (Boere 1995), and the international conservation plan for the Greenland White-fronted Goose population initiated in 1992 (Stroud 1992), is the first flyway based plan in this part of the world. The need for such a conservation plan is due to the fact that despite an increase in population number, the world population is small with a limited range, the productivity is generally low, wintering habitats are lost and disturbed, about 60% of the wintering population is concentrated on only two sites and the geese are disturbed on their staging areas.

A flyway encompasses the geographical range and the migration routes of a population during its annual cycle, and the flyway based plan includes population status, dynamics and ecology, together with the actual management performed inside the different range states involved (Madsen 1990). These management plans must especially focus on bottlenecks or nutritional bottlenecks, which can be defined as periods when birds are most likely to be stressed and malnutrition is most likely to occur (King & Murphy 1985). Such periods, where extra energy and nutrients are demanded, are spring and autumn migrations, breeding (egg-laying and incubation), moulting and over-wintering periods. Not only should these periods be highlighted, but their relative magnitude should be determined as well (Fox 1996).

Lovvorn & Barzen (1988) claimed that the major metabolic periods are non-overlapping in the annual cycle and therefore could be described with a "staggered cost" hypothesis. A variation of this hypothesis is the "sequential events" hypothesis (Lovvorn & Barzen 1988), where one of the bottleneck periods must be completed before the start of a new energy demanding period. Following this hypothesis, the different bottleneck periods could be dealt with separately, but examples of female geese that exhibits low breeding success after staging on degraded or disturbed spring habitats (Black et al. 1991, Madsen 1994) show that the different periods are more or less dependant of each other.

In the following, the different nutritional bottlenecks in the annual cycle of the Greenland White-fronted Goose together with other constrains to the population are described and compared with such periods in other arctic breeding geese. Special emphasise is placed on the spring migration and moulting periods, and the selection of these periods for more thorough studies in this Ph.D.-Thesis is discussed.

The annual cycle of the Greenland White-fronted Goose is shortly that the geese arrive during October in the Irish and British winter range where they stay for six months. In the middle of April the geese migrate north to Iceland, where they stage for about two weeks. In early May they migrate west across Danmark Strædet and the Greenland ice-cap to the breeding grounds in West Greenland. They stage for one or two weeks at specific staging areas situated in the central breeding range before they continue to their ultimate breeding grounds. Incubation lasts one month, from late May to late June. The geese moult from early July to mid August, the family groups moult two weeks later than the non-breeders. In mid September the geese migrate to Iceland and continue to the wintering grounds during October.

2 Over-wintering

The Greenland White-fronted Goose winters in Ireland and western Scotland, and the wintering population numbered in 1997 about 33,000 birds (A. D. Fox, pers. comm.). About two thirds of the population is confined to only two sites, Islay in Scotland and Wexford in Ireland, whereas the last third consists of about 80 smaller flocks scattered over the winter range (Fox et al. 1998a). The traditional wintering habitat of the Greenland White-fronted Goose is bogland, with callows and rough grasslands as additional habitats (Norriss & Wilson 1993). In the last 15 years the geese have shifted to grasslands that during the same period have been managed more intensively. Since this shift preceded serious bogland changes, Norriss & Wilson (1993) concluded that the farmland changes were responsible for the shift in habitat. Because of continued bogland exploitation, fragmentation and disturbance, these traditional habitats have become even less attractive to the geese. The recent status of flocks using boglands is that seven flocks have become extinct during the last 15 years, five are close to extinction, 18 have declined, 35 are stable and 20 are increasing (Fox et al. 1998a). These different trends are contradictory to the general increasing trend of the total population following hunting bans in the wintering range in 1982-83 (Fox et al. 1998a).

Following the protective legislation, the wintering population increased by 6.6% per annum from 1982-83 to 1991-92, followed by a smaller increase rate in the last four or five years. The total population increased during the 15 year period from about 16,500 to 30,500, and it is concluded that the hunting restrictions are responsible for the increase (Fox et al. 1998a). The increase can not be explained by increases in the production of young, since this production has been stable, yet heavily fluctuating, during the period (Fox et al. 1998a). A similar increase in many western Palearctic goose populations (Madsen 1991) in recent years is considered also to be a consequence of reduced mortality rates due to hunting bans and restrictions (Ebbinge 1991). Ebbinge (1991) argued that the improved feeding conditions on the wintering grounds only played a minor role in these population increases.

During autumn and winter the Greenland White-fronted Geese forage on energy rich foods such as seeds and overwinter storage organs, and during spring the geese shift to grasslands with easily digestible and protein-rich foods, as do most other arctic breeding goose populations (Owen 1980). The restrictions in diet choice due to loss of bogland habitats can affect winter condition, if the geese are not supplied with additional foods such as, e.g., sugar beet on Wexford Slobs (Mayes 1991). Poor grassland quality and disturbance prior to spring migration could be an explanation to the decline in the number of geese in Wexford and to early departure, as observed in 1997 (Alyn Walsh, pers. comm., Glahder & Fox 1997). The geese moved to grasslands in Northern Ireland where they stayed for one week prior to northward migration to Iceland (Glahder & Fox 1997). The weather in spring this year was extremely dry in the Wexford area (Alyn Walsh, pers. comm.).

2.1 Conclusion to over-wintering

It is obvious that the major problem for the Greenland White-fronted Goose population has been the hunting pressure in the wintering range. By elimination of this pressure the population promptly reacted with a rapid increase in numbers. Yet, there are indications that some flocks, both small and big ones, can meet periods of stress during winter due to nutritional deficiencies. Probing in the boglands for plant storage organs is time consuming and can be impossible during periods of severe frosts. In these situations the geese move to grasslands where foods are relative poor in energy and nutrition. On the Wexford Slobs, one of the two major wintering sites, the geese are unable to attain their energy balance during mid-winter solely by grazing (Mayes 1991), but have to supplement their diet with sugar beet cultivated on the reserve. During early spring, grazing is important because the geese need to improve their condition rapidly and to store protein for the future egg-laying period. There are indications that geese during, e.g., a dry spring period leave Wexford early because of poor grass quality inside the reserve and because of intensive scaring outside the reserve.

An additional stress is put on the bogland flocks, because human exploitation has fragmented the feeding areas and the geese are more sensitive to disturbances on smaller areas. These are among the reasons why some bogland flocks have become extinct or have declined in recent years. In order to maintain the wintering range of the Greenland White-fronted Goose, it is important to protect these flocks by adequate conservational steps.

3 Spring migration and staging

Most arctic breeding goose populations build up stores on the wintering grounds prior to spring migration, and then supplement their condition at one or more spring staging areas before they reach their breeding grounds (8, i.e., the publication in chapter 8 of this Ph.D.-Thesis). The Giant Canada Goose *Branta canadensis maxima* probably only build up condition on the wintering grounds, whereas two populations of Canada Geese *Branta c. minima* (Cackling) and *B. c. occidentalis* (Dusky), the Greater White-fronted Goose *Anser albifrons frontalis* and the two subspecies of Snow Goose, *Anser caerulescens caerulescens* (Lesser) and *A. c. atlanticus* (Greater), are feeding on the breeding grounds prior to nesting (8). The spring migration strategy of the Greenland White-fronted Goose is most comparable to the latter group of goose populations, but pre-breeding feeding is confined to specific spring staging areas. Unlike most of the arctic breeding geese, the Greenland White-fronted Geese must rely on only one spring staging range, i.e., Iceland, because most of the migration route is across ocean and ice.

It has been shown that feeding on the wintering grounds and on the spring staging areas, to acquire adequate nutrient and energy reserves prior to the breeding season, is of considerable importance for the geese to breed successful (8). Because geese produce precocious hatchlings much energy and nutrients must be invested in the egg production. The major components of the eggs are lipids, protein and calcium. Lipids can be stored to a great extend in the body, and are metabolised from a variety of vegetable foods. Differences in digestibility and energy content of the food influence the time necessary for feeding, so geese that forage on foliage spend about 80% of the daylight hours feeding during early spring (9, Raveling 1979 in Krapu & Reinecke 1992, Boudewijn 1984, Madsen 1985) compared to a much lesser effort when geese are feeding on barley grains (Madsen 1985). Proteins are stored to a much lesser extend than lipids, so protein is often considered the most limiting nutrient to reproduction among geese (Krapu & Reinecke 1992). Most goose species acquire protein on the staging areas or on the breeding grounds primarily from fresh foliage of grasses, sedges and herbs. As the geese migrate north, they are able to take advantage of the protein rich initial stages of plant-growth, the so called "protein-wave " (Drent et al. 1978). The Dusky Canada Goose delays nesting until new sedge shoots are available on the breeding grounds (Bromley 1984 in Krapu & Reinecke 1992). Calcium is, in most goose species, acquired on the breeding grounds primarily from underground plant parts, and from associated soil minerals (Krapu & Reinecke 1992).

The Greenland White-fronted Goose shifts to grasslands on the wintering grounds early in spring, and the stored energy is mainly used for the migration to Iceland, a distance of about 1,500 km. On Iceland, the geese sequentially feed on improved grassland habitats, and recent studies have shown that the geese feed on the youngest lamina of the grass *Phleum pratensis*, and that the fields are generally exploited three and four times during spring staging (Fox et al. 1998b).

Much of the stored energy is probably used during the c. 1,500 km long migration to West Greenland, as indicated by the low abdominal profile index, API, of the arriving geese (9). The median API of arriving female was 1.5, increasing to 2.5 after about two weeks (9). In female Barnacle Geese *Branta leucopsis*, migrating a similar distance as the Greenland White-fronted Geese, the API decreased about 1.5 to 2.0 (Owen 1981). Greater Snow Geese and Dusky Canada Geese depleted 44% and 52% of their accumulated fat reserves, respectively, during migration distances of 2,600-3,000 km (Gauthier et al. 1992, Bromley & Jarvis 1993).

Upon arrival on the spring staging areas in central West Greenland, the female Greenland White-fronted Goose feeds for nearly 80% of the diurnal period during 3-19 May (9). The geese feed mainly on over-wintering storage organs such as the stem-bases of *Eriophorum angustifolium* and *Carex cfr. bigelowii*, the rhizomes of *Polygonum viviparum* and buds of *Triglochin palustre*. These foods are mainly eaten for the build-up of fat deposits, but *Polygonum* buds holds about 13% protein (Krapu & Reinecke 1992), and the necessary calcium intake is probably sufficient from these foods. Protein is obtained from, e.g., sedge sprouts (9) and early stages of grasses from the Icelandic staging habitats. An average length of stay of about seven days was calculated (9), but it is perhaps slightly longer, as shown by three adult males fitted with satellite transmitters (10); their staging period was between 8-10 days (Glahder et al. 1998). Since a period of 11-14 days is thought necessary for rapid oocyte growth (C. R. Grau in Ely & Raveling 1984), the final development probably takes place on the breeding ground.

It is obvious that most of the stress during the pre-breeding period is on the female goose, because she both has to put much energy into clutch production, and must have energy reserves to withstand the incubation period. The male uses much of his pre-breeding time being alert (20-55% of the time budget) and feeds only for about 40% of the time (9). Male vigilance is essential for the female to devote most of her time to forage. As a consequence of the time spend alert, the median male API increased only to 2.0 by the end of the spring staging period compared to 2.5 in the female (9). In pre-breeding male Greater Snow Geese, Gauthier & Tradif (1991) found that feeding for 44% of the time was not sufficient to meet the daily energy expenditures, and male Lesser Snow Geese used their somatic reserves during that period (Chonière & Gauthier 1995). Chonière & Gauthier (1995) speculated that male vigilance was essential also to protect his paternity from male intruders; this is probably more important in colony breeding geese, e.g., snow geese, than in solitary breeders like the Greenland White-fronted Goose.

The Greenland White-fronted Goose arrives in West Greenland in small flocks of on average 7.7 birds, and these are almost exclusively adult birds (9). On a survey of possible spring staging areas, 75% of the observed geese were concentrated on eight areas only (8). The number of potentially breeding birds was calculated to c. 6,000, and the number of successfully breeding birds to about 3,400 (8). This number of successfully breeding birds is low compared to other subspecies of the White-fronted Goose (Stroud 1992). Following the spring staging period, the geese move to their breeding grounds, which, in the central breeding areas, are situated c. 50 km from the staging areas, but more than 600 km away in northern breeding geese. These movements are based on only three satellite fitted adult geese (10, Glahder et al. 1998), and needs to be substantiated.

During the spring migration and the pre-breeding period, the Greenland White-fronted Goose is, or can be, exposed to human impacts that adds to the natural stress of the potentially breeding birds. The geese stage in West and South Iceland for two to three weeks (Fransis & Fox 1987, Fox et al. 1997, Glahder et al. 1998). Here, conflicts with farmers are possible, because wetlands recently have been converted to agricultural use. Illegal spring hunting is thought to occur and may be widespread in some areas (Stroud 1992). Goose hunting in Iceland is popular and increasing. There are few refuges for waterfowl, e.g., Hvanneyri in West Iceland where hunting is not allowed (Stroud 1992, Fox et al. 1994).

Upon arrival in Greenland, there seems to be no problems on the east coast where the geese rest for only one or two days (Stroud & Fox 1981, Glahder et al. 1998). In West Greenland, illegal hunting is thought to take place at, at least, one of the eight most important staging areas. During this period of the year, areas are difficult to reach by boat, skidoo or dog sledge due to much ice in the fjords and little snow on the ground. There is a potential disturbance risk from the increasing mineral exploration in Greenland. Not only is the number of activities increasing, but also the exploration period has been extended, and covers today most of the year. For example, diamond exploration in West Greenland is common during early spring. Helicopters, widely used in mineral exploration, are the greatest potential disturber, but also exploration teams and drill rigs can cause disturbances during spring (8, 9).

3.1 Conclusion to spring migration and staging

This period of the annual cycle of the Greenland White-fronted Goose is probably the most energy demanding. Especially the female must use most of her time feeding, to acquire enough fat, protein and calcium for the egg production, on top of the energy required for long distance migration and maintenance. Also, the male must rely on stored energy during this period, because much of the time is spend vigilant in order to protect the heavily feeding female from predators and secure her optimal feeding from intraspecific competition. In flock pairs the male spends more than twice the time being alert than in single pairs, whereas the female feeding activity is unaffected by group size (9, Fox & Madsen 1981).

New grass shoots, easily digestible and protein rich, as well as protein rich winter wheat foliage and energy rich grains, can facilitate energy and nutrient intake. Food intake is facilitated as well because of the almost diurnal daylight the geese meet while moving northward. Yet, severe weather conditions, e.g., heavy snow fall, during this period can promptly reverse these advantages. In order to save energy during the migration, the geese seem to take advantage of tailwinds or calm weather (Owen 1980, Glahder & Fox 1997, Glahder et al. 1998). Predominant tailwind during the spring migration of Brent Geese, had a positive influence on their breeding success (Ebbinge 1989).

The breeding success can be affected by heavy disturbance during this period, for example from hunting or scaring by farmers (Madsen 1994). Such effects are most likely to occur in Iceland, because of wetland conversions to farmland, few protected feeding habitats and some illegal hunting. In Greenland some illegal hunting, unfortunately on one of the probably most important staging areas, can affect reproduction output, and mineral exploration is a potential source of disturbance. However, the eight most important spring staging areas are currently included as "Important Areas to Wildlife" in mineral rules and regulations from the Greenland Bureau of Minerals and Petroleum.

4 Breeding

The breeding range of the Greenland White-fronted Goose is the low arctic tundra of West Greenland between 64°-72°30'N (Salomonsen 1950). The nest is most often placed on gently sloping hills or on top of elevated ground near lakes and marshes, at altitudes from 50 to 700 meters (Salomonsen 1950, Fox & Stroud 1988). The Greenland White-fronted Goose is solitary nesting with nest densities <0.5 pr. km^2, which is lower than recorded for other subspecies of the White-fronted Goose (Fox & Stroud 1988). Clutch initiation is between 19-28 May, and incubation lasts for 26-27 days (Owen 1980, Stroud 1981). The normal clutch size is six.

The strategy of the Greenland White-fronted Goose, as well as of Greater White-fronted Goose (Ely & Raveling 1984) and Greater Snow Goose (Choinière & Gauthier 1995), is to start oocyte development upon arrival on the breeding range. The advantage of this strategy is that clutch formation can be halted in severe weather conditions, such as snow cover and frost, where feeding opportunities are difficult and nest sites are not available. On the other hand, in favourable weather situations the goose has to wait for about two weeks before clutch initiation. In two years with very different weather conditions, Fox & Stroud (1988) found no differences in percentage young and mean brood size on the wintering grounds. This indicates that waiting for optimal breeding conditions is a possibility, at least to low arctic breeding geese, because of a relatively long summering period. Prop & Vries (1993) found that in high arctic (78°N) breeding Barnacle Geese intermediate or early breeding pairs were apparently evolutionary favoured.

An alternative strategy is found in Lesser Snow Goose and Ross' Goose *Anser rossii*, where the geese are ready to start egg-laying a few days after their arrival on the breeding grounds (Ryder 1972, Ankney & MacInnes 1978, Owen 1980). One of the draw backs of this strategy is that in late seasons breeding fails almost completely, because follicles are resorbed and relaying is normally not observed in arctic breeding geese (Barry 1962, Klopman 1958 in Johnson et al. 1992).

The eggs are incubated solely by the female Greenland White-fronted Goose and during this period feeding is negligible (Fox & Stroud 1988). The time spent incubating is >99.99% in Greenland White-fronted Goose compared to 97.3% in Greater White-fronted Goose and 96.2% in colony breeding Pink-footed Geese *Anser brachyrhynchus* (Fox & Stroud 1988). There are indications that geese with a larger body size incubate for a longer period, and feeds less, due to lower mass specific metabolic rates; yet, this pattern is not found in the relatively large Greater Snow Goose, where females incubate for only 93% of the time and loose only 17% of their body mass due to periods of intensive feeding (Reed et al. 1995).

During incubation the female looses about 40% of her body mass as demonstrated in Lesser Snow Goose (Ankney & MacInnes 1978) and in captive Barnacle Geese (Owen 1980). Greatest weight losses are found during egg-laying, but as incubation proceeds weight losses decreases because metabolic maintenance decreases with falling body weight. The female gains weight again after hatching. The fact that the female is stressed by the end of incubation is illustrated by records of Lesser Snow Geese dying on the nests, usually following bad weather conditions (Harvey 1971 in Owen 1980).

The male Greenland White-fronted Goose stays vigilant for most of the time, but has also time to feed in the nearby marshes (Fox & Stroud 1988). The male Lesser Snow Goose looses, despite feeding, on average 20% of his initial weight during the pre-breeding and incubation period. The male continues to loose weight after hatching (Ankney 1977 in Owen 1980, Ankney 1979). That female and male use most of their time either incubating or vigilant, is obviously a necessity in order to defend the clutch from predators, mainly Arctic Foxes *Alopex lagopus*, but also Ravens *Corvus corax*, and it is shown that female vigilance is positively correlated to Arctic Fox activities (Fox & Stroud 1988). The rate of Greenland White-fronted Goose nests predated by foxes in two study years was very high (62%) compared to a 5% rate in Greater White-fronted Goose in Alaska (Ely & Raveling 1984). In colony breeding Red-breasted Goose *Branta ruficollis* 14.6% of nests were destroyed by Arctic Foxes during 1977-1983 (Kostin & Mooij 1995). This loss was evident despite the strategy of Red-breasted Goose to select nesting sites close to nesting birds of prey, or near gull colonies, in order to obtain protection against Arctic Foxes (Kostin & Mooij 1995). Following lemming (*Discrostonyx torquatus* and *Lemmus sibiricus*) peak years, Ebbinge (1989) found that Brent Geese were unable to reproduce because of heavy Arctic Fox predation. So, comparing the percent of nests lost to predation, it seems that solitary breeding Greenland White-fronted Goose are disfavoured; but, probably the predation rate found by Fox & Stroud (1988) is biased by the presence of the observers and the material is small, i.e., 13 nests in two years. In a study of breeding Pink-footed Geese in East Greenland (Cabot et al. 1984 in Fox & Stroud 1988) solitary nesting pairs laid significantly larger clutches and probably raised bigger broods than more gregarious breeders.

In the area studied by Fox & Stroud (1988) the newly hatched brood was led to an area with high plateau lakes abundant in food and refuge lakes. There were indications that favoured nesting sites were close to these plateaus, probably in order to minimise the predation risk during the move from nests to feeding areas (Fox & Stroud 1988). During the period from hatching to fledging the geese followed another "protein-wave" gradient than the latitudinal gradient used during spring; here, the emerging plant growth followed an altitudinal gradient combined with late snow melt, especially on northfacing slopes (Madsen & Fox 1981). Thereby, the goslings were able to maximise their energy and nutrient intake, so important in order to achieve fledging before the foraging conditions deteriorate. Two weeks after hatching, up to 50% of the gosling diet constituted *Equisetum variegatum*, which is easily digestible but relatively poor in nutrient content. Yet, Hughes et al. (1994) found *Equisetum arvense* of particular importance to newly hatched Greater Snow Geese, because of the plants being rich in minerals (Thomas & Prevett 1982). The goslings of the Greenland White-fronted Goose also grazed herbs

(*Stellaria* and *Polygonum*) absent from the adult diet. In the following weeks the differences in gosling and adult diet became less apparent (Madsen & Fox 1981).

During the post-hatching period bad weather conditions such as heavy rains, can have a negative influence on goose productivity as measured on the wintering grounds in White-fronted Goose *Anser albifrons albifrons* (Boyd 1966 in Fox & Stroud 1988). Fox & Stroud (1988) speculated that the higher proportion of young on the wintering grounds could be a result of dry summers. The annual productivity on the two major wintering sites (Wexford and Islay) differed during the last three decades between 5% and 35% young (Fox et al. 1998a), but so far, no connection has been established between productivity and conditions on the breeding grounds (as tried by e.g., Ebbinge 1989). Fox et al. (1998a) demonstrated that there was no significant difference in percentage of young between the periods before and after hunting protection on the two wintering sites. The mean annual percentage of young was during 1983-1995, 15.4% on Islay and 17.7% on Wexford (Fox et al. 1998a). This percentage is very low compared to percentages of 30-38 in other populations of White-fronted Geese (Stroud 1992). Because the brood size of Greenland White-fronted Geese is higher (2.7-3.6) than in other White-fronted Geese (2.2-2.6), Stroud (1992) concluded that the low productivity and high average brood size indicate that an exceptionally small number of pairs breed successfully.

Other factors affecting the reproductive success is the age and behaviour of the breeding pair of geese. In general, older females lay earlier and produce larger clutches than younger females (Raveling 1981, Fox 1996), and acquired experience seems to explain this relationship the best for geese up to six years of age (Fox 1996). Studies of feral Canada Geese have shown that pair dominance allowed the female to feed more, which was positively correlated with earlier breeding, increase clutch size and fledging success (Warren 1994 in Fox 1996).

Human impacts during the breeding period that can affect the breeding success seem to be of minor importance. Hunting of any species is not allowed during this period. Mineral exploration, described in the previous chapter, can cause some disturbance during nest site selection, late incubation and post-hatching, but because of the low density of nests, disturbances are probably negligible. Tourists and locals can visit the breeding areas late in the breeding period, and most visits are on foot in smaller groups.

4.1 Conclusion to breeding

This is the period of the annual cycle where all of the increase to the population occurs, and much of the mortality is connected to this period as well. Compared to other White-fronted Goose populations the reproductive output in the Greenland White-fronted Goose is small, with only about 15% yearlings of the total wintering population, and above 30% in other subspecies. The reason for this marked difference remains unclear, but can be an evolutionary trait. Hunting bans in Ireland and the British Islands had no positive effect on the percentage of yearlings on the wintering grounds (Fox et al. 1998a). Yet, autumn hunting in Greenland and Iceland, with some 3,000 geese shot in Iceland (Sigfusson 1996), could be responsible to the low production, especially if yearlings are shot the most. A possible way to test this hypothesis would be to introduce a hunting moratorium of, for example three years. It is obvious from the high year to year variability in production output (Fox et al. 1998a), not uncommon in arctic breeding geese (e.g., Ebbinge 1989) that other factors, such as weather and predation, influence reproduction.

During incubation in the female, and both during incubation and post-hatching in the male, the geese are increasingly stressed because of no or little feeding. Heavy disturbance late in the incubation period and early in the post-hatching period could impact negatively on reproduction because of extra energy used for escape flights. Probably, there is little human impact during this period, both because of relatively little activity in most breeding areas, and because of the low nest density.

5 Moult and post-moult

Immature and non-breeding Greenland White-fronted Geese increase in flock size from June onwards and they moult from the first to the fourth week of July, while the breeding birds start about two weeks later (Fox et al. 1983). There seems to be no moult migration in immature and non-breeding Greenland White-fronted Goose (Salomonsen 1968). Such a moult migration is described in many arctic breeding goose populations, and most are in a northerly direction (Salomonsen 1968, Hohman et al. 1992). In East Greenland, the Icelandic and Greenland population of the Pink-footed Goose migrates north, whereas the Barnacle Goose also shows a southward moult migration (Madsen et al. 1984). In West Greenland a north-eastward moult migration of Canada Geese from Canada has occurred during the last 10-15 years (Fox et al. 1996). The purpose of the moult migration in immature and non-breeding adults is probably to avoid competing for food with the family groups (Salomonsen 1968, Madsen 1990). According to another theory put forward by Krohn & Bizeau (1979, in Hohman et al. 1992), the moult migration results from increased survival in birds participating in moult migrations compared to birds that do not. The problem with this theory is that all groups in the following year can be part of the breeding population and therefore do not participate in the moult migration. The northward movement is thought to be an adaptation to the later growth start of the vegetation to the north (again the geese take advantage of the "protein-wave"), which provides the geese with early and more nutritious growth stages of food plants.

Instead of a moult migration, the non-breeding Greenland White-fronted Geese follow an altitudinal gradient as described in the post-hatching breeding birds in the previous chapter. Such a moult strategy has been described also in the Lesser White-fronted Goose *Anser erythropus* (Ekman 1922 in Owen 1980). The moulting behaviour of Greenland White-fronted Geese was studied in mountainous areas (Madsen & Fox 1981), while the feeding strategy in lowland areas like Naternaq (11) has not yet been studied. Regular grazing by the geese is, in these lowland areas, a way to keep plants at an early stage of growth and maintain high nutrient levels (Ydenberg & Prins 1981, Fox et al. 1998b). A possible explanation to the fact that non-breeders moult in the breeding range is that the density of breeding pairs is low, and thus intraspecific competition is low (Fox & Stroud 1988). Due to the increase in Canada Geese in West Greenland (Fox et al. 1996, Glahder et al. 1996), interspecific competition of the two species is a possibility. Because the body size of the Greenland White-fronted Goose is smaller than that of the Canada Goose, this competition can lead to a poorer diet in the Greenland White-fronted Goose, as Madsen & Mortensen (1987) observed in Barnacle Goose and Pink-footed Goose in East Greenland.

During moult the Greenland White-fronted Geese graze the fresh shoots and leaves of sedges, grasses and *Eriophorum* sp., and no roots are found in the droppings. Late in the moulting period a snow-patch grass *Trisetum spicatum* was found with increasing frequency in the droppings (Madsen & Fox 1981). During moult, the geese feed close to lakes or rivers that serve as refuges from predators.

In most goose populations studied during moult, the time spend feeding is moderate compared to the pre-breeding period. In general, female attending broods feeds more than the male, which on the contrary spend more time vigilant than the female. Feeding in female Greater White-fronted Goose, Pink-footed Goose, Greater Snow Goose and Cackling Canada Goose varies between 25% and 46% of the time budget, whereas Lesser Snow Goose female spends more than 77% of the day feeding (Hohman et al. 1992). There seems to be no clear pattern in the time spend feeding in non-breeding geese compared to the breeding geese. In Greater Snow Geese there seem to be no difference, in Lesser Snow Geese non-breeders feed more than breeders and in Pink-footed Geese non-breeders feed less than breeders (Hohman et al. 1992). Non-breeding Barnacle Geese feed for 33% of the time which is comparable to the time spend feeding during winter (Owen 1980). Owen (1980) argued that the extra energy used by the geese during moult was compensated for by remaining relatively inactive, i.e., flightless. Much energy is saved in this way, because flying is the most costly activity performed by birds.

Parents in most studied goose species start their moult when the goslings are 3-4 weeks old, and it seems that the moult of the male and female are controlled by different factors. In male Barnacle Geese there was a significant correlation between the moult stage and the mean weight of the brood (Owen 1980), which was not the case in the female. The relationship meant that males were flightless 1-2 weeks after the fledging of the goslings, but were able to fly and defend the goslings from flying predators during the critical first weeks of the goslings (Hohman et al. 1992). Owen (1980) speculated that the female goose, low in body weight following the egg-laying and incubation, had to gain weight up to a minimum level before she could initiate moult.

Geese have only one body moult every year and most conspicuous is the wing moult. During moult, up to one third of the total body protein content is shed and must be replaced over a relative short period (Hohman et al. 1992). Studies have shown that geese are able to meet their energy and protein demands by feeding during the moult, and do not necessarily have to deplete their energy and nutrient reserves. In Canada Geese, Lesser Snow Geese and Brent Geese, protein reserves are in general either unchanged or increasing during moult (Hohman et al. 1992). In both male and female Brent Goose (Ankney 1984) and Lesser Snow Goose (Ankney 1979), the protein content in leg muscles increased. These changes are ascribed to disuse-use of muscle groups, with degraded proteins from breast muscles build into leg muscles (Hohman et al. 1992).

Prior to the wing moult the body mass of female Snow Geese and Canada Geese, and male Brent Goose, do increase (Ankney 1979, 1984; Raveling 1979) and through the moulting period the body mass is constant or increasing (Hohman et al. 1992). Owen (1980) observed a constant body mass in breeding Barnacle Geese, but declines in body mass in four out of five age and sex classes of immatures and non-breeders. Some of the immatures weighed only about 60% of the winter weight late in the moulting period and they were thought close to starvation. The amount of food was low during their moulting period which was initiated a few weeks earlier than that of breeding birds. These observations do suggest that non-breeders might be stressed in periods of food shortage, due to bad weather, or due to intra or interspecific competition.

Arctic breeding geese complete the wing moult more rapidly than do some duck species, and Snow Geese and Brent Geese are able to regain flight within only 21 days and 22-25 days, respectively (Hohman et al. 1992). This rapid development of the remigies is probably an adaptation to the short arctic summer period.

The moulting areas of both immatures, failed breeders and breeding Greenland White-fronted Geese are in the West Greenland breeding range. In the study on distribution and concentrations of moulting Greenland White-fronted Geese (10), areas in the northern part of the breeding range, i.e., between 67°-72°N, were surveyed from the air during July 1992 and 1995. About 10,000 km^2 was covered of a total potential moulting area of about 45,000 km^2, and about 25% of the wintering population was counted during each of the two years. Most moulting geese (≥95%), in the breeding range south of 69°N, were associated to moderate vegetation index values (Normalised Difference Vegetation Index, NDVI, (11)), and it was argued (11) that this NDVI index could be used to delimitate potential moulting areas. The average flock size the two years was about 25 geese, with a maximum flock size of 454 geese. The average densities were about 1 goose pr. km^2, ranging from 0.3 to 2.6 goose pr. km^2. Many of the flocks included family groups, but the percentages of young were only about 25% of that observed on the wintering grounds. This indicates that many families moult separately, but a substantial part of the families were probably overlooked in the dense flocks observed from the air. The distribution of moulting geese the two years was very different, and an explanation could be the very different weather conditions the two years. In a cold spring and summer, e.g., that of 1992, the moulting geese will concentrate in the central breeding range, with northern and southern areas being able to support only about half the numbers they can support in a warm spring and summer, e.g., 1995 (11). Also, productivity was affected in 1992, with a juvenile production of only about 40% of that in 1995, the latter production being close to the mean of c. 17%; production was calculated from the percentage of juveniles in the population the following winter (Fox et al. 1998a).

Following the moulting period, all migratory waterfowl increase their body mass (Hohman et al. 1992). By this time of the year the geese feed on seeds or storage organs as they move southward (Owen 1980). Many geese populations breeding in North America and Siberia move gradually southwards, for example in front of freezing conditions as observed in Canada Geese (Owen 1980). The Greenland White-fronted Goose crosses the ice-cap and oceans on their way back to the wintering grounds, and Iceland contains the only suitable staging areas en route; here, the geese feed on *Polygonum* bulbils and *Carex* seedheads (Fox et al. 1983). Lesser Snow

Geese increased their fat reserves significantly during the autumn, and Wypkema & Ankney (1979) suggested that this fat gain influenced their ability to complete normal autumn migration, and that prolonged disturbance of the geese could potentially affect migration. In Barnacle Geese breeding in Svalbard, Owen & Black (1991) found that the 3,000 km autumn migration was the most hazardous period of the annual cycle of both adults and juveniles. In one year there were indications that 35% of young geese died during autumn migration. Owen & Black (1991) demonstrated that natural mortality was density dependant for both adults and young, and they suggested that competition for food during the rearing and fattening periods be responsible for the observed mortality.

The Greenland White-fronted Goose moults and breeds in the same West Greenland areas. Thus, disturbance from mineral exploration, as described in previous chapters, is a possibility during moult. Because of the flocking behaviour of the moulting geese, these disturbances can have a greater effect during moult than during the breeding period, where densities are low. Moreover, geese are probably much more sensitive to disturbances during moult than at any other period of the annual cycle (Mosbech & Glahder 1991). In the study it was demonstrated that Pink-footed and Barnacle Geese reacted to approaching helicopters at distances of 3-9 km. Probably the geese are highly sensitive during the period just prior to the moult, and heavy disturbance during this period is likely to make the geese abandon potential moulting grounds, as indicated by Mosbech & Glahder (1991). Many of the important moulting grounds are protected against disturbances from mineral exploration activities (MRA 1996).

The Greenland White-fronted Goose is legal quarry in West Greenland during 16 August-30 April. The total number of all geese species shot in Greenland in 1995 was 1716 (Anon. 1997), and in 1993 the West Greenland proportion made up about 75% (Anon. 1995). Thus about 1300 geese were shot in West Greenland, and among these a considerable part must be Canada Geese (Fox et al. 1996, Glahder et al. 1996). Probably most Greenland White-fronted Geese are shot during autumn, but illegal hunting is thought to take place in spring. The Caribou *Rangifer tarandus* is hunted in West Greenland during 10 August-10 September and some hundreds of hunters hold a licence. The Caribou is distributed in most of the Greenland White-fronted Goose summer range but with highest densities between 62° and 68°N. Disturbance of the geese from the Caribou hunt is a possibility, but probably only to a minor extend because most geese are thought to stay far inland near the ice-cap by this time of the year.

In Iceland the Greenland White-fronted Geese are legal quarry in autumn and about 3,000 birds are shot annually (Sigfusson 1996). Effects of disturbances during hunting are likely because Iceland has no officially designated refuges for waterfowl (Stroud 1992, Fox et al. 1994).

5.1 Conclusion to moult and post-moult

It is a common viewpoint that the moulting period causes nutritional stress in waterfowl (Hohman et al. 1992), but in most studied goose populations the body mass and protein reserves are stable or increasing during moult. So, under normal conditions the geese do not deplete their energy and nutrient reserves during moult, but are able to meet the demands during moult through food intake. The time spend feeding is in most goose populations about 30%-40% of the time budget, which indicates that energy and nutrients are achieved from relative easily digestible, and energy and nutrient rich foods. This is in agreement with the geese mostly feeding on emerging shoots and leaves of grasses and sedges. Probably because of intraspecific competition for foods, immatures and failed breeders in many arctic breeding goose populations exhibits moult migrations, and most migrations are in a northerly direction. Such a northward moult migration is not observed in the Greenland White-fronted Goose, but in some moulting areas of West Greenland non-breeders take advantage of a comparable altitudinal gradient to forage on newly emerging plants. During the period prior to the autumn migration, the geese increase their body weight mostly by feeding on storage organs. Limited amounts of food during moult can lead to a decrease in body mass as observed in immatures and failed breeders of Barnacle Geese (Owen 1980).

Owen & Black (1991) found that autumn migration in Barnacle Geese, with a substantial part of the 3,000 km route across ocean, was the period of the annual cycle in the non-hunted population with the highest mortality. Competition for food was suggested to be responsible for the observed mortality. The autumn migration of the Greenland White-fronted Goose is similar in both length and ocean crossing, but no estimates have been made on mortality during this flight. Moreover, the Greenland White-fronted Goose is hunted in Greenland and Iceland with a harvest of at least 10% of the wintering population. Beside the goose hunting, Caribou hunting can disturb the geese, but probably only to a minor extend, because most geese are thought to stay on rather inaccessible places by this time of the year. The moulting grounds of the West Greenland tundra are today not developed by humans, but mineral exploitation can open up these areas by construction of mines, roads and air strips. Mineral exploration, especially if conducted by the use of helicopters, can make the geese abandon potential moulting grounds prior to moult, and can affect the moulting geese because of their high sensitivity during this period.

6 Conclusion

In the introduction, bottlenecks or nutritionally bottlenecks are, according to King & Murphy (1985), defined as periods when the birds are most likely to be stressed and malnutrition is most likely to occur. In the previous chapters, the different bottlenecks: over-wintering, spring migration, breeding, and moulting, including the autumn migration, have been described in the Greenland White-fronted Goose, with examples from other arctic breeding goose populations, and with a discussion of possible human impacts. Here, the relative magnitude of the different constraints to the population of today and in the future will be discussed.

The body mass of arctic breeding geese shows considerable fluctuations during the annual cycle, and the body mass can be used as an indication of the general condition of the goose. Changes in the body mass are greatly influenced by the lipid metabolism, or the energy demand of the goose, whereas the need for proteins and minerals are less well expressed by this parameter. According to Owen (1980) the body mass in female Lesser Snow Goose changed by 73% of the minimum weight (1.7 kg) and in male by 42% of the minimum weight (2.0 kg). A low body mass does not necessarily mean that the goose is nutritionally stressed. If the autumn migration is months away and food is abundant and nutritious, the geese do not need to be fat (Ankney 1979). Low body weight during late moult can shorten the flightless period, and in general, geese are able to regain flight when remiges are about 70% of their final length (Hohman et al. 1992). But, in general, a relative low body mass gives the goose a smaller margin to withstand stressful situations, exemplified in female Lesser Snow Geese dying on the nest (Harvey 1971 in Owen 1980), and in Pink-footed Geese, disturbed on the spring staging areas, reproducing less successful than undisturbed geese (Madsen 1994).

The periods during the annual cycle of the Greenland White-fronted Goose, where the body mass is or can be expected to be at its lowest, is during late winter, after the different sections of the migration and during incubation. Also, the body mass can be low in immatures and failed breeders during late moult (Owen 1980). Extra stress as for example disturbances from mineral activities, hunting and other recreational activities added to the bottleneck periods can impact negatively on the population.

During winter, hunting was in former days the most important human stress factor that influenced the Greenland White-fronted Goose population. Following hunting bans throughout the winter range in 1982-83, the population increased rapidly and almost doubled during a period of about 10 years (Fox et al. 1998a). Two-thirds of the population is protected on areas designated as Ramsar sites (Islay in Scotland and Wexford in Ireland), and Special Protection Areas (SPA) (Islay) (Stroud 1992). So, in general the Greenland White-fronted Goose is well protected during the late winter period. Yet, the last third of the population is confined to about 80 rather small and unprotected sites, and an additional stress is put on these flocks because of human exploitation and fragmentation. Despite the overall increase in the Greenland White-fronted Goose population some of these flocks have declined in recent years.

The Greenland White-fronted Goose incubates in June in West Greenland. During this period most disturbances are probably caused by mineral exploration activities, and their use of helicopters. The effects of these activities are probably small, overall, because of the huge breeding range, the low nest densities and the regulations of mineral exploration activities. The mineral activities are regulated inside "Areas Important to Wildlife" (MRA 1996) during the periods 15-31 May and 15 June-10 August. These areas cover a substantial part of the breeding population (10, MRA 1996).

The Greenland White-fronted Goose arrives in Iceland twice a year and stage each period for two to three weeks. Iceland serves as a stepping stone where the geese built up their condition prior to further migration. In spring, most disturbance is probably caused by scaring the geese from improved hayfields and other farmlands, but illegal hunting of unknown magnitude can cause disturbance too. There are no statutorily protected areas for the Greenland White-fronted Goose in Iceland, but e.g., the Hvanneyri area in West Iceland is voluntarily protected (Fox et al. 1994). In autumn, the hunting pressure is today the highest throughout the flyway with about 10% of the population being shot in Iceland every year. An increase in the number of hunters, both residents and foreigners, can in the future put an extra pressure on the population. Again, because of the lack of protected staging areas, the disturbance can have a major negative impact on the population.

During early May the Greenland White-fronted Goose arrives on a number of spring staging areas in the central breeding range of West Greenland. There are only few important staging areas and their extension is relatively small, so there is a potential disturbance risk to the geese during this period. Illegal hunting is thought to take place on one of the maybe most important spring staging areas, whereas disturbances from mineral exploration is negligible for the moment. In the future, mineral exploration can put these staging areas under pressure both because the exploration effort has increased dramatically over a five years period (MRA 1998), and because the exploration period has been extended over the year. The eight most important staging areas (8) are about to be included in the mineral regulations, put forward by the Bureau of Minerals and Petroleum in Greenland. The protection period covers 1-20 May.

Finally the moulting period was mentioned as a bottleneck period for, at least, the immature and failed breeding birds. Because most of the Greenland White-fronted Geese during moult are non-breeders, there is a potential problem to a major proportion of the population. Disturbances during this period are likely to put additional stress to the geese, both because they are gregarious and probably more sensitive than at any other period of their annual cycle. Mineral exploration is the most important activity to cause disturbances, because exploration is geographically widespread and dependant of helicopters. Yet, many important moulting areas are designated as "Areas Important to Wildlife" with a protection period from 15 June-10 August (MRA 1996) and as Ramsar sites (Stroud 1992, Fox et. al 1994, Jepsen et al. 1996).

From the previous discussion it is obvious that the highest pressure is put on the Greenland White-fronted Goose population while it is staging in Iceland during spring and autumn. This pressure comes from both biological factors, such as high energy and nutrient demands necessary for migration, reproduction and survival of yearlings, and from human factors, like wetland conversion to farmland, illegal and legal hunting, and lack of refuge areas. Problems in Iceland are most likely to increase in the future, for example because of the increase in hunters, both locals and tourist hunters.

In Greenland the most stressful period to the breeding part of the population is the late incubation period, followed by the spring staging period and the moulting period. Because the breeding population is small, solitary nesting in low densities, the two other periods are more likely to be affected by human disturbances. During these periods geese are gregarious, heavily dependent of feeding (spring) or highly sensitive to disturbance (moult). Yet, human impacts are thought to be small because mineral activities are regulated to a great extend, and hunting is difficult in the inland and the Caribou is a higher ranked quarry species than the Greenland White-fronted Goose.

It is recommended that Iceland designate staging areas where the Greenland White-fronted Goose is protected during both spring and autumn, bring illegal hunting to an end and regulate autumn hunting; a hunting moratorium lasting for e.g., three years could be used to test the effect of the Icelandic hunting pressure.

In Greenland it is recommended to study and, if necessary, designate more important spring staging and moulting areas, study disturbance reactions of spring staging and moulting geese, bring illegal spring hunting to an end, change the hunting period to, e.g., 16 August-1 October, and make it possible in the bag reporting to distinguish between Greenland White-fronted Geese and Canada Geese.

In Ireland and Britain it is recommended to study and protect the most vulnerable bogland flocks, and to enhance grassland feeding on the Wexford reserve.

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8 Spring staging areas of the Greenland White-fronted Goose *Anser albifrons flavirostris* in West Greenland

Spring Staging Areas of the Greenland White-fronted Goose *Anser albifrons flavirostris* in West Greenland

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ABSTRACT

The Greenland white-fronted goose migrates about 3000 km from wintering grounds in Ireland and Britain to breeding grounds in West Greenland (64°-72°N), including long flights over the ocean and over the Greenland ice-cap. To obtain optimal reproduction output, it is important to the geese to build-up their condition at specific spring staging areas before they disperse to the breeding grounds. Two such staging areas had been described earlier. The purpose of this study was to find the most important spring staging areas in order to protect the geese from disturbance from mineral exploration, tourism, etc. The number of breeding birds concentrated on the spring staging areas is only about 6000 of a total population of 30 000. This population size is small compared to other world goose populations. Fifty areas were selected from geodetic maps (1:250 000) and matched with snow coverage and a vegetation index (NDVI) from NOAA satellite images (in 1985 and 1988) covering the early spring period. A total of 35 potential spring staging areas between 63° and 70°N were then surveyed from the air during 9-12 May 1995 and 1997, and examined on the ground during May and June 1994 and 1996. Between 1000 and 1500 geese were observed in 28 areas, but eight areas supported 75% of the geese, and four areas supported more than 50%. Among these four were the two areas discovered earlier. The majority of the geese (94.5%) were observed in the Kangerlussuaq area (66°29´N-68°21´N), and it is recommended that eight areas be designated as protected areas during the period 1-20 May.

Keywords: Greenland white-fronted goose, spring staging areas, West Greenland, NOAA satellite images, snow coverage, NDVI, management.

INTRODUCTION

It is of considerable importance to arctic breeding geese to acquire adequate nutrient reserves for reproduction prior to the breeding season. It has been shown that geese in good body condition lay larger clutches (Ankney and MacInnes, 1978) and are the most successful breeders that bring more offspring back to the wintering grounds (Ebbinge et al., 1982; Ebbinge, 1989; Prop and Deerenberg, 1991; Ebbinge and Spaans, 1992; Johnson and Sibly, 1993). Goose species adopt different strategies to obtain optimal condition, but most studied populations build up stores on the wintering grounds prior to spring migration, and then supplement their condition at one or more spring staging areas before reaching the breeding grounds (Barry, 1962; MacInnes et al., 1974; Ankney and MacInnes, 1978; Owen, 1981; Gauthier et al., 1984; Prevett et al., 1985; Vangilder et al., 1986; Ely and Raveling, 1989; Budeau et al., 1991; Ebbinge and Spaans, 1992). Giant Canada geese (*Branta canadensis maxima)* probably only build up condition on the wintering grounds (McLandress and Raveling, 1981), whereas cackling Canada geese (*Branta canadensis minima)*, dusky Canada geese *(Branta canadensis occidentalis)*, and greater white-fronted geese (*Anser albifrons frontalis)* rely on pre-nesting feeding on the breeding grounds (Raveling, 1978; Bromley, 1984 in Budeau et al., 1991; Ely and Raveling, 1989). Recent studies have shown that female lesser snow geese (*Anser caerulescens caerulescens)* and greater snow geese (*Anser caerulescens atlanticus)* in addition to feeding on spring staging areas feed extensively on the breeding grounds prior to incubation (Ganter and Cooke, 1996; Choinière and Gauthier, 1995). In this paper the generic name (*Anser*) (Cramp and Simmons, 1977) is used rather than (*Chen*).

The Greenland white-fronted goose feeds in West Greenland breeding range (Cramp and Simmons, 1977) at specific spring staging areas (Fox et al., 1983; Fox and Stroud, 1988) before they disperse to breed in single pairs. At the Kuuk spring staging area (Figs 2 and 3) the geese fed on perennating plant organs for 68% of the total diurnal activity, the female up to 80% of the time (Fox and Madsen, 1981b; Glahder et al., in prep.). The build-up of body condition at the spring staging areas is important because Greenland white-fronted geese have long energy demanding migration flights over ocean or ice. The geese migrate about 3000 km from the wintering grounds in Ireland and Britain to Iceland and then across the Greenland ice-cap to West Greenland (Salomonsen, 1967; Fox et al., 1983; Francis and Fox, 1987). A substantial number of Greenland white-fronted geese stage in Iceland (Fox et al., 1983; Francis and Fox, 1987), whereas the geese probably do not stage in the Ammassalik area in East Greenland (Salomonsen, 1950; 1967; Stroud and Fox, 1981). Another migration route from the wintering grounds to South Greenland involves a non-stop 2200 km transoceanic flight and a further northward flight along the west coast (Salomonsen, 1950, 1967). However, few observations support this route. It is a relatively small proportion (c. 20%) of the total wintering population of 30 000 Greenland white-fronted geese that are potential breeding birds (Fox and Stroud, 1988; Stroud, 1992; Fox et al., 1998). The total population is small in number compared to other world goose populations (del Hoyo et al., 1992) and has a generally low productivity (Stroud, 1992). An international conservation plan for the Greenland white-fronted goose population was initiated by the range states in early 1990s (Stroud, 1993).

An increase in mineral exploration in Greenland in the last few years (MRA, 1997) combined with an extension of the exploration period over the year is a potential source of disturbance to the geese during the pre-nesting period. The mineral exploration is normally performed by the use of helicopters which can cause considerable disturbance to geese (Mosbech and Glahder, 1991; Ward et al., 1994; Miller, 1994; Holm, 1997). A high percentage of spring and fall-staging greater snow geese abandoned the staging area for a period when heavily disturbed, especially by low flying aeroplanes (Bélanger and Bédard, 1989), and it was concluded that the disturbance can have significant energetic consequences for fall-staging greater snow geese (Bélanger and Bédard, 1990). Madsen (1995) showed that pink-footed geese (*Anser brachyrhynchus)* feeding on undisturbed spring staging areas in northern Norway reproduced better than geese staging on disturbed areas. To protect the geese during spring staging it is therefore necessary to know the staging period and which are the most important spring staging areas.

This paper describes an efficient approach to identify spring staging areas in remote areas of West Greenland. By using information available from two known spring staging areas in West Greenland (Fox and Madsen, 1981a, b; Fox et al., 1983) similar sites were searched for on geodetic maps covering West Greenland. These areas were matched with NOAA satellite images processed to show snow coverage and a vegetation index. Early snow-free areas were surveyed from the air during the known spring staging period for the geese. The most important areas are identified, factors which may determine the choice of the geese are discussed, and management implications are considered. Satellite tracking of individual geese to the breeding grounds can supplement the above identification method (Glahder et al., 1996, 1997), and data from May 1998 has confirmed staging (Glahder et al., 1998)(see Discussion).

METHODS

Areas identified using topographical criteria

All ice-free land in West Greenland (62°-72°N) was searched for potential spring staging areas on geodetic maps (1:250 000) (KMS 1974-89). This area covers approximately the breeding range (64°-72°30'N) of Greenland white-fronted geese (Salomonsen, 1950; Cramp and Simmons, 1977). The area includes the two known spring staging areas, Kuuk (B, Fig. 1) to the North of

Kangerlussuaq/Søndre Strømfjord (67°31'N; 50°34'W), and Itinneq (A, Fig. 1) to the East of Sisimiut (66°59'N; 52°20'W). The characteristics of these two areas are that they are lowland areas (below 200 m a.s.l.) of 10 to 20 km^2, they contain a river, many small lakes and a "sand and clay" signature. A total of 50 potential spring staging areas was selected (see Table 1, Fig. 2).

Early snow-free areas

The areas found using topographical criteria were matched with snow and vegetation coverage on NOAA-AVHRR (National Oceanographic and Atmospheric Administration-Advanced Very High Resolution Radiometer) satellite images from the early spring period, i.e. April and May. The satellite data has a spatial resolution of 1.1 km (at Nadir), a swath width of c. 3000 km, and five channels that measure reflected solar radiation and infrared radiation (Mather, 1991). The data were geometrically corrected, and snow coverage and NDVI index (Normalised Difference Vegetation Index) were calculated and corrected for clouds and haze (Hansen and Mosbech, 1994). Snow coverage was classified in four groups: 1 = 20-40, 2 = 40-60, 3 = 60-80, and 4 = 80-100% snow cover. Snow coverage <20% was included in the NDVI index (<0.1). The NDVI index was classified in 6 groups: <0.1, 0.1-0.2, 0.2-0.3, 0.3-0.4, 0.4-0.5, and >0.5, with higher values associated with greater density and greenness of vegetation (Mosbech and Hansen, 1994).

The spring staging period covers a period from 1 to 28 May. Most observations of first arrival are during the first week of May (Fox and Madsen, 1981a, b; Fox and Ridgill, 1985; K. Rosing-Asvid, pers. comm. 1996; Glahder et al., in prep.). At the Kuuk spring staging area in West Greenland (Figs. 2 and 3) the first geese were seen on 7 May, with a peak number of 93 on 12 May and with only few birds left on 17 May (Fox and Madsen, 1981a). A recent study in the same area (Glahder et al., in prep.) observed a peak number of 470 geese on 3 May and 70 on 19 May. Normal clutch initiation is between 19 and 28 May (Salomonsen, 1950; Fencker, 1950; Fox and Madsen, 1981b; Fox and Stroud, 1988). In a year with very late spring thaw clutch initiation was between 6 and 17 June (Fox and Stroud, 1988).

To qualify as a potential spring staging area snow must have melted by early May under different weather conditions. During the period 1979 to 1992 precipitation (mm) and mean winter (December, January, and February), and spring (March, April, and May) temperatures were obtained from four climatic stations at Paamiut (62°00'N, 49°40'W), Sisimiut (66°56'N, 53°42'W), Aasiaat (68°42'N, 52°53'W), and Kangerlussuaq (67°01'N, 50°42'W). During this period of 14 years, only 1985 and 1988 had reasonably good satellite image coverage (Jørgensen, 1993) because the period of snow melt in West Greenland is often characterised by periods of thick cloud cover. In 1985 snow melt was earlier than normal, whereas snow melt in 1988 was delayed compared to normal years. In 1985 satellite images were available for the area from Paamiut to Nuussuaq (62°-70°N) on 17 and 23 April and on 19 and 23 May. Coverage was also available on 12 May for the southern part (62°-66°N), and on 16 May for the northern part (66°-70°N). In 1988 satellite imagery was available for the same area only on 10 and 22 May. The snow coverage on 23 April 1985, just one week prior to the arrival of the geese, is shown in Figure 1.

The following criteria were used to select potential spring staging areas: A <u>potential area</u> must on 23 April 1985 have had snow coverage ≤20-40%, and on 12 or 16 May 1985, and on 10 May 1988 have had a vegetation index of <0.1 or higher. An <u>uncertain potential area</u> must on 23 April 1985 have had a snow coverage of 40-100%, but must on 12 or 16 May 1985 have had a vegetation index of <0.1 or higher, and must on 10 May 1988 have had a snow coverage of ≤20-40% and on 22 May a vegetation index of <0.1 or higher. Areas still with snow coverage on 12 or 16 May 1985, and on

10 and 22 May 1988 were considered as non-potential areas. In this way 11 areas were omitted, and three more were rejected because they were north of the area covered by the NOAA satellite scenes (i.e. north of 71°N, areas 32-34, Table 1, Fig. 2). This left 36 potential areas.

Aerial survey and ground truthing

The potential spring staging areas derived from the geodetic maps and NOAA satellite scenes were then examined from ground visits and aerial surveys. During the period 23 May to 6 June 1994, seven potential sites in the Kangerlussuaq area were visited with helicopter support and examined for habitat characteristics, goose droppings, and signs of feeding. Because of low goose activity on the sites no quantitative methods and results are reported. This pilot study lead to the more comprehensive aerial surveys earlier in May. At the staging area at Kuuk feeding behaviour, habitat use and geese numbers were studied during 3 to 19 May 1996 (Glahder et al., in prep.). On 9 and 10 May 1995, 33 potential areas between 63°N and 70°N were surveyed from the air, and on 12 May 1997, 20 potential areas between 66°N and 69°N were surveyed. The survey plane was a Partenavia Observer with Plexiglas front and bubble windows on both sides. Three observers surveyed in 1995 and one in 1997. At the potential areas ground speed was 85-90 knots (c.160 km/h) and altitude above ground was about 250 feet (c.75 m). Each area was covered in the most optimal way by following rivers, and circle over lakes, marshes and dwarf-scrubs. It is believed that all geese in the area were flushed with only few birds either overlooked or counted twice. The route between areas was the shortest possible, air speed was about 110 knots (c. 200 km/h) and altitude above ground 250 to 500 feet (75-150 m); geese were looked for during these flights as well.

The number of lakes smaller than 10 000 m^2 were counted in each staging area from aerial photos (KMS, 1985), ranked and correlated with the number of geese using the Spearman rank correlation coefficient (Table 2).

RESULTS

Weather

In 1985, one of the years with satellite image coverage, mean spring temperatures in the area were slightly higher than normal (1-2ºC), but at Kangerlussuaq about 4ºC higher. Precipitation was normal except at Kangerlussuaq where it was about twice the normal. In 1988, mean spring temperatures were normal, and precipitation was above normal; at Kangerlussuaq it was about double the normal (Asiaq, 1995-97). Snow melt in 1988 was much delayed compared to 1985.

During the two survey years 1995 and 1997, mean spring temperatures in the area (62°-69°N) were normal to slightly above normal (1-2°C), whereas temperatures at Kangerlussuaq were about 4°C higher (1995) and 2-3°C higher than normal (May 1997). Precipitation in the area both years was normal, except at Kangerlussuaq, where it was very low in 1995 and zero in 1997 (Asiaq, 1995-97). Compared to the weather situation in spring 1985/88, mean temperatures and precipitation were about the same, yet precipitation in 1988 was above normal. The greatest exception was the extremely low precipitation at Kangerlussuaq in 1995/97.

Aerial survey

During the two aerial surveys, a total of 1096 and 1615 geese were observed, respectively. In 1995 a total of 1085 geese were seen on 26 of the 33 areas visited; the remainder (11) were seen outside the areas. In 1997, 1448 geese were seen on 18 of the 22 areas visited, with 167 geese seen outside the areas (Table 2, Figs. 2 and 3).

In 1995, the majority of the geese (94.5%) was observed between 66° and 69°N, with a peak between 67° and 68°N (47.1%) (Table 3). In 1997, geese were only censused in the area between 66° and 69°N, but the distribution was similar to 1995 (Table 3). Number and distribution (in mean %) at each area are shown in Table 2. Because not all areas were visited both years, the total mean percentage exceeded 100 (i.e., 115.9), so the mean percentages in Table 2 were adjusted to total 100. Geese were observed on 28 of the 35 areas surveyed, but only very few areas held a substantial number of geese, as shown in Figure 4. More than 50% of the geese were observed in four areas (A, 16, B and 20), among these the two known areas A and B. About 75% of the geese counted were observed in eight areas (A, 16, B, 20, 18, 47, 2 and 6).

There was a significant positive correlation between number of geese and number of smaller lakes in the staging areas ($p < 0.01$, $n = 35$, $r_s = 0.5895$, Spearman rank correlation coefficient).

Ground truthing

A total of eight areas (Table 2, Geese 1994) were visited on the ground. In 1994, the areas were visited shortly after the geese had left for the breeding grounds, and only at area 5 were there signs of substantial goose activity. In 1996, the known spring staging area, Kuuk (B), was studied during 3 to 19 May. On 3 May 470 Greenland white-fronted geese were observed and this number had declined to 70 geese on 19 May. Mean maximum number between 3 and 12 May was 280.1 (SD = 92.0, n = 10)(Table 2).

DISCUSSION

Fencker (1950) was the first to describe pre-nesting feeding in Greenland white-fronted geese during the 3-week period from arrival to egg-laying. Fox et al. (1983) described at least two spring staging areas (including the Kuuk area), and concentrations of early arrivals at a small number of traditional lowland areas were thought to be a common phenomenon. The present study found 28 areas supporting between 1 and 328 geese during 9 -12 May, although only four areas supported more than 50% of the geese observed, and only eight areas supported 75%. Since the areas were visited only once during the aerial surveys there is no proof that these areas are used for prolonged spring staging periods. However, it seems likely that these are important staging areas for the following reasons: (i) the four most important areas include the two previously described spring staging areas, (ii) of the 10 highest-ranked areas, six ranked highest in both years, (iii) the observation dates were later than the normal arrival period, and (iv) only 1% (1995) and 10% (1997) were observed outside the surveyed potential areas.

The majority of the occupied areas and geese (94.5%) were observed between 66°29´N and 68°21´N, in an area, extending from Sukkertoppen Iskappe north to Disko Bugt. In most years early snow-free areas occur in the inner parts of this area, which is the most extensive land in West Greenland with 150-200 km from coast to ice-cap. Figure 1 shows this situation in a normal year. These inland areas experience a dry continental climate (Nørrevang and Lundø, 1981) with very low annual precipitation (e.g., 149 mm at Kangerlussuaq (Asiaq, 1995-97)) and temperatures rapidly increasing from March to May (Asiaq, 1995-97). Also, the low precipitation is due to the Sukkertoppen Iskappe where most precipitation falls on the south-west side of the glacier (Secher et al., 1987).

It was expected that early snow-free areas found from NOAA satellite images in 1985 and 1988, i.e., + or (+) both years (Table 1), would support most geese. But areas with these characters (areas 1, 5, 7, 8, 15, 16 and 39, Table 1) were, except for area 16, not ranked very high (Table 2). Furthermore, comparing snow coverage for the 8 highest ranked areas, holding about 75% of the geese, with the 8 lowest ranked areas, holding less than 1% of the geese, showed no differences. Obviously, early spring thaw is not the only important condition to the geese, but in most years the Greenland white-fronted geese probably are able to find snow-free or rapidly thawing staging areas in the Kangerlussuaq area. In only a few years, like in 1984 (Fox and Stroud, 1988), the geese must seek alternatives, e.g., in the highlands as described by Fencker (1950), until the high priority areas become available.

Another condition important to the arriving geese is abundant and nutritious food. At the Kuuk area in 1996 (Glahder et al., in prep.) we observed geese feeding most of the time in smaller lakes with abundant common cottongrass (*Eriophorum angustifolium*), one of the most important food items for the Greenland white-fronted geese (Madsen and Fox, 1981). In the present study a positive correlation was found between the number of geese and the number of smaller lakes in the areas, suggesting the importance of lake-related food items.

The Kangerlussuaq area is centrally situated in the breeding range and probably supports the highest breeding densities of Greenland white-fronted geese (Salomonsen, 1950, 1967). This area is en route for geese migrating from Iceland across the ice-cap to West Greenland. When the geese cross the ice-cap there, they have the advantage of crossing where the centre of the ice-cap is at its lowest, about 2200 m a.s.l., a route suggested by Wilson (1981, in Stroud and Fox, 1981). Gudmundsson et al. (1995) found that spring migrating brent geese (*Branta bernicla)*, equipped with satellite transmitters, crossed there, and three Greenland white-fronted geese fitted with satellite transmitters used this route during 7-10 May 1998 (Glahder et al., 1998). Spring migrating Greenland white-fronted geese have been observed from the ice-cap between Ammassalik and Kangerlussuaq during spring 1970 (Salomonsen, 1979) and during 10-12 May 1995 (Ø. Slettemark, pers. comm. 1996). With the huge Kangerlussuaq area holding the most important spring staging areas, it seems likely, that the migration route across the ice-cap is of great importance, as suggested by Fox et al. (1983) and Francis and Fox (1987). When the Greenland white-fronted geese first arrive in West Greenland they may find the breeding grounds snow-free. Despite this, they stage at the spring staging areas or at the breeding grounds for a minimum of two weeks, i.e., from arrival (1-7 May) to clutch initiation (19-28 May). The three Greenland white-fronted geese equipped with satellite transmitters in 1998 confirm a staging period of 8 to 10 days (Glahder et al., 1998). This period is thought necessary to the geese for rapid oocyte growth (Fox and Stroud, 1988) which in greater white-fronted goose is found to last 11-14 days (C. R. Grau in Ely and Raveling, 1984).

To evaluate the applicability of the described method to discover spring staging areas in West Greenland, the number of Greenland white-fronted geese enumerated during the aerial surveys is compared to the total number of potentially breeding birds. The number of potentially breeding geese can be calculated from the number of families with young's returning to the wintering grounds and the proportion of successfully breeding birds. From 1982 to 1990, an average of 11.4% (SD = 2.3, n = 9) of the total population returned to the wintering grounds with juvenile geese (Stroud, 1992), i.e., about 3400 successfully breeding birds out of a total population of 30 000 geese. In the only study of Greenland white-fronted geese on the breeding grounds, Fox and Stroud (1988) found that only 31% were successful breeders (n = 13, in two different years). They thought the high predation rate, mainly due to Arctic foxes *Alopex lagopus*, may have been due to the presence of the researchers. In greater white-fronted geese, Ely and Raveling (1984) found a nesting success of 62% (n = 102) or 79% (n = 29) for nests not flooded, which is probably not a serious problem for the Greenland white-fronted geese (Fencker, 1950; Salomonsen, 1950; Fox and Stroud, 1988). The use of these success rates and a total population of 30 000 geese suggests a number of potentially breeding birds between 4300 (79%) and 11 000 (31%), or around 6200 geese (an average per cent of 55). The number of geese counted during the aerial surveys constitutes almost exclusively of potentially breeding birds. This is confirmed by observations in West Greenland in early May, where almost all birds were adult birds (Stroud, 1981; Fox et al., 1983; Glahder et al., in prep.), and most were in pairs (Fox and Madsen, 1981b; Glahder et al., in prep.). How many staging geese the surveyed numbers of 1085 (1995) and 1448 (1997) represent can be calculated from the study of Øien et al. (1996). Over the five years of their of lesser white-fronted geese (*Anser erythropus*) on a spring staging area in northern Norway the average maximum number of geese on one day was 31.6 (SD = 10.0), whereas the total number of staging individuals calculated using a belly bar identification method was 60.6 (SD = 5.1). So, if the geese counted between 9-12 May

1995 and 1997 represent the maximum numbers on each staging area, it is possible that 2-3000 geese will stage at the areas during the course of the whole spring staging period or up to 50% of the potentially breeding birds. This high proportion suggests that a relative high number of important staging areas has been discovered in West Greenland. It is unknown, whether the later arriving immatures and non-breeders use these staging areas or whether they migrate directly to the breeding grounds, i.e., their summering areas.

MANAGEMENT RECOMMENDATIONS

The total population of the Greenland white-fronted goose was in the late 1970s down to about 15000 geese (Ruttledge and Ogilvie, 1979), but hunting bans on the wintering grounds in Scotland and Ireland resulted in an increase of the wintering population to about 30 000 geese in the early 1990s (Fox et al., 1998). The population is today stable around this number which is thought to represent an absolute minimum (Stroud, 1992). The Range States (Greenland/Denmark, Iceland, Ireland and the United Kingdom) initiated in early 1990s the development of an international conservation plan (Stroud, 1992, 1993) which addresses the different concerns for the long-term well-being of the population: The world population is small with a limited range, the productivity is generally low, wintering habitats are lost and disturbed, about 60% of the wintering population are concentrated on only two sites and the geese are disturbed on staging areas.

In Greenland this study has shown that the relatively small number of potentially breeding birds concentrate for a limited period on a few spring staging areas. To contribute to the conservation of the Greenland white-fronted goose, the geese should be protected from disturbances caused by mineral exploration and other activities on the eight highest ranked areas (A, 16, B, 20, 18, 47, 2 and 6). The most important areas are A, 16 and B, each with more than 10% of the geese counted.

Areas A and B meet the 1% population criteria for wetlands of international importance according to the Ramsar convention (Ramsar Convention Bureau, 1990). In order to protect a greater proportion of the breeding population and to cover a wider range, it is suggested to supplement the three most important areas with another five. The number of geese so protected would constitute about 75% of the geese counted, and the eight areas are distributed over the whole Kangerlussuaq area (Fig. 3).

The protection period should cover the period from the first arrival on 1 May to 20 May where most geese, according to the Kuuk study (Glahder et al., in prep.), have left for the breeding grounds. Studies at the Kuuk area (Glahder et al., in prep.) of disturbance reactions of the geese to walking persons and fixed-wing aircraft indicate a 500-1000 m protection zone around the staging area. On a staging area used by greater snow geese, Bélanger and Bédard (1989) suggested that aeroplane flights below 500 m should be prohibited. Reactions to helicopters were not observed at the Kuuk area, but would likely add to the protection distance. It has been demonstrated that moulting geese react to approaching helicopters at distances of 3-9 km (Mosbech and Glahder, 1991), but moulting geese are probably much more sensitive to disturbance than geese able to fly. The Greenland white-fronted goose is protected from hunting during this period as hunting is allowed only from 16 August to 30 April (Greenland Home Rule, 1995).

Future studies on the West Greenland spring staging areas should include evaluation of possible new staging areas used by geese attached with satellite transmitters, in addition to further confirmation of consistently used staging areas; also, studies on disturbance reactions of the geese, especially to helicopters, are highly needed. Most important to achieve the sustainability objective of the international conservation plan is probably studies on the different stress factors, put on the population while staging in Iceland during spring and fall; the hunting pressure is the highest throughout the flyway (Sigfusson, 1996; Fox et al., 1998), wetlands are converted to farmland (Stroud, 1992), and no areas are statutorily protected (Stroud, 1992; Fox et al., 1994).

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TABLE 1. Snow cover and vegetation index from NOAA satellite images during spring 1985 and 1988.

Snow cover indices are as follows: 1=20-40%, 2=40-60%, 3=60-80%, 4=80-100%; NDVI index consists of the following six groups: <0.1, 0.1-0.2, 0.2-0.3, 0.3-0.4, 0.4-0.5, and >0.5 (low to high density and greenness). Areas A and B are the two known spring staging areas. Open cells: no NOAA scene available. Cl = clouds covering the area.; Evaluation (in 1985/in 1988 = final); + = potential area; (+) = uncertain potential area; ÷ = non-potential area; ? = no evaluation possible.

No	Name and co-ordinates	1985						1988			Evaluation
		17.4	23.4	12.5	16.5	19.5	23.5	10.5	22.5	2.6	
A	Itinneq 66°59´N,52°20´W	1-2	1,<0.1	<0.1				2-3	0.1-0.1		+/÷ = (+)
B	Kuuk 67°31´N,50°34´W	2-3	1,<0.1	<0.1				2-3	<0.1		+/÷ = (+)
1	Sarfartooq 66°29´N,51°55´W	1,<0.1	<0.1	<0.1				1,<0.1	<0.1		+/(+) = (+)
2	Itillinguaq 66°31´N,52°25´W	2-3	1	<0.1				2-3	<0.1		+/÷ = (+)
3	Aussiviit 66°33´N,52°25´W	2	1,<0.1					2-3	<0.1		+/÷ = (+)
4	Eqalugarniarfik 66°48´N,52°20´W	3-4	3	<0.1				4	<0.1		(+)/÷ = (+)
5	Sarfartooq 66°30´N,51°30´W	1,<0.1	<0.1	<0.1				<0.1	<0.1		+/+ = +
6	Maniitsut 66°45´N,50°05´W	<0.1	<0.1	0.1-0.2				1-2	<0.1		+/÷ = (+)
7	Maniitsut 66°50´N,50°20´W	<0.1	<0.1	0.1-0.2				1	0.1-0.2		+/(+) = (+)
8	Pinguarssuup 66°52´N,50°22´W	<0.1	<0.1	0.1-0.2				1	0.1-0.2		+/(+) = (+)
9	Pinguarssuup 66°52´N,50°15´W	<0.1	<0.1	0.1-0.2				1-2	0.1-0.2		+/÷ = (+)
10	Aussivit 67°24´N,52°10´W	1,<0.1	<0.1	cl		<0.1		2	0.1-0.2		+/÷ = (+)
11	Ørkendalen 67°01´N,50°15´W	<0.1	<0.1	0.1-0.2				3	<0.1		+/÷ = (+)
12	Ilivilik 67°09´N,51°10´W	<0.1	<0.1	cl		<0.1		3	0.1-0.2		+/÷ = (+)
13	Guutaap 67°18´N,51°25´W	1,<0.1	<0.1	cl		<0.1		2	0.1-0.2		+/÷ = (+)
14	Siorarssuit 67°22´N,51°30´W	1-2	<0.1	cl		<0.1		2	<0.1		+/÷ = (+)
15	Qivitoq 67°21´N,51°45´W	1,<0.1	<0.1	cl		<0.1		<0.1	0.1-0.2		+/+ = +
16	Qorllortoq 67°37´N,50°55´W	3	1-2	<0.1				1,<0.1	<0.1		(+)/(+) =(+)
17	Qorllortoq 67°45´N,50°05´W	1-2	1	<0.1				3	0.1-0.2		+/÷ = (+)

18	Avissaariaata 68°18´N,52°30´W	1	1,<0.1	<0.1				2	cl		+/÷ = (+)
19	Pakalalik 68°21´N,52°35´W	3	3	2-3		<0.1		4	cl		÷/÷ = ÷
20	Akullinguit 68°09´N,50°55´W	2-3	2	1,<0.1		<0.1		3	<0.1		(+)/÷ = (+)
21	Anoritooq 68°37´N,50°50´W	2-3	1	<0.1				3	0.1-0.2		+/÷ = (+)
22	Kangikerlak 69°27´N,53°20´W		3-4	1-2		cl	<0.1	3	<0.1		÷/÷ = ÷
23	Kuannersuit 69°35´N,53°20´W		2-3	2		cl	<0.1	3	1,<0.1		÷/÷ = ÷
24	Allangissat 69°35´N,53°50´W		3	3		cl	<0.1	4			÷/÷ = ÷
25	Qinguata Kuus. 69°36´N,54°00´W		3	3		cl	1,<0.1	4			÷/÷ = ÷
26	Qinguata Marr. 69°40´N,54°20´W		4	4		cl	1,<0.1	4			÷/÷ = ÷
27	Kuussuaq 69°56´N,54°15´W		1	3		cl	<0.1	4			÷/÷ = ÷
28	Aqajarua 69°42´N,52°00´W		4	3		<0.1	<0.1	4	1,<0.1		÷/÷ = ÷
29	Nunatarssuaq 69°16´N,50°10´W	2-3	1	1		1,<0.1		4	<0.1		÷/÷ = ÷
30	Qimmilivik 69°45´N,50°15´W	1	2-3	<0.1		0.1-0.2		1-3	0.1-0.4		(+)/÷ = (+)
31	Noorlinguaq 70°03´N,52°05´W		2-3	2		<0.1	<0.1	4			÷/÷ = ÷
32	Tasiussaq 71°26´N,54°55´W										?
33	Usuit 71°38´N,54°10´W										?
34	Itsako 71°42´N,54°00´W										?
35	Qingua 62°16´N,49°20´W	<0.1	cl		<0.1				cl	cl	+/? = (+)
36	Nigerliip Qin. 62°24´N,49°45´W	1	1,cl		<0.1				cl	cl	+/? = (+)
37	Kussuup Alaan. 63°23´N,50°50´W	3	1		<0.1				2	<0.1	+/÷ = (+)
38	Kuussuaq 63°28´N,50°35´W	2-3	1,<0,1		<0.1				cl	1	+/÷ = (+)
39	Narsarsuaq 64°46´N,51°00´W	2-3	<0.1		<0.1				<0.1	<0.1	+/(+) = (+)
40	Nipaiitsoq 64°05´N,50°05´W	<0.1	<0.1		<0.1				cl	<0.1	+/? = (+)
41	Austmannadal 64°12´N,50°05´W	<0.1	<0.1		0.1-0.2				cl	0.1-0.2	+/? = (+)
42	Igassup Kuua 64°51N,50°30´W	1	<0.1		0.1-0.2				1,<0.1	<0.1	+/÷ = (+)
43	Kuussua 64°54´N,50°40´W	3	1,<0.1		0.1-0.2				1	<0.1	+/÷ = (+)
44	Majorqaq Pingo 65°39´N,51°50´W	3	1-2		1-2				3	3	÷/÷ = ÷
45	Majorqaq Kigu. 65°47´N,51°10´W	3-4	1-2		0.1-0.2				3	1-2	(+)/÷ = (+)
46	Majorqaq Qoor. 65°44´N,50°45´W	2	1,<0.1		<0.1				3	1,<0.1	+/÷ = (+)
47	O Nordenskj. G 68°01´N,50°20´W	3	2-3	<0.1				4	0.1-0.2		(+)/÷ = (+)
48	Polynia Gletsc. 67°55´N,50°15´W	3-4	1-3	<0.1				3-4	0.1-0.2		(+)/÷ = (+)

TABLE 2. Number of Greenland white-fronted geese on potential spring staging areas surveyed in May 1995 and 1997 and visited on the ground in May/June 1994. The areas are ranked according to % Geese.

- = Areas not visited, * = Mean maximum number on area B, 3-12 May 1996. Inside/Outside = geese counted inside/outside the staging areas.

Area no	Geese 1995	Geese 1997	% Geese	Rank, geese	Geese 1994	Lakes	Rank, lakes
A	178	328	16.9	35	-	165	34
B	85	290	12.0	33	280*	62	29
1	5	52	1.8	22	0	7	7.5
2	36	106	4.6	29	-	52	26.5
3	2	2	0.2	9	-	5	5
4	0	0	0.0	4	-	9	11.5
5	47	2	1.9	23	8 pairs, 20	28	19
6	55	-	4.4	28	4 pairs, 14	29	20
7	4	4	0.3	11	5 pairs, 2	0	1.5
8	17	0	0.7	15	3 pairs	27	18
9	18	0	0.8	17.5	9 pairs, 1	6	6
10	57	11	2.7	25	-	31	21
11	89	4	3.7	27	-	14	15
12	18	2	0.8	17.5	10 pairs, 1	13	13
13	6	0	0.3	10	-	3	3
14	4	8	0.4	12	-	7	7.5
15	26	2	1.1	19	-	4	4
16	191	253	15.2	34	-	75	31
17	35	4	1.6	21	-	67	30
18	90	-	7.2	31	-	52	26.5
19	6	-	0.5	13	-	110	32
20	44	218	8.3	32	-	198	35
21	10	9	0.7	15	-	14	15

30	0	-	0.0	4	-	35	22
37	0	-	0.0	4	-	0	1.5
38	0	-	0.0	4	-	8	9.5
39	9	-	0.7	15	-	112	33
40	0	-	0.0	4	-	14	15
41	0	-	0.0	4	-	8	9,5
42	0	-	0.0	4	-	47	25
43	16	-	1.3	20	-	22	17
45	1	-	0.1	8	-	9	11.5
46	36	-	2.8	26	-	39	23
47	-	113	6.7	30	-	43	24
48	-	40	2.4	24	-	53	28
Inside	1085	1448					
Outside	11	167					
Total	1096	1615					

TABLE 3. Distribution of Greenland white-fronted geese in West Greenland between 63° and 70°N.

The aerial survey in 1995 covered the whole area (bold and normal figures in area no's), while the 1997 survey only covered the area 66°-69°N (bold and italics). % total geese is adjusted to equal 100.

Latitude °N	% geese 1995	% geese 1997	% geese total	area no.'s
69 - 70	0.0	-	0.0	30
68 - 69	13.9	23.5	23.4	18, 19, **20**, **21**, *47*
67 - 68	47.1	42.5	40.1	**B**, **10**, **11**, **12**, **13**, **14**, **15**, **16**, **17**, *48*
66 - 67	33.5	34.1	31.6	**A**, 1, 2, **3**, **4**, **5**, 6, 7, **8**, **9**
65 - 66	3.4	-	2.9	45, 46
64 - 65	2.3	-	2.0	39, 40, 41, 42, 43
63 - 64	0.0	-	0.0	37, 38

FIG. 1. Snow coverage in West Greenland (66°-70°N) on 23 April 1985.

Snow coverage (%) is classified in four groups and vegetation (NDVI) index in six groups: <0.1 to >0.5. Snow coverage <20% is included in the NDVI group <0.1.

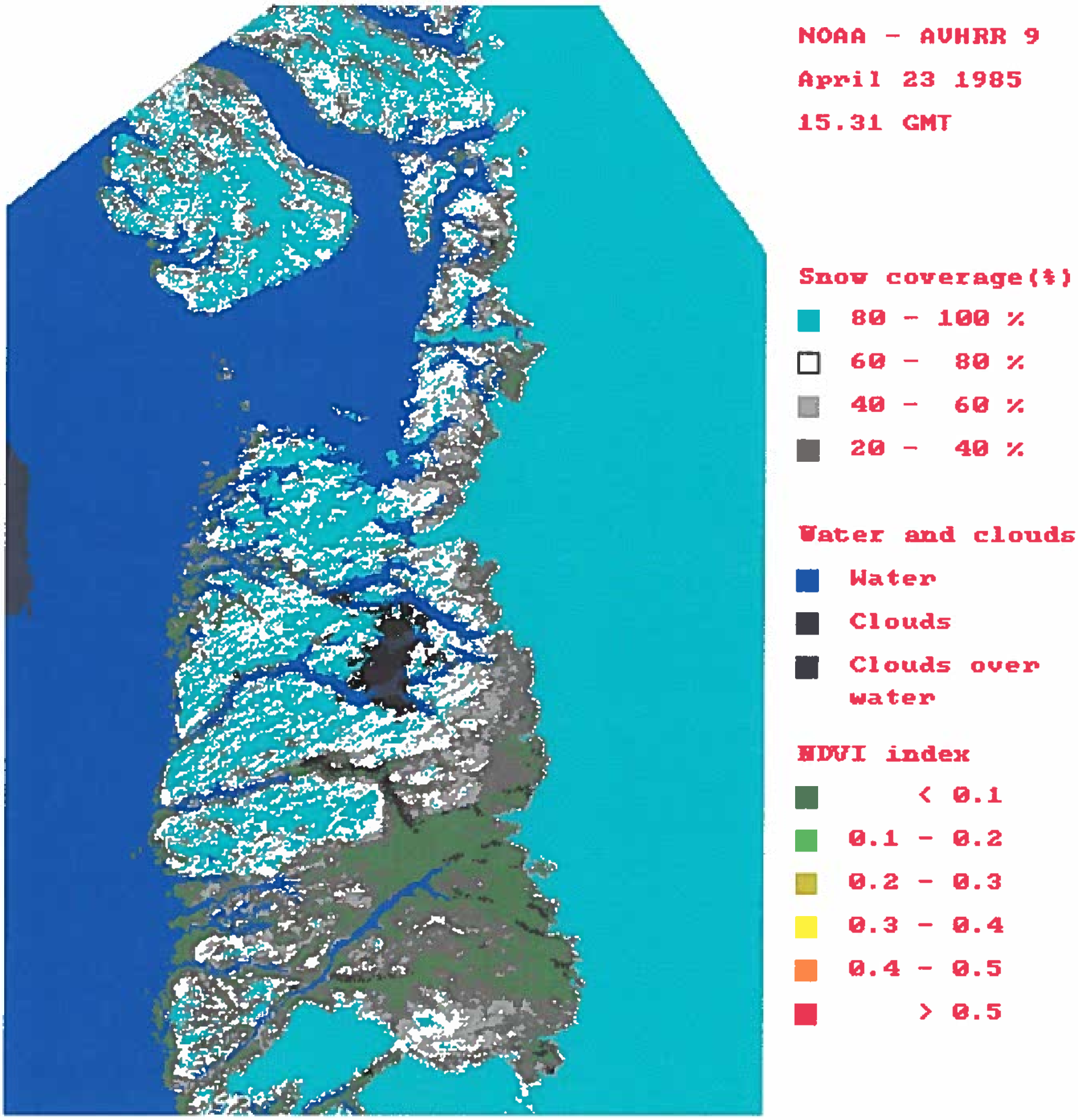
FIG. 2. Potential spring staging areas in West Greenland (62°-72°N).

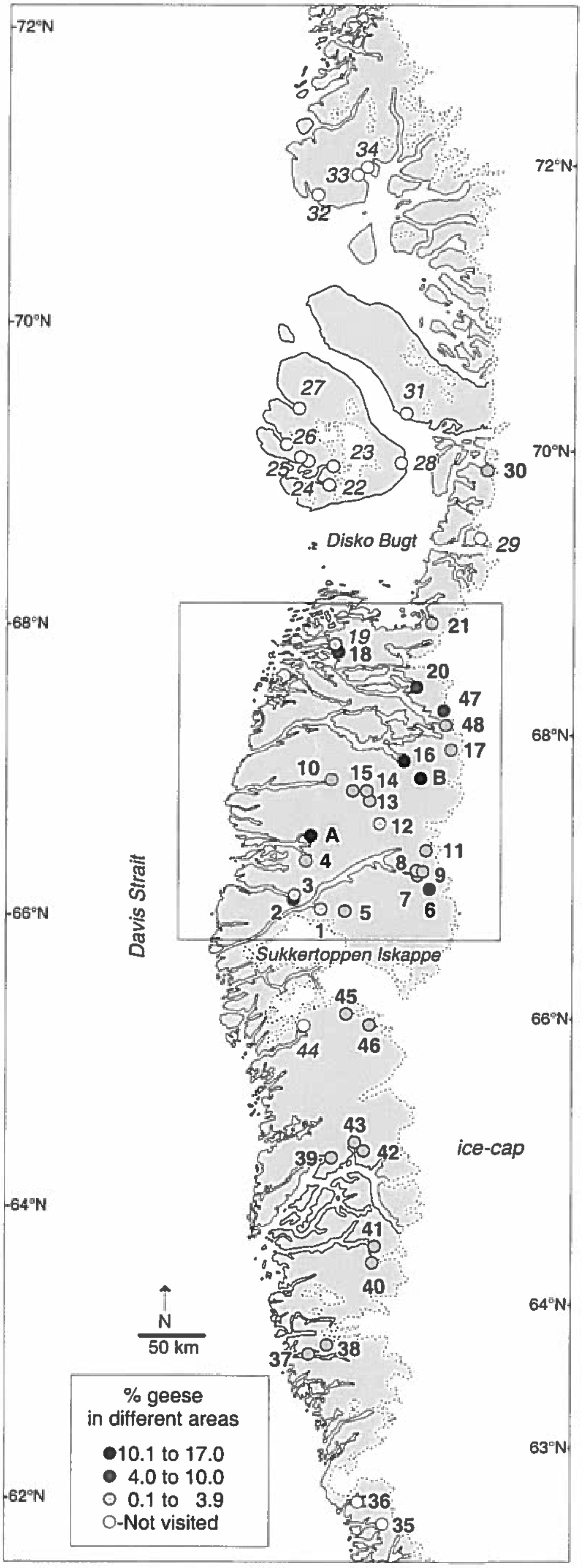
Of the 50 areas selected from topographical criteria (1-48, A and B), 14 were rejected because of heavy snow coverage or lack of NOAA satellite scenes (figures in italics). 35 areas were aerial surveyed in 1995 and 1997 (grey and black dots). % geese in different areas from the two years are also indicated (see TABLE 1). Area inside frame, see Fig. 3.

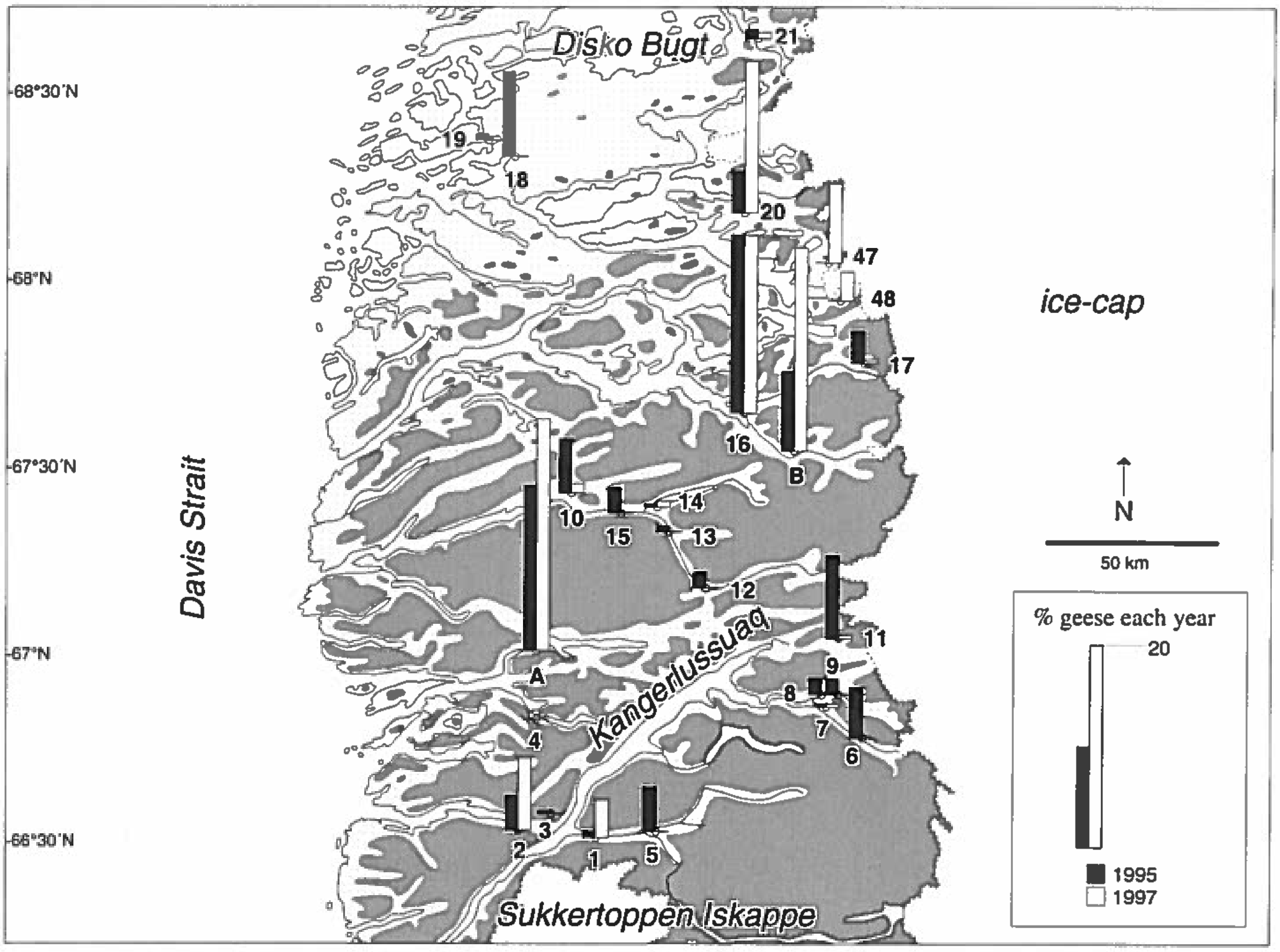
FIG. 3. Spring staging areas in the Kangerlussuaq area (66°-69°N) with % Greenland white-fronted geese observed on aerial surveys in 1995 (black bars) and 1997 (white bars)(see Table 1). In 1995 areas 47 and 48, and in 1997 areas 6, 18 and 19 were not visited. Light grey areas are below 300 m a.s.l., dark grey areas are between 300 and 1500 m a.s.l.

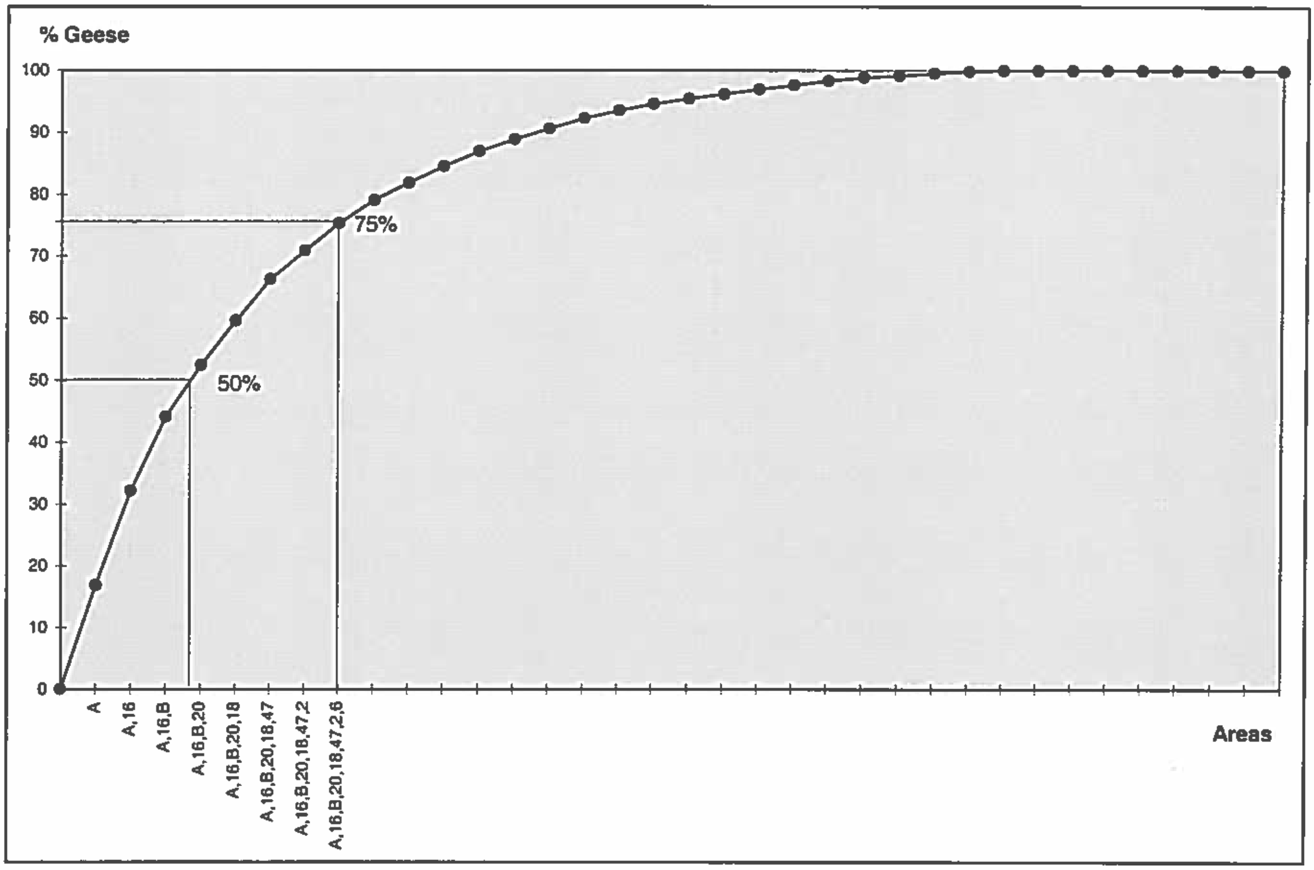
FIG 4. Percentage of Greenland white-fronted geese observed on the 35 areas surveyed in 1995 and 1997.

The % geese are summed over the ranked areas (see Table 2). More than 50% of all geese were counted in the four highest ranked areas (A, 16, B, 20), and 75% were within eight areas (A, 16, B, 20, 18, 47, 2, 6).


NOAA - AVHRR 9
April 23 1985
15.31 GMT
Snow coverage(%)
80 - 100 %
60 - 80 %
40 - 60 %
20 - 40 %
Water and clouds
Water
Clouds
Clouds over water
NDVI index
< 0.1
0.1 - 0.2
0.2 - 0.3
0.3 - 0.4
0.4 - 0.5
> 0.5


72°N
70°N
68°N
66°N
64°N
62°N
72°N
70°N
68°N
66°N
64°N
63°N
Disko Bugt
Davis Strait
Sukkertoppen Iskappe
ice-cap
N
50 km
% geese
in different areas
10.1 to 17.0
4.0 to 10.0
0.1 to 3.9
-Not visited
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 A B


Disko Bugt
68°30'N
68°N
67°30'N
67°N
66°30'N
Davis Strait
ice-cap
Kangerlussuaq
Sukkertoppen Iskappe
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
47
48
A
B
N
50 km
% geese each year
20
1995
1997


% Geese
100
90
80
70
60
50
40
30
20
10
0
75%
50%
A
A,16
A,16,B
A,16,B,20
A,16,B,20,18
A,16,B,20,18,47
A,16,B,20,18,47,2
A,16,B,20,18,47,2,6
Areas

9 Feeding behaviour and habitat use of the Greenland White-fronted Goose at a specific spring staging area

Feeding behaviour and habitat use of Greenland White-fronted Goose at a specific spring staging area

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Abstract

When the Greenland White-fronted Geese *Anser albifrons flavirostris* (Dalgety and Scott) arrive in West Greenland in early May, they stage on a few spring staging areas where they build up body condition prior to breeding. Disturbance on these areas may cause a marked decrease in the breeding success of the geese. In order to obtain information for protecting the geese from different sources of disturbance, e.g. mineral exploration, a specific spring staging area was studied to define habitat use, feeding behaviour, length of stay, reactions to disturbance etc. The Kuuk Marshes (67°31´N, 50°34´W), one of the most important staging areas, was studied during 3 to 19 May 1996. On 2 May 1014 Greenland White-fronted Geese migrated north at Kangerlussuaq 50 km south of Kuuk, and on 3 May 470 geese were counted at Kuuk. During the study period the daily maximum number declined to about 70 on 19 May. Based on observations of neckcollared birds, individuals staged for 1-5 days. The geese used the area most intensively in the first half of the period feeding more than 78% of the time, declining significantly to 55% during the last period. The most important feeding habitat was the beach pools used by 69% of the geese during the entire period. Here the preferred food items were the stem-bases of Common Cotton-grass *Eriophorum angustifolium* (Honck.) and sedge *Carex cfr. bigelowii* (Torr.). The goose fed significantly more than the gander (77% versus 34% in solitary pairs, 82% versus 58% in flock pairs), while the gander spend significantly more time than the goose in alert position (52% versus 7% in solitary pairs, 18% versus 4% in flock pairs). Thus, the gander took advantage of feeding in groups by sharing alertness. The median abdominal profile index (API) increased in both sexes during the staging period, and was significantly higher in the goose (1.5 to 2.5) than in the gander (1.0 to 2.0). Disturbance reactions to walking persons and fixed-wing aeroplanes were observed at distances between 200 and 700 m. It is suggested that the area should be protected from 1 to 20 May.

Keywords: Greenland White-fronted Goose, spring staging area, behaviour, feeding, alert, abdominal profile index, management implications

Introduction

The Greenland White-fronted Goose *Anser albifrons flavirostris* migrates about 3000 km from the wintering grounds in Ireland and Britain to the breeding grounds in West Greenland. The breeding birds, numbering only about 6000 birds or 20% of the total population (Glahder 1999, Fox et al. 1998), must therefore rely on staging areas in Iceland and Greenland to build up body condition prior to further migration or clutch initiation. Until recently only two spring staging areas in West Greenland were known (Fox and Madsen 1981a, b, Fox et al. 1983), but aerial surveys during the spring staging period in May 1995 and 1997 discovered another six important staging areas, all situated in the central breeding area (66°29'N - 68°21'N)(Glahder 1999).

It has been shown that geese in good body condition are the most successful breeders (e.g., Ebbinge et al. 1982, Ebbinge 1989, Prop and Deerenberg 1991, Ebbinge and Spaans 1992, Johnson and Sibly 1993, Boyd and Fox 1995). Pink-footed Geese *Anser brachyrhynchus* (Baillon) that were disturbed on their spring staging areas in northern Norway were not able to improve their body condition (measured as abdominal profile index (API)) and this resulted in a marked decrease in breeding success (Madsen 1994, Madsen et al. 1997). In West Greenland hunting is not allowed after 30 April (Anon. 1997), so mineral exploration is the most probable source of disturbance in these rather inaccessible areas in early spring. In the last few years mineral exploration in this area has increased and the exploration period has in general been extended over the year (MRA 1997).

To protect the geese at the spring staging areas it is important to know the staging period and the number of geese staging during that period, the distribution and activity of the geese inside of the study area and their sensitivity to different sources of disturbance. One of the most important staging areas, the Kuuk Marshes, was chosen for a more thorough study of the feeding behaviour and habitat use of the Greenland White-fronted Geese. The area is situated central in the region holding the most important spring staging areas and it is possible to overview the entire area from only two observation points. The flux through the area was calculated both from the daily maximum number derived from 15 minutes scan counts and readings of neckcollars. The feeding behaviour of all geese as well as of separate pairs was studied, abdominal profiles of pairs were scored regularly, the distribution of the geese within four subareas were followed and disturbance reactions to different sources were noted.

Study area and methods

The Kuuk Marshes (67°31´N, 50°34´W) is a low-land area below 200 m a.s.l that covers about 5 km^2 of sand dunes, marshes, small pools and dwarf-shrub (Fig. 1). The dwarf-shrub zone contains, e.g., Arctic Blueberry *Vaccinium uliginosum* (L.), Northern Willow *Salix glauca* (L.), Dwarf Birch *Betula nana* (L.), Crowberry *Empetrum hermaphroditum* (L.), Viviparous Knotweed *Polygonum viviparum* (L.) and grasses. The marshes and especially the small pools are rich in Common Cotton-grass *Eriophorum angustifolium*, Rigid Sedge *Carex bigelowii*, Common Mare´s-tail *Hippuris vulgaris* (L.) and *Ranunculus hyperboreus* (Rottb.). At the two mud banks (A and B, Fig. 1) bulbous buds of Marsh Arrow-grass *Triglochin palustre* (L.) were hidden about 5 cm below the surface. Dunes delineate the area to the west where the huge, silty Kuuk River flows. An area frequently used by the geese about two kilometres east of the Kuuk Marshes is a smaller marsh area similar to the study area. The Kuuk area is surrounded by mountains of 400-600 m a.s.l.

The weather measured at Kangerlussuaq (67°01´N, 50°43´W) in May 1996 (Asiaq 1995, 1996) was warmer and more wet than normal. Daily mean temperature was +6°C compared to +3°C as normal daily mean for May. Precipitation was 26 mm compared to 7 mm as normal precipitation for May. Upon arrival on 3 May the Kuuk area was snow free and only the bigger lakes, e.g. Long-tail Pool, were about 50% ice covered. Ice disappeared on 8 May, except on Manx Lake, which stayed ice covered during the entire period except for a narrow zone of land water.

The geese were studied primarily from observation point 1 (see Fig. 1), while point 2 was used mainly for counting geese in the Hidden Beach area (HB) which was not visible from point 1. Each observation point was accessible without disturbing the geese. The geese were studied using the following methods:

(i) The total area was scanned every fifteen minute, and the number of geese was noted in each of the three sub-areas (Beach area, BA, Long-tail Lake area, LA, and Swamp area, SA). Two diurnal observation periods were performed on 4-5 May (17:00-11:45) and on 11-12 May (22:30-13:00), while the observations on the remainder days covered the daytime from about 9-20. The behaviour of the geese was classified in feed, alert, stand, sit, roost, swim, preen, walk, fly, drink and aggression.

(ii) Pairs of geese were observed and the behavioural classifications mentioned above were noted in 5-seconds intervals. Each mate in a pair was observed for periods of 10 minutes and each pair was observed contemporaneously for a period of 20 to 120 minutes. The majority of geese were observed from 20 to 60 minutes. Both solitary pairs and flock pairs were observed. Solitary pairs were observed on the dates: 3-5, 7, 10, 13 and 16 May, and flock pairs on 3, 4, 6, 7, 10, 16 and 19 May. The observations covered the hours from 7-23, with most observations between 10-19.

(iii) Abdominal profiles were scored during the whole study period in 0.5 intervals (between 1.0 and 4.0, Owen 1981) for both sexes in a pair. Between 10 and 22 pairs (mean=17.7, SD=9.6, n=9) were scored daily during a relatively short period around 11 a.m.

The mean percent activity was calculated from the time the geese were actually observed. Because no diurnal behavioural rhythm was observed, the time budgets are likely to cover 24 hours a day.

Each of the above mentioned three studies were in general performed by the same observer during the entire study period. An exception was two diurnal observations in study (i). The geese were studied with 30 x and 20-60 x telescopes and 10 x binoculars. The behaviour of the geese (refer to (ii)) was tape-recorded and the tapes were read the same or the following day.

In order not to interfere with the distribution of the geese, disturbance tests, sampling of plants and goose droppings were done by the end of the study period, i.e. on 18 May. Uprooted plants and different plant species were collected in BA, SA and on B (Fig. 1). Disturbances from aeroplanes (Dash-7, 4 engines, c. 55 passengers; Twin-Otter, 2 engines, c. 20 passengers), walking persons, White-tailed Eagles *Haliaeetus albicilla* (L.), Arctic Foxes *Alopex lagopus* (L.) and Ravens *Corvus corax* (L.), were observed during the study period, and disturbance reactions (alert, walk, fly) and distances to the sources were noted. In one disturbance test the one observer walked straight down-hill towards 21 geese, while the other observer noted disturbance reactions. The disturbance distances were paced out afterwards.

The daily maximum number of geese on the Kuuk marshes was calculated both from obs. point 1, which covered areas BA, LA and SA, and from obs. point 1 plus 2, which also included HB. The latter maximum number represents the sum at the same 15 minutes period. Yet, on 7 May there was half an hour difference between the two periods.

Much effort was put into reading neckcollars, but readings were difficult since often the collars had to be read at distances of more than 500 m not to disturb the geese. Later in the study period heat haze made reading even more difficult. The 20-60 x telescope was used. Results were consulted with the Greenland White-fronted Goose Study (GWfGS) Data Base (A. D. Fox, pers. comm.).

Results

Migration

Migrating Greenland White-fronted Geese were observed on 2 May 1996 from an observation point situated one km east of the Kangerlussuaq airport (67°01´N, 50°43´W). The wind was 4-5 m/sec. from east and the visibility >10 km. Migration was observed from 8:45-12:00 and from 13:15 to 15:45. A total of 1014 geese were counted and the majority migrated N (481) and ENE (230). Most geese were observed during the first observation period, with a peak of 230 geese around 10:30. The average flock size was 7.7 (SD=5.3, n=130, min-max=1-30). The first geese were heard in the morning at 5:00 on 2 May. No geese were observed on 1 May. At Ilulissat (69°13´N, 51°06´W) the first Greenland White-fronted Geese were sighted on 2 May, where normal arrival is 5 May (K. Rosing-Asvid, pers.comm.).

At the Kuuk Marshes a total of 353 geese were observed migrating primarily north and west from 3 to 12 May, with a peak of 214 geese on 6 May. During this period 110 geese landed at Kuuk, whereas 37 were observed leaving Kuuk.

Number of geese

The fluctuations of the daily maximum number of geese are shown in Fig. 2. Greatest fluctuations and differences between the two calculation methods occurred during the first five days and can perhaps be explained by the two migration "waves" on 2 and 6 May. The number of geese on the area two km to the east of Manx Lake (refer to Fig. 1) is not included in the maximum numbers. On 11 May 137 Greenland White-fronted Geese were counted here, but no geese were counted at the

Kuuk Marshes during the same period. On 13 and 14 May no geese were observed east of the Kuuk Marshes.

Distribution of geese

The percentage distribution of Greenland White-fronted Geese on the three areas of the Kuuk Marshes is shown in three-hours periods during the study period (Fig. 3). Each three-hours period represents the average of 15-minutes scans during the period. The area most used during the study period was BA (mean=69.0%, SD=16.5, n=63), followed by SA (mean=19.3%, SD=15.5, n=63) and LA (mean=11.6%, SD=6.4, n=63). The mean number of geese on each of the three areas, evaluated from the mean of each three hours period, differs significantly from each other (paired t-test, BA/SA, t_{62}=9.4263, P<0.001; BA/LA, t_{62}=15.3079, P<0.001; SA/LA, t_{62}=3.1946, P=0.01). Fig. 3 indicates that the use of BA is increasing from 5 to 15 May and that 70-90% of the geese used BA from 10 to 16 May. The use of SA was minimal from 10 to 15 May.

Behaviour

The mean percentage of each behavioural class was calculated for every day (method (i)) and changes in feeding, alert and roosting behaviours are shown in Fig. 4. Each of the remaining behavioural classes was about or less than 5%, except for swim/walk/fly on 3 May (32%) and stand/sit on 5 May (33%). Feeding was by far the most important of all behavioural classes with a mean of 68.6% (SD=16.6, n=17) for the whole period (see also Fig. 6). The time spent feeding was significantly higher (Mann-Whitney U=6.5, P<0.05) during the first period from 3 to 12 May with a mean of 78.3% (SD=13.4, n=10) compared to the period 13 to 19 May with a mean of 54.9% (SD=9.6, n=7).

The activity budgets for females and males in solitary pairs are shown in Fig. 5A. The females fed more than the males (Wilcoxon T=9.5, n=25, P<0.002) while males stayed more alert than females (Wilcoxon T=11, n=27, P<0.002). None of the other behavioural classes differed significantly. Fig. 5B shows the activity budgets for females and males in flock pairs. The figure is similar to Fig. 5A, though differences between females and males are less pronounced. Again, females fed more than males (Wilcoxon T=29, n=23, P<0.002) and males were more vigilant than females (Wilcoxon

T=4.5, n=22, P<0.002). Also, males in flock pairs were more aggressive than females (Wilcoxon T=16, n=14, P<0.02) although male aggression was below 5% of the activity budget.

Behavioural differences between the two groups (solitary pairs and flock pairs) were compared in females and males, respectively. Females showed no differences in any of the behavioural classes (Mann-Whitney, P>0.05), whereas males showed differences in feeding (Mann-Whitney U=184, z=2.453, P<0.02), alert (Mann-Whitney U=97.5, z=4.146, P<0.001) and aggressive behaviour (Mann-Whitney U=150.5, z=3.114, P<0.01). Reference is made to Fig. 5 for direction of differences: males in solitary pairs spent much more time in alert position than males in flock pairs, leaving less time for feeding.

The overall activity budget calculated from the 15 minutes scan study and from the study of individual pairs is shown in Fig. 6. The Chi-square test showed no significant difference between the activity budget derived from the two methods (χ^2=7.99, P>0.10, df=5).

Abdominal profile index

The abdominal profile index was scored during the whole study period and median APIs for both males and females are shown in Fig. 7. The female median API was significantly higher than the male median API (Mann-Whitney U=14, n_1=n_2=9, P<0.05), whereas there seemed to be no differences in the increase rate of the median API of males and females.

Diet

In the BA the only up-rooted plants found were *Eriophorum angustifolium*. It was obvious that the lower parts were eaten while the leaves were left. At the fringes of the BA ponds we collected *E. cfr. angustifolium* and *Carex cfr. bigelowii*. In the SA, plants were collected at the central lakes, at the lakes on the western side of mud bank B and on the dwarf-scrub heath (the southern part of SA, see Fig. 1). The following up-rooted plants were found: *cfr. E. angustifolium* (at both lake areas), *Ranunculus hyperboreus*, *Hippuris vulgaris* and *Carex* sp (*subspatacea ?* (Wormsk.)). Sprouts of the latter were found in high numbers floating on the surface. Bulbous buds of *Triglochin palustre* were dug from the mud (at B) where the geese had been feeding, and *Polygonum viviparum* bulbous rhizomes were eaten by the geese, indicated by lots of c. 3 cm holes in an area rich in *P. viviparum*. There seamed to be no depletion of especially *E. angustifolium* in the important BA feeding area.

Disturbances

Table 1 summarises the geese' reactions and distances to different sources of disturbance. Most reactions were observed at distances between 200 to 700 m from the source. Between 10 and 16 May at least two White-tailed Eagles were observed in the area. The geese were flushed by the eagles at least seven times during the period. The eagles were seen either soaring or chasing the geese actively, and each time all geese were flushed. In most cases the geese resumed their activities after 30 to 60 minutes. Arctic Foxes hunted often in the area and in most cases (n=13) geese were little disturbed and stayed on ground (refer to Table 1 with only one observation of flying reaction). At least five times the geese took to flight for no obvious reason, but a couple of times a soaring Raven appeared, maybe mistaken for an eagle.

Neckcollar readings

Five different neckcollars were read and identified from the GWfGS Data Base. Four birds had been ringed in Ireland, Wexford, and one in West Greenland just north of Kangerlussuaq. One of these was observed for three consecutive days (6-8 May), one for two days (17 and 18 May) and the rest for only one day (5, 10 and 19 May, respectively). Between two and five other neckcollared geese were observed between 6 and 15 May, and one adult male with leg rings only was observed for five days (6-10 May).

Discussion

From the present study it is obvious that the Kuuk Marshes represents an important area for the Greenland White-fronted Geese during the period from arrival to clutch initiation. The geese most likely arrived at Kuuk on 2 May, the day where more than 1000 geese migrated north in West Greenland, and some stayed to at least 19 May. Yet, the area was most intensively used between 3 and 12 May with a mean maximum number of 280.1 (SD=92.0, n=10). Also, the time spent feeding was significantly higher during this period compared to the later period. After around 12 May both maximum number of geese and feeding intensity decreased, and during this later period pairs of geese were seen more often in the surrounding terrain in search for suitable nest sites. The importance of the area is underlined both by the number of adult, potentially breeding birds that visits the area during the prebreeding period and by the use of the area for intensive feeding.

Number of geese

To evaluate the total number of geese which has visited the Kuuk Marshes during the spring staging period, it is important to know of both the daily maximum number and the mean duration of stay. The daily maximum number is available from the present study (refer to Fig. 2), whereas the turnover rate is poorly known. From observations of only six marked geese the mean duration of stay would be 2.2 days (SD=1.6, range 1-5). This is thought to be a minimum number since some of the unread collars could add to the staging period and collared geese could be overlooked. With a mean maximum number of 199.8 (SD=121.4, n=17) over the entire study period this means that about 1500 geese have visited the area, or about 25% of the calculated 6000 breeding birds (Glahder1999). Aarvak et al (1997) found in five consecutive years a mean duration of stay of 6.9 days (number of pairs=111) in spring staging Lesser White-fronted Goose *Anser erythropus* (L.). Using this staging period would mean that about 500 geese have staged in the Kuuk Marshes. From the maximum number counted on the first day and geese observed to land on the Kuuk Marshes (110) at least 500 geese, or more than 8% of the breeding birds, must have visited the area. Aerial surveys conducted in May 1995 and 97 found the Kuuk area ranked third highest of 35 areas visited, holding 12% of the counted geese (Glahder 1999). This percentage of the 6000 breeding birds would account for about 700 geese and a mean duration of stay of 4.7 days. Assuming an even distribution of neckcollared individuals in the entire population of the Greenland White-fronted Goose (389 of c. 30,000 in 1996, A. D. Fox, pers. comm.), 8-11 neckcollared birds correspond to a total number of 617-848 staging geese.

The two estimates of a mean duration of stay of 2.2 and 6.9 days on spring staging areas in the breeding range are substantially shorter than the period of 11-14 days thought necessary for rapid oocyte growth (in Greater White-fronted Goose *Anser albifrons frontalis* (Baird), C. R. Grau in Ely and Raveling 1984). This indicates that less than half of the prebreeding period is spent on the spring staging areas. Given the average duration of stay is only 2.2 days, the observed increase in median API (cf. Fig. 7) would probably not be possible after the geese have migrated about 1500 km from Iceland. If, on the other hand, the spring staging period was in the range of 11-14 days, the arriving geese would stage at the area for almost the entire study period and start breeding between 14 and 17 May. This longer period fits well with observations of geese searching for nest sites around 12 May and with the increasing median API, but not with the decrease in daily maximum number before 12 May. So, possible way to explain the data is that some geese use the Kuuk Marshes during most of the period as a staging area near the breeding grounds and that others use Kuuk only as a stop over site on their way to the breeding grounds. An average staging period of about 7 days seems to fit with the moderate increase in average API of 1.0 pr. 10 days, given an increase of 1.5-2.5 pr. 10 days is thought possible in Greenland White-fronted Geese (refer to Table 2, Madsen 1994, Madsen et al. 1997). An average length of stay of at least 7 days is confirmed by three adult males fitted with satellite transmitters. The geese staged on spring staging areas in West Greenland for 8 to 10 days (on 9-19 May 1998) before they continued to their possible breeding grounds. (Glahder et al. 1998).

Feeding in the area

The geese were feeding for 68.6% of their time during the study period, which corresponds well with the 68% found in the same area during 9-12 May 1979 (Fox and Madsen 1981b). During the first period (3-12 May) the geese fed for 78 % of their time, which declined to about 55% during the later period (13-19 May). The female fed for almost 80% of the time during the whole period and the median API increased from 1.5 to 2.5. This approximate an increase in API of 1.0 in 10 days, which is comparable to an increase of 0.5-1.5 in 10 days in other spring staging geese species (refer to Table 2). The feeding in the female was independent of whether the pair was solitary or in a flock. The reason for this was that the male in solitary pairs spent more than half of his time being alert leaving only one third for feeding. The male took advantage of flocking so that less than 20% of the time was spent being alert, leaving almost 60% for feeding; this pattern was found also by Fox and Madsen (1981b). The male median API only increased from 1.0 to 2.0. The decrease in time spent feeding in the second half study period can maybe be explained by the fact that fewer birds were left on the Kuuk area so that a higher percentage would feed in solitary pairs. During the same period there was an increase in the alert behaviour (see Fig. 4).

Most of the Kuuk Marshes was used by the geese and mainly for feeding. The pools in BA were by far the most intensively used with two-thirds of all geese using this area. The importance of this area was most pronounced during the middle period (10-16 May). The reason that these pools were used the most is due to the abundant supply of *Eriophorum angustifolium* which the geese up-rooted and ate the stem-bases. Madsen and Fox (1981) found that *Eriophorum* spp were the most important food item in Greenland. *Eriophorum* sp was also important to spring staging Greenland White-fronted Geese in Greenland (Fox and Ridgill 1985) and Iceland (Fox et al. 1983), and during winter (Fox et al. 1990). Fox and Madsen (1981a) found the most important feeding areas to be the mud bank A and the BA pools. When A and the surrounding smaller pools started to freeze late in the evening the geese were forced to the larger Beach Pools until morning thaw. This was thought to cause the diurnal feeding rhythm. No such pattern was found in our study, maybe due to warmer weather conditions. Early in the spring staging period geese increased in number up until midday on the heath areas of SA. Here they fed primarily on the hazelnut-like rhizomes of *Polygonum viviparum*. These over-wintering storage organs such as rhizomes, stem-bases and buds are highly nutritious (Fox and Madsen 1981b, Fox et al. 1990).

Management implications

The study has shown that about 10% of the potential breeding Greenland White-fronted Geese (about 600) and c. 2% of the total population stage on the Kuuk Marshes. The latter percentage qualify the area as a Ramsar site (Grimmett and Jones 1989), and in fact the area is part of the bigger Eqalummiut Nunaat-Nassuttuup Nunaa Ramsar site (Jepsen et al. 1996).

During a period of about 10 days almost 80% (=19 hours) of the diurnal period the geese spent feeding in the area. This indicates that any disturbance during this period can cause a delay in breeding initiation and may influence the breeding success negatively. White-tailed Eagles caused the most significant natural disturbance by flushing all geese for up to one hour, on average once each day later in the period. Human disturbances (aeroplanes and walking persons) flushed the geese at distances between 200 and 700 m, whereas planes above 1000 m above ground caused no reactions. Ward et al. (1994) showed that fixed-wing aeroplanes caused greater flight response when passing below 610 m altitude and less than 800 m lateral distance to flocks of fall-staging Brent Geese *Branta bernicla nigricans* (Lawrence). Alert reactions were observed at distances to the aeroplanes of 2.6 km. Helicopters are known to cause more disturbance to geese than fixed-wing planes (Mosbech and Glahder 1991, Ward et al. 1994), and should pass the area at, at least 1000 m above ground. In a simulation study (Miller 1994) small helicopters at altitudes above 1220 m and large above 1680 m caused no disturbance to Brent Geese (measured as weight loss due to flight reactions). Walking persons should pass the area at a distance of not less than 500 m. Since the most important staging period is the first 14 days upon arrival and normal arrival dates are between 1 and 7 May (Fox and Madsen 1981a, b, Fox and Ridgill 1985, K. Rosing-Asvid, pers. comm.) a protection period from 1 to 20 May is recommended.

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Table 1 Disturbance reactions and distances (m) to the source.

The distances to the aeroplanes (Dash-7, Twin-Otter) are given in m above ground. Person (other) indicates that geese were flushed by accident. The White-tailed Eagles (White-t Eagle) flushed all geese in the area; the distance to the eagles were difficult to calculate, because geese took to flight before the eagles were observed. The geese in most cases resumed their activities after 30-60 minutes.

Source	Disturbance reaction				Obs. number
	No reaction	Alert	Walk	Fly	
Dash-7	≥1000	-	-	-	4
Twin-Otter	-	-	-	700	1
Person (test)	>675	675	445	245	1
Person (other)	-	-	-	2-500	4
Arctic Fox	-	-	-	50-100	1
White-t Eagle	-	-	-	>500	7

Table 2 Increase in female goose API during spring staging

The change in API for a 10 days period (API/10 days) for Barnacle Goose *Branta leucopsis* (Bechstein), Pink-footed Goose and Greenland White-fronted Goose derived from literature (Figs) or own observations; [1]fertilised grassland, [2]non fertilised marsh, [3]no information.

Reference	Goose species	Country	Period	API/10 days
Owen 1981	Barnacle	North Norway [3]	7-17 May	0.5
Boyd and Fox 1995	Pink-footed	Iceland 1989 [1]	28 April-7 May	1.1
		Iceland 1990 [1]	21 April-12 May	0.6
		Iceland 1991 [1]	24 April-13 May	0.6
		Iceland 1992 [1]	22 April-10 May	0.6
Madsen 1994	Pink-footed	North Norway [1]	7-17 May	1.5
Madsen et al. 1997	Pink-footed	North Norway [1]	c.15-20 May	2.1-2.5
This study	Gr. White-fronted	Greenland [2]	4-19 May	1.0

Fig. 1 The Kuuk Marshes in central West Greenland.

BA: Beach area, HB: Hidden Beach area, LA: Long-tail Pool area, SA: Swamp area, A and B: Mud banks. *1 and *2: Observation points, Black areas: Pools. (Fig. modified from Fox and Madsen 1981a.)

Fig. 2 Maximum number of Greenland White-fronted Geese on the Kuuk Marshes.

Maximum number of geese on the areas BA, LA and SA (solid line) and on BA, LA and SA + HB (broken line). Migration "waves" on 2 and 6 May are indicated with arrows.

Fig. 3 The percentage distribution of geese on three areas of the Kuuk Marshes.

The percentage distribution of geese on the areas BA, LA and SA is given in 3-hours periods from 3 to 19 May. The 3-hours distribution is a mean of 15-minutes scans.

Fig. 4 Feeding, alert and roosting behaviour as percentages of total activity budget during the study period, 3-19 May.

The mean percentage of each of the three behavioural class are calculated for each day. The remainder of the behavioural classes are in general low and are not depicted in the figure.

Fig. 5 Activity budgets for females and males in

A: Solitary pairs (n=27), B: Flock pairs (n=23).

Fig. 6 Activity budgets for Greenland White-fronted Geese calculated in two different ways.

The activity budget is both calculated from the 15-minutes scan method ((i) in method-chapter): "Scan", and from observations of individual pairs ((ii) in method-chapter): "Pairs".

Fig. 7 Median Abdominal Profile Indexes (APIs) for females and males on the Kuuk Marshes.

The number of pairs scored each day is indicated in brackets.

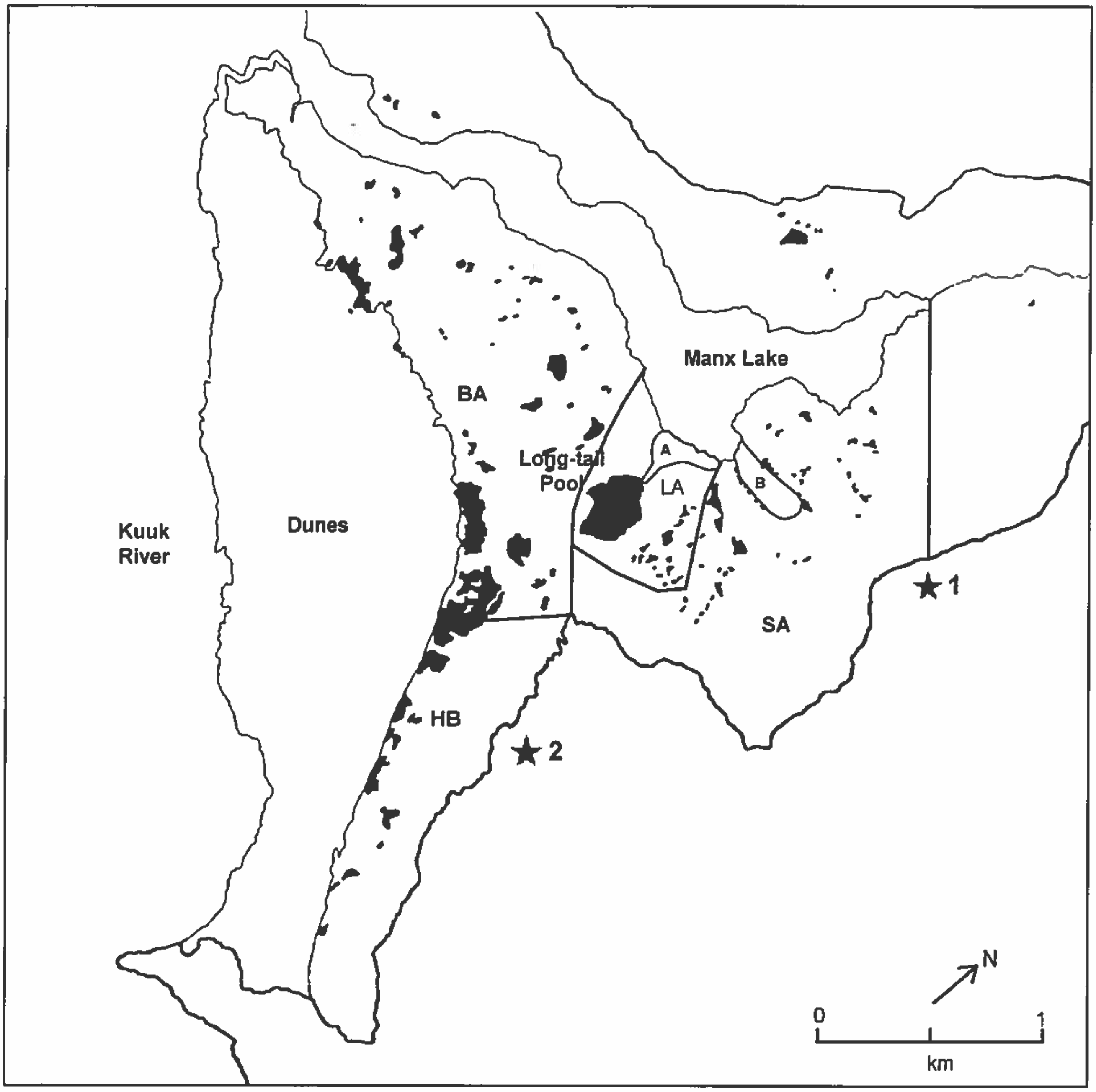

Fig. 1

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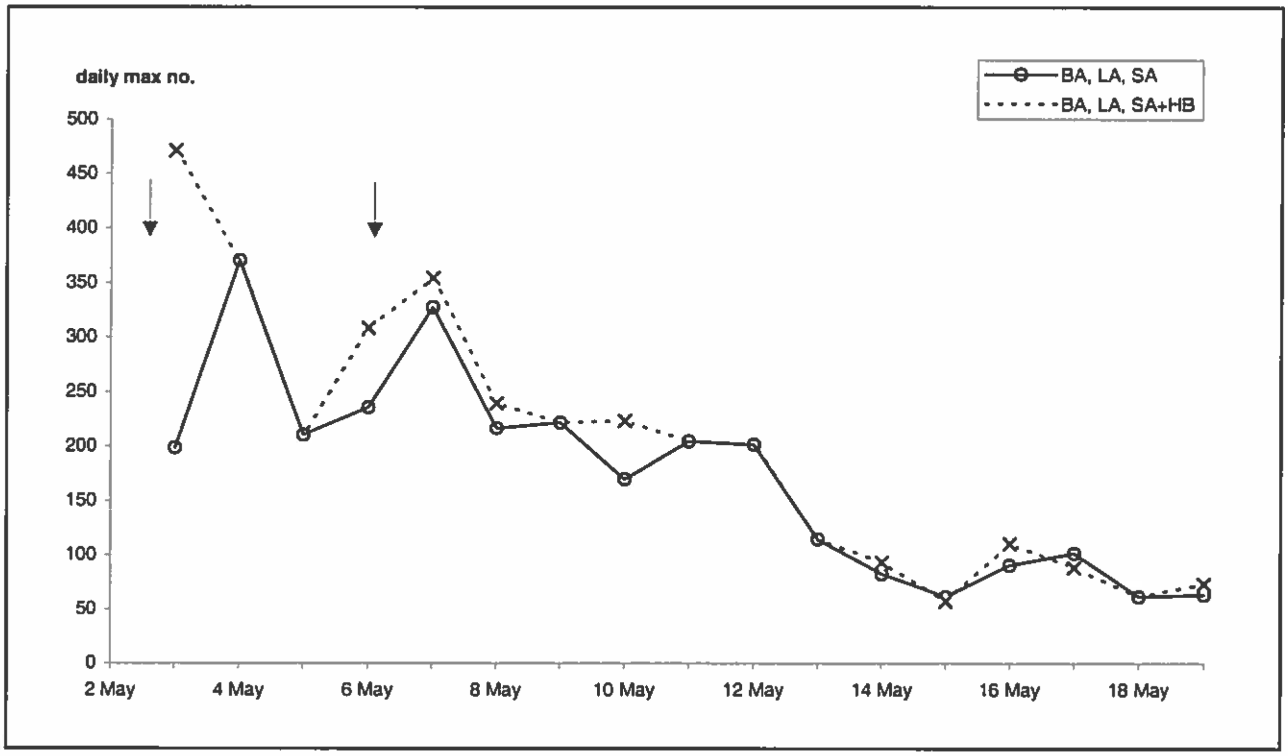

Fig. 2

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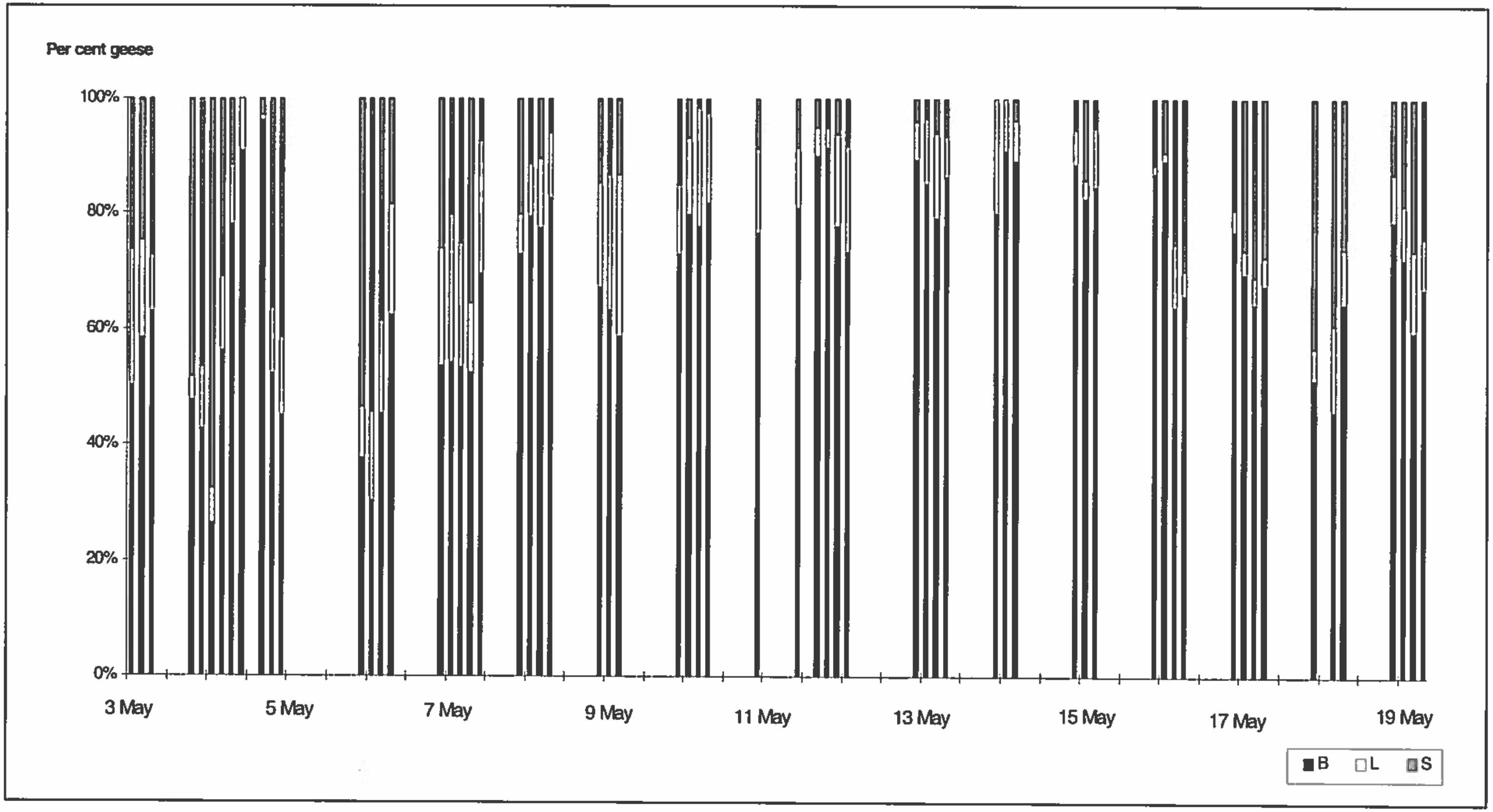

Per cent geese
100%
80%
60%
40%
20%
0%
3 May
5 May
7 May
9 May
11 May
13 May
15 May
17 May
19 May
B
L
S

Fig. 3

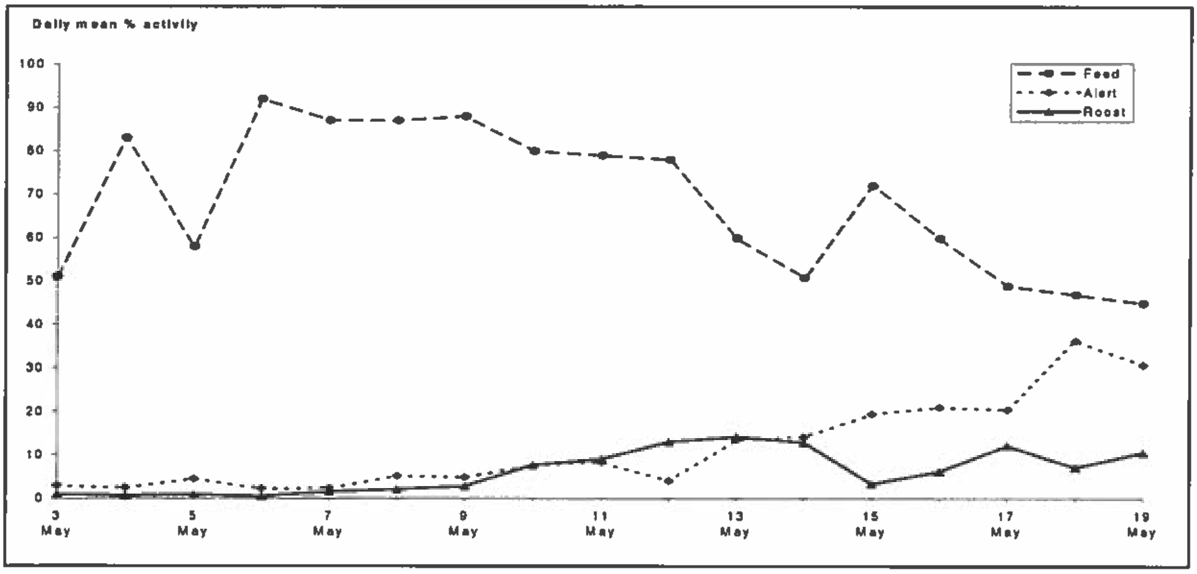


Fig. 4

Christian M. Glahder, Josephine Nymand and Marianne Krag Petersen

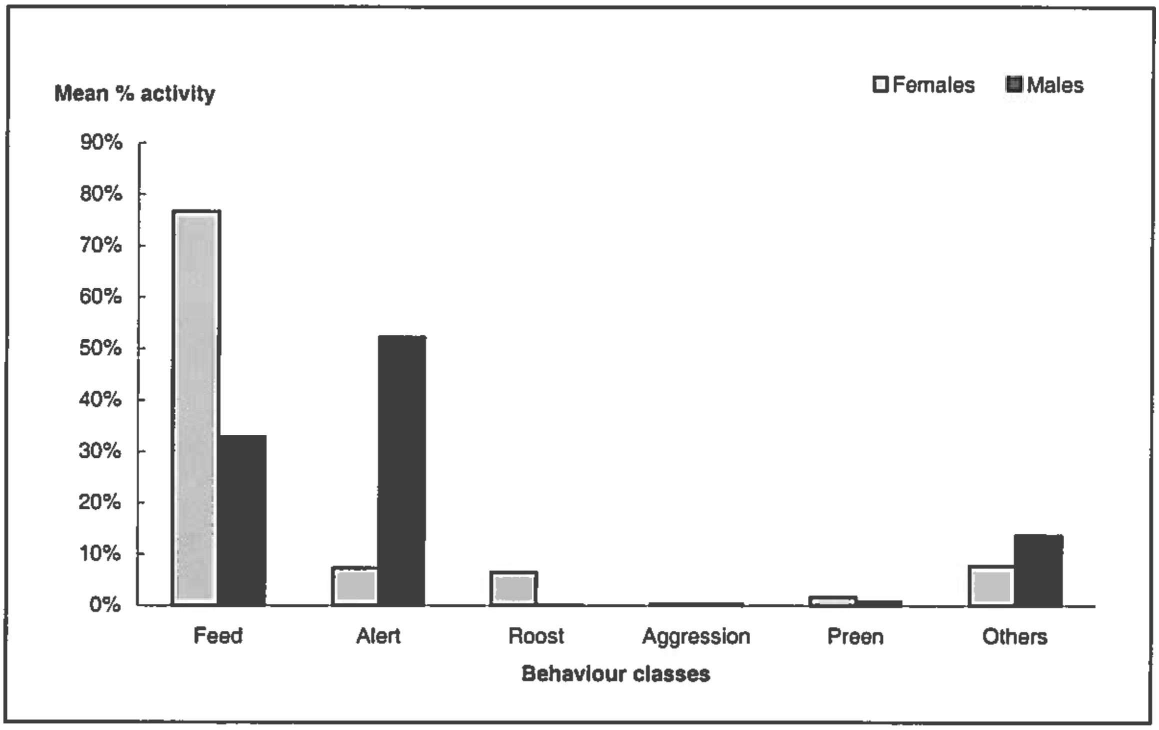


Fig. 5A

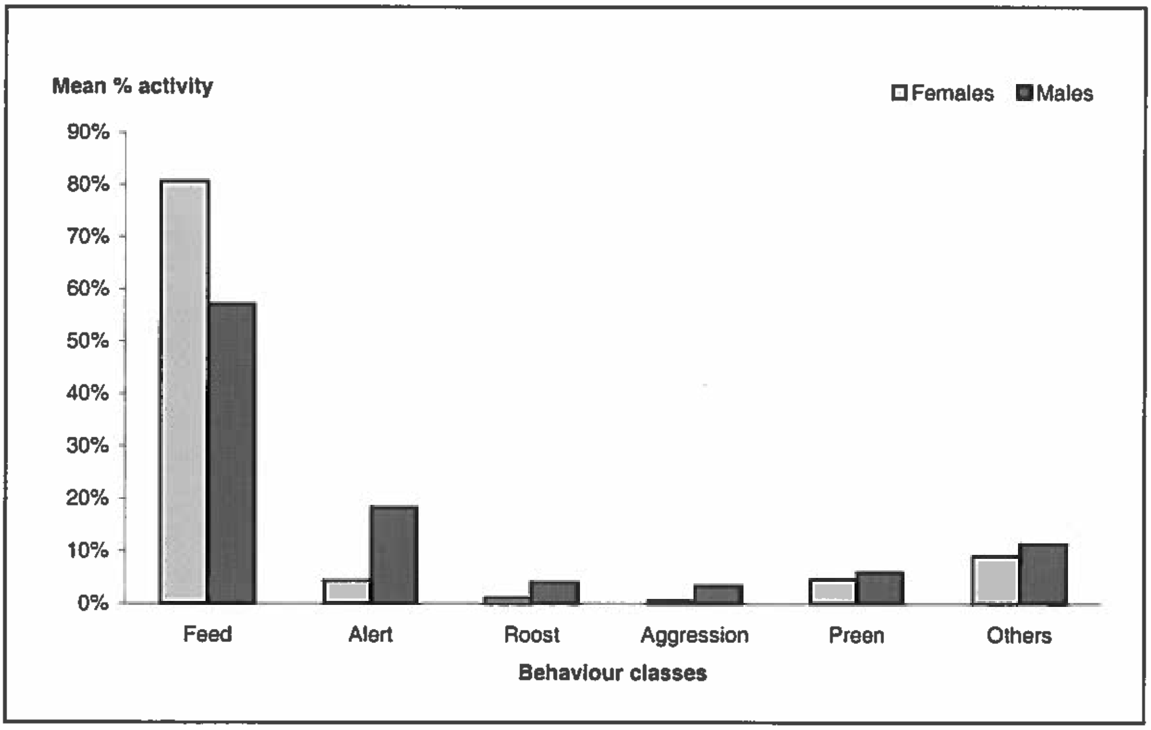
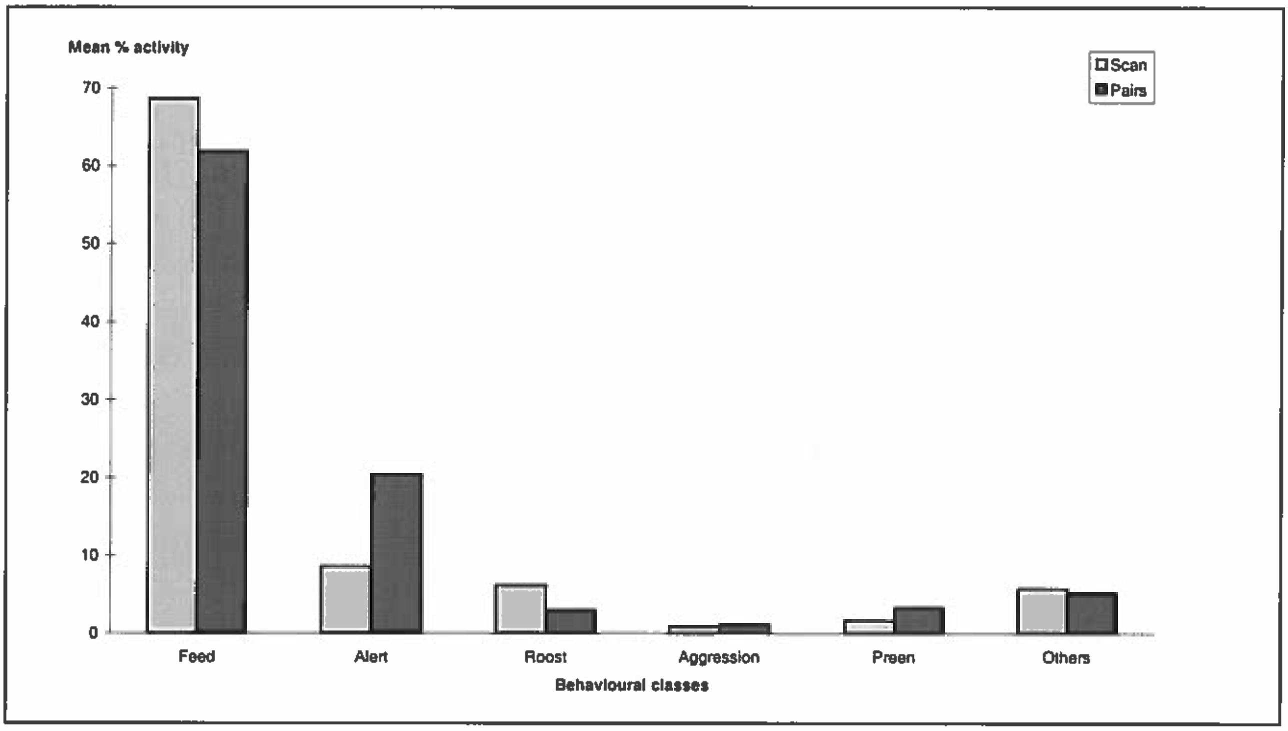


Fig. 5B

Christian M. Glahder, Josephine Nymand and Marianne Krag Petersen



Mean % activity
70
60
50
40
30
20
10
0
Scan
Pairs
Feed
Alert
Roost
Aggression
Preen
Others
Behavioural classes

Fig. 6

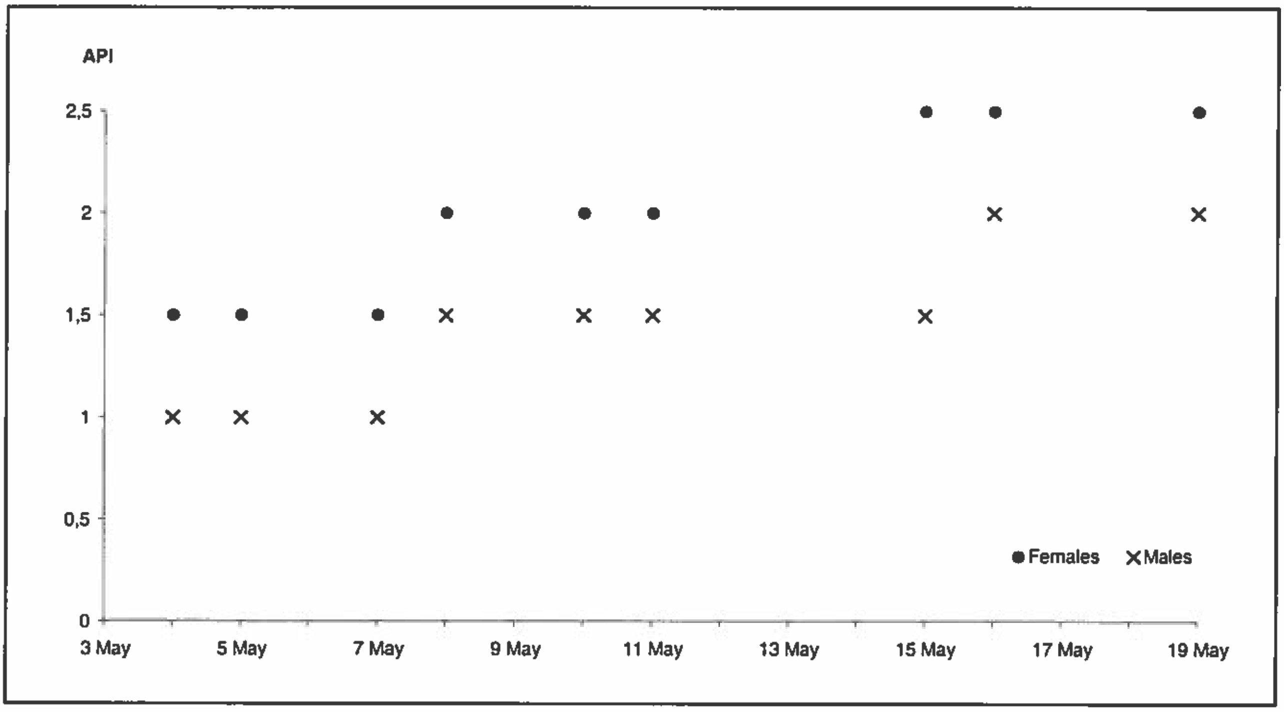

API
2,5
2
1,5
1
0,5
0
3 May
5 May
7 May
9 May
11 May
13 May
15 May
17 May
19 May
Females
Males

Fig. 7

10 Effects of fitting dummy satellite transmitters to Greenland White-fronted Geese *Anser albifrons flavirostris*

Effects of fitting dummy satellite transmitters to Greenland White-fronted Geese *Anser albifrons flavirostris.*

C. M. GLAHDER, A. D. FOX & A. J. WALSH

Before attaching satellite transmitters to Greenland White-fronted Geese to study spring migration and spring staging areas in Greenland and Iceland, dummies including a radio transmitter were attached to the geese to study the effects on e.g. behaviour and condition, and to find an effective harness material. Twelve free-flying Whitefronts were tracked and studied in a three month period on the wintering grounds at Wexford Slobs in Ireland. The dummy-fitted geese preened significantly more than controls two to three days after the attachment, but one week after handling the behaviour seemed to have normalised. There were indications that dummy-fitted geese increased their abdominal profile index less than controls during a one month period. Other behaviour such as site fidelity, flying to roost and family group cohesion all appeared normal. The knicker elastic harness proved more effective than the neoprene harness. It is recommended that satellite transmitters are attached to the geese at least two weeks prior to spring migration, that transmitters are as light as possible, that transmitters are fixed to the harness to prevent sideways slippage and that a less robust harness design be developed to ensure packages fall off within the course of a year.

Keywords: Greenland White-fronted Goose, Satellite Transmitters, Harnesses, Behaviour, Body Condition

Introduction

The population of Greenland White-fronted Goose *Anser albifrons flavirostris* has almost doubled since the early 1980s to its current level of about 30,000 (Fox et al. 1994), but despite this, it is important to identify and designate specific sensitive areas and periods, since the population size on a world scale is small, has a restricted geographic distribution and low productivity (Fox et al. 1983). Most wintering grounds in Ireland and Britain are well known and regularly censused, whereas spring staging areas in Iceland and Greenland and moulting grounds in Greenland are poorly known.

Some major spring staging areas have been localised in Iceland (Francis & Fox 1987) and in recent years research work on abundance and staging has been carried out (Fox et al. 1994). In Greenland, moulting grounds holding more than one quarter of the total population have been identified from aerial surveys in 1988, 89, 92 and 95, carried out by the Greenland White-fronted Goose Study (GWGS) and Greenland Environmental Research Institute (GERI) (Fox et al. 1994). Many of these areas have been designated as "areas important to wildlife" (MRA 1996). Research on spring staging areas has been carried out by GERI since 1994 using aerial surveys, ground surveys and behavioural studies at one specific site.

In order to supplement the research work already carried out in the vast and remote areas of Iceland and Greenland, a satellite tracking project was initiated in 1996 by two departments of the National Environmental Research Institute (NERI) in Denmark (Glahder et al. 1996). Apart from identifying spring staging areas and the length of the stay and movements between areas, the objectives of the project were also to shed light on the course and duration of the spring migration from Ireland to Greenland.

Different studies on attaching satellite or radio transmitters to birds have revealed the following negative effects: weight loss and intensified preening (Greenwood & Sargeant 1973, Perry 1981, Johnson & Berner 1980, French & Goriup 1992), reduced survival (Johnson & Berner 1980, Warner & Etter 1983, Marks & Marks 1987, Paton et al. 1991) and increased nest desertion and decreased reproductive success (Erikstad 1979, Sibly & McCleery 1980, Warner & Etter 1983, Massey et al. 1988, Paton et al. 1991, Falk & Møller 1995, Ward & Flint 1995).

In order to determine the best techniques to be employed it was decided to test the effects of different dummy transmitter weights and the use of different harness types on the behaviour of wild Greenland White-fronted Geese prior to the satellite tracking project. Two transmitter weights and two harness types were tested on Greenland White-fronted Geese on the wintering grounds at Wexford Slobs, Ireland, from 13 January to 22 April 1996. The majority of geese migrated north between 27 and 29 April.

During the period shortly after the attachment of the dummy satellite transmitters, intensive observations of the behaviour of geese with and without transmitters were carried out to assess the effects of the harnesses and transmitters on the geese so fitted. During the rest of the study period the geese were tracked on the Wexford Slobs to check feeding and roosting sites, abdominal profiles and the attachment of the dummies.

Materials and methods

The lightest satellite transmitters on the market in early 1996 were produced by Toyocom and Microwave (25-30 grams). Addition of, for example, a waterproof housing and a pressure sensor would increase weights to about 50 grams. Therefore we decided to test dummy transmitters with approximately these two weights. The actual weight groups turned out to be on average 38.0 g (SD±2.3 g, n=6) and 54.1 g (SD±2.2 g, n=6), in this paper called "light" and "heavy" dummies, respectively. All dummies were approximately 65x16x25 mm in size and made of blocks of epoxy resin with a radio transmitter (Biotrack Ltd., TW-2, 16 g, antenna plastic coated, length 28 cm) embedded within them. The size and shape of the dummies differed little from those of the Microwave type, which was subsequently chosen for the study. The antenna lay almost flat along the back when attached because of the radio transmitter design and not at the 45° angle of the satellite transmitters. Lead shot pellets were added into the resin to produce the heavy dummies. The dummy was prepared for the harness by drilling two holes into the resin block in front and at the back above the antenna, and a 50 mm long plastic tube, diameter 4 mm, was glued into each hole.

In this study knicker elastic and neoprene tape were chosen as harness materials because they both were strong and elastic and had the ability to degrade. The knicker elastic, (trade name "Grober"), bought in an ordinary draper´s shop in 3 m length, was black, five-strand elastic, 7 mm wide, 1 mm thick, weighing 7.0 g pr. m. The neoprene tape, delivered in 1 m lengths from O'Dare Ireland Ltd, manufacturer of divers wet suits, was covered on two sides with a blue and a black nylon covering, was 6 mm wide, 4 mm thick and weighed 5.5 g pr. m. Stretching tests with the two harness materials showed that knicker elastic could be stretched to a maximum of some 225% of its unstretched length, while neoprene tape could be stretched more than 350%. After such treatment, relaxed knicker elastic was 3% longer than the initial length, while neoprene tape had stretched an extra 62% in length.

Knicker elastic has been fitted on Woodcocks *Scolopax rusticola* (H. J. Wilson, pers. comm.) and neoprene tape was used on Whooper Swans *Cygnus cygnus* (Pennycuick et al. 1996), both yielding good results. Other attachment methods have been used, e.g. flexible leather strip harness (Jouventin & Weimerskirch 1990), Teflon-coated ribbon or wire harness (Greenwood & Sargeant 1973, Paton et al. 1991, Falk & Møller 1995, S-H. Lorentsen, pers. comm.), glue on the back (Massey et al. 1988, Sodhi et al. 1991, Gudmundsson et al. 1995), plastic plate on upper tail or neck collar (Kurechi et al. 1995) and implantation (Petersen et al. 1995).

The harness went round the body behind the wings and forward of the legs, with the dummy glued to the middle of the back using the cyanoacrylate glue "Superattack". The knicker elastic was looped twice around the goose, the two ends knotted and glued. Two loops of neoprene tape were used and all four ends joint in one knot and glued (Fig. 1). To obtain an appropriate and regular tension on the knicker elastic harness when fitted to the goose, a spring balance holding the dummy with the harness preliminary attached should show c. 1.6 kg with the dummy lifted 100 mm above the back of the goose. To obtain consistent tension, c. 1.1 kg was applied using neoprene tape. Knicker elastic was thus tensioned to c. 125% of its unstretched length and neoprene tape to c. 130%. Results from the stretching tests showed that placing knicker elastic and neoprene under similar tensions, elongation stabilised after a few hours under tension to 101.2% of the original length in knicker elastic and 106.9% in neoprene.

In total 12 Greenland White-fronted Geese were fitted with dummy satellite transmitters, six with light and six with heavy dummies. Only five geese had dummies attached with a neoprene harness because only 10 strips were delivered, the remainder were fitted with a knicker elastic harness. The geese were cannon-netted on the same field on the Wexford North Slob on 13 and 19 January 1996. The first catch was of a family group of 10 from which one escaped from under the net, nine were marked with neck collars and leg rings, six of which were fitted with dummies (3 light, 3 heavy) attached with a knicker elastic harness. In the second catch two related family groups of 19 geese in total were caught and marked, and five fitted with neoprene attached dummies (3 light, 2 heavy), one with a knicker elastic attached dummy (heavy).

The geese were tracked with a M-57 Mariner Radar receiver with a standard 3-element Yagi antenna on the Wexford North Slob and at their roost site on the sand banks south of Raven Point (Fig. 2). The Wexford North Slob situated in south-east Ireland, is an area of 1,000 ha of intertidal flats converted to intensive agricultural use, such as grassland for stock, root crops and cereals. The North Slob includes the 100 ha Wexford Wildfowl Reserve, which includes one field of unharvested sugar beet made available to the geese during the winter (Fig. 2).

The family flocks were sighted, positioned and the abdominal profile index, API (a fatness index) scored using 0.5 intervals between 1.0 to 4.0 (Owen 1981). Behavioural studies were carried out in the first 14 days after the catch. The family flock was filmed with a video camera (8x magnification) and neck collar codes were read, using a 30-60x telescope, repeatedly into the camera sound track to enable identification of individual geese on film. The following behaviours were noted at 5 second intervals: sit, stand, sleep, alert, walk, swim, feed, drink, bathe, aggressive and preen. Preening was divided into preening of: neck, breast, flanks, belly, under tail, upper tail, back, back plus antenna, under wing, upper wing, wing stretch, leg ring, foot and bill in water.

The effects of dummies on behaviour were tested two and three days after the attachment by pooling activity budgets for geese fitted with both knicker elastic and neoprene harnesses. The differences in activity budgets between geese fitted with dummies and controls were tested with t-tests on each behaviour after data were normalised with an arcsine transformation. Variances in the two groups were tested with an F-test and showed no differences.

Results

Behaviour, activity budgets

Geese attached with dummy satellite transmitters preened significantly more than controls two to three days after the attachment ("preen all" in Table 1). The back and neck were preened significantly more by geese attached with a dummy than by controls, and preening the flanks was almost significantly different from controls (P=0.052, Table 1).

The material shows considerable individual differences, with dummy-fitted birds preening their back for 0 to 5.9% of the time, the flanks for 0 to 12.2% and the neck for 0.5 to 39.2%; corresponding differences in controls were 0 - 5.2%, 0 - 10.9% and 0.8 - 11.7%.

Seven days after the handling of the geese attached with a knicker elastic harness, dummy-fitted geese and controls showed almost exactly the same behaviour, and none of the groups were observed preening. It should be noted, that the sample periods were restricted, i.e. dummy-fitted geese/controls: Obs. time: 13.5/15.2 mins; number of geese: 2/2.

Site fidelity and roost

All family groups showed high site fidelity over the three month period (Fig. 2). The family group with geese fitted with a knicker elastic harness was sighted 30 times with 83% of the sightings in or within 400 m of the sugar beet field (Fig. 2,A). The two related family groups with members fitted with neoprene harnesses hadmost sightings in two different fields (Fig. 2,B). Of the 29 sightings, 27% were from the sugar beet field, and 42% from the field to the northeast of this. The two groups are comparable to typical "home ranges" on the Wexford North Slob (0.4-0.6 km^2, Wilson et al. 1991).

On fourteen evenings over the three month period the family groups were tracked to their roosting site on the sand banks south of Raven Point.

Abdominal profile index

During the period from 29 February to 5 or 8 April all geese but one increased their API. The differences in the API for geese fitted with light and heavy dummies and control geese are compared in Table 2. There is a tendency for more controls to have an API difference ≥+1.0 than geese fitted with a light or a heavy dummy, and that more geese with a light dummy have an API difference ≥+1.0 than geese fitted with a heavy dummy, although these differences did not attain statistical significance.

Attachment

All the seven Greenland White-fronted Geese with a knicker elastic harness had their dummy satellite transmitter attached on 21 April after 99 days. The dummies were securely attached on the back of six of the geese; on the seventh goose the dummy had sat on the back for 72-86 days but had slipped onto the flank for the following 13-27 days. Five of the seven Greenland White-fronted Geese attached with a dummy were sighted on Wexford Slobs (4) and Islay, Scotland (1) 314 days after attachment. The dummy was on the flank of three of the geese (all juveniles), whereas two (adults) were without a dummy.

On 21 April, after 93 days, only one of the five geese with a neoprene harness had the dummy satellite transmitter securely attached. The dummy had slipped to the flank on three of the geese, two of those after 38-41 days, and one after 81-93 days. The fifth dummy was lost after 4-6 days and retrieved from a receding pool on the North Slob on 26 February. The neoprene tapes were gone, and the antenna was reduced from 28.0 to 15.3 cm. About ten mantle feathers were attached to the dummy. Three of the five

Greenland White-fronted Geese fitted with a dummy were sighted on Wexford Slobs 308 days after handling and all had lost their dummy. One of these was sighted on Iceland 1 May 1996 with the dummy on the flank (Ó. Einarsson, pers. comm.).

Discussion

Preening behaviour

Greenland White-fronted Geese with harness-attached dummy satellite transmitters preened significantly more than controls two to three days after attachment and back, neck and flank were the areas preened the most. The geese preened for nearly ¼ of the total time budget. One week after handling the behaviour seemed to have normalised. One of the geese was observed several times pulling on the dummy and managed to remove it four to six days after attachment.

Increased preening and attention to attached transmitters and harnesses have been shown in different studies. Perry (1981) reported, that 11 Canvasbacks *Aythya valisineria* equipped with radio transmitters and tracked for about one week, spent about ¾ of the daylight hours pulling on the transmitter. It was stated that Canvasbacks probably failed to adapt to the transmitters and acted abnormally until they dislodged the unit or died. Periodic observations during a 13 weeks period on 30 captive Mallards *Anas platyrhynchos* and 30 Blue-winged Teal *A. discors* fitted with radio transmitters suggested that treated birds preened more than the control birds and appeared preoccupied with the transmitters (Greenwood & Sargeant 1973). Three captive Houbara Bustards *Chlamydotis undulata macqueeni* fitted with dummy satellite transmitters and studied for eight weeks spent more time preening, especially where the harness came in contact with keel, belly, shoulders and neck (French & Goriup 1992). The only unusual behaviour observed in 12 radio tagged Merlins *Falco* *columbarius* was initial preening of the transmitter for a few hours after release (Sodhi et al 1991).

These studies referred to were not quantitative, but indicate that different bird species when fitted with a transmitter show very different behavioural responses, ranging from rapid acceptance to no adaptation. The results of both studies of Canvasbacks and Whitefronts suggest that there is considerable inter- and intraspecific variation in response to transmitter attachment. The Greenland White-fronted Geese seem to show fairly rapid adaptation within a period of about one week.

Other general behaviour such as site fidelity, flying to roost and family groups cohesion all appeared normal over the three month period prior to the departure in spring.

Condition

The increase in time spent preening by the Greenland White-fronted Geese seemed to occur at a cost to feeding (38.9 versus 50.3% in controls), although this difference was not significant. There are indications that, in the period from late February to early April, the dummy-fitted geese did not increase their condition, here expressed as difference in API, as much as the control geese. On average dummy-fitted geese increased API by 0.8; control geese increased API by 1.3, compared to an increase of 1.0-1.5 in more general studies of Greenland White-fronted Geese feeding during the same period at the same site (Mayes 1991). The weights of the attached dummies were 1.5-2.1% of the body weights.

It has been reported in several studies that birds fitted with transmitters or dummy transmitters lose weight, and the decrease in the body weight is in some of these studies connected to increased preening. This was most dramatically demonstrated in the Canvasback study (Perry 1981), where three of the birds were not observed feeding during a one week period. Three other birds had serious weight loss after nine days. Transmitter weights were between 1.3 and 1.8% of body weights. The captive Mallards and Blue-winged Teals fitted with dummy transmitters lost significantly ($P<0.10$) more weight than did controls (Greenwood & Sargeant 1973). In the Mallards this weight loss were apparent after one week, in teals after seven weeks. It was observed that the dummy-fitted birds apparently preened more than controls, but no connection between preening and weight loss was concluded. Dummy weights were 1.5-3.7% if initial body weights. Two captive Hubara Bustards equipped with dummy satellite transmitters weighing 14% of their body weight lost between 4 and 9% of body weight in a two month period; most was lost during the first week (French & Goriup 1992). One bird fitted with a dummy of 10% of the body weight lost some weight in the first week, but gained weight by the end of the period. The dummy-fitted birds preened more than controls, but it was concluded that weight losses were a consequence of the extra weight of the dummy. Johnsen & Berner (1980) concluded, that attached dummy transmitters may affect weight gain of Ring-necked Pheasants *Phasianus colchicus* with a body weight less than 897g, i.e. when the dummy weight was above 3.1% of the body weight. On the other hand, satellite transmitter studies on Wandering Albatrosses *Diomeda exulans* (Jouventin & Weimerskirch 1990) and studies on Brent Geese *Branta bernicla nigricans* (Ward & Flint 1995) fitted with radio transmitters showed normal weight gains in albatrosses and no differences in the mean body mass between dummy fitted Brents and controls. The transmitters weighed 2 and 2.5-3.4% of the body weights, respectively.

In the studies where birds lose weight because of attached transmitters, most transmitter weights were between 1.3 and 3.7% of the body weight. No effects were observed in studies where transmitter weights constituted between 2 and 3.4% of the body weight. So, from these studies there is no obvious relationship between relative transmitter weight and effect. Weight loss as a result of attached transmitters is clearly species-dependant, and in some cases a higher weight loss was found in bird species fitted with heavier transmitters (Blue-winged Teal (Greenwood & Sargeant 1973) and maybe Greenland Whitefronts (Table 2)). In long distance migratory birds like the Greenland White-fronted Goose optimal weight gain in spring is important to make the c. 1,500 km´s from Wexford to Iceland, and the same distance further on to West Greenland; Owen (1981) demonstrated that spring migrating Barnacle Geese *Branta leucopsis* on a comparable distance had a decrease in API of about 1.5.

From sightings performed between April and December 1996 of the marked geese, migration appeared normal in the dummy-fitted geese. One was sighted on SW Iceland on 1 May still with the dummy attached. In late November 1996 14 of the 17 geese in two of the marked groups had returned to Wexford (12), Swilly, NW Ireland (1) and Islay, Scotland (1). The three geese missing were one dummy-fitted and two controls, all juveniles. The remaining group of 11 including three neoprene harnessed geese was not sighted in early December 1996. There was no difference in API (about 2.0) between dummy-fitted geese and controls.

Harnesses

The knicker elastic harness proved to be the most effective type of the two tested. One of the reasons may be that the elasticity of knicker elastic is more robust under tension than that of neoprene tape as shown in the stretching tests. Another reason is probably that the harnesses were not pre-stretched before fitting. This may have given the knicker elastic an advantage over neoprene because stretching of knicker elastic under controlled conditions similar to that used on the living birds caused only a 1.2% extension of length compared to a 6.9% increase in neoprene. The neoprene harness is therefore likely to become looser under tension and permit the dummy to slip whilst on the body. Since the dummies were not physically fixed to the harness, this would cause the dummies to become displaced from the back once the glue no longer fastened the pack to the back. Finally, knicker elastic may prove more resistant to biting by geese since it comprises five-strand elastics rather than the single strand neoprene tape.

Conclusions and recommendations

Greenland White-fronted Geese fitted with dummy satellite transmitters preened significantly more than controls shortly after the attachment, although there are indications that this effect declines within a few days. For that reason, it is recommended that transmitters are attached at least two weeks prior to spring migration, i.e. in late March. There were indications of reduced fat build-up in the dummy-fitted geese, and that this was maybe more pronounced in geese fitted with heavy dummies (54 g versus 38 g). Therefore, satellite transmitters attached to Greenland White-fronted Geese should be as light as possible, but still with a robust housing and antenna, the latter fixed well at the base. The knicker elastic harness proved to be an effective one since these were still attached to three out of seven geese 10 months after handling. It is recommended that a less robust design for the knicker elastic harness be developed to ensure packages fall off within the course of a year. Satellite transmitters must be prevented to slip sideways along the knicker elastic strings by fixing the transmitter to the harness.

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Table 1. Activity budgets of Greenland White-fronted Geese attached with dummy satellite transmitters and controls from the same family group. Mean activity budgets are calculated from behavioural studies of two family groups performed 2 and 3 days after the catch. "Preening rest" includes: preening breast and upper wing, wing stretch and shake feathers. P-values in bold are significant (<0.05).

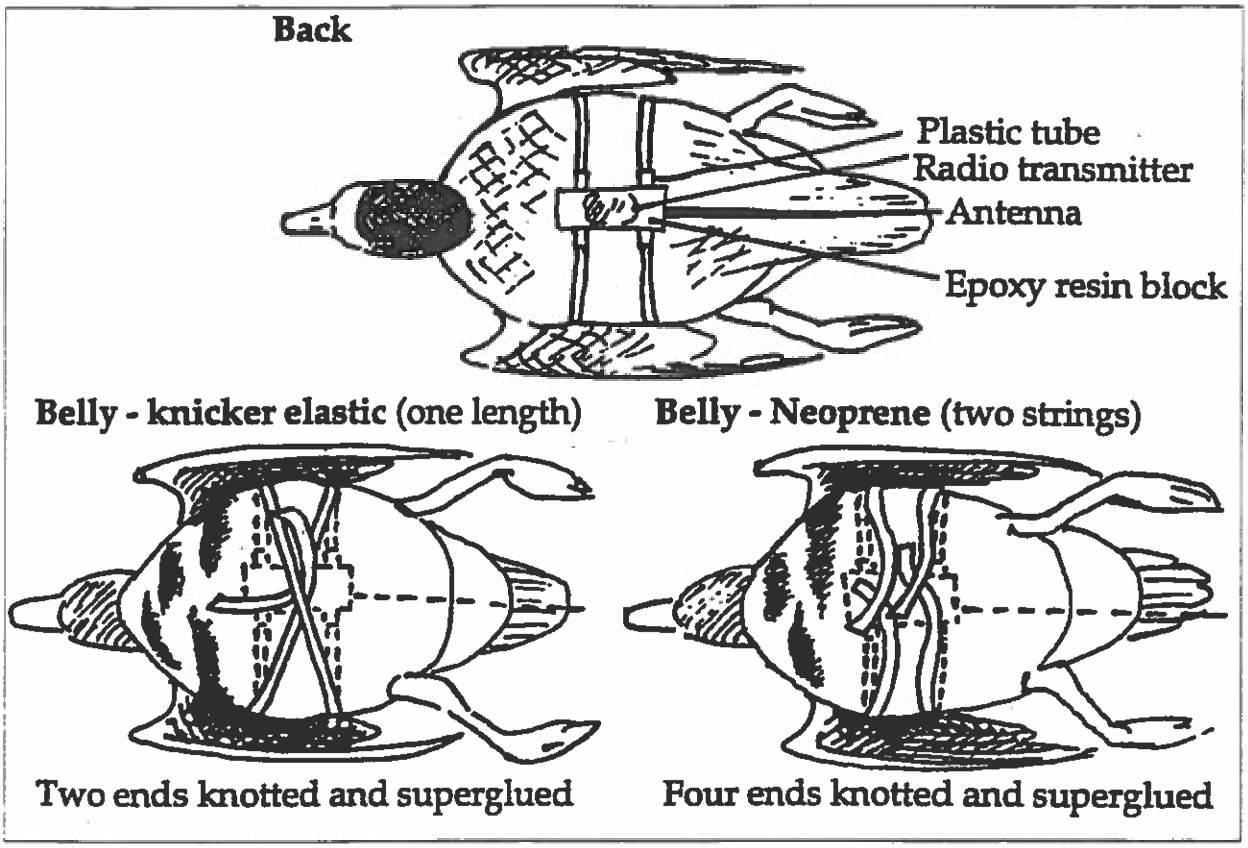
Behaviour	Dummies mean (%) (SE)	Controls mean (%) (SE)	P
Preen back	2.4 (0.6)	0.6 (0.4)	**0.007**
Preen flank	3.9 (1.3)	1.1 (0.8)	0.052
Preen neck	10.9 (3.5)	3.3 (1.1)	**0.038**
Preen belly	0.2 (0.1)	0.0 (0.0)	0.137
Preen rest	6.1 (1.5)	3.5 (1.7)	0.118
Preen all	23.4 (6.5)	8.6 (3.0)	**0.030**
Sit & stand	22.1 (4.9)	22.1 (6.4)	0.731
Sleep	10.4 (5.8)	11.0 (6.9)	0.855
Walk	3.8 (0.8)	5.9 (1.5)	0.638
Feed	38.9 (6.1)	50.3 (6.6)	0.256
Drink	1.3 (0.7)	2.1 (1.2)	0.840
Obs. time (bird mins)	142.3	166.8	
Number of birds (n)	11	13	

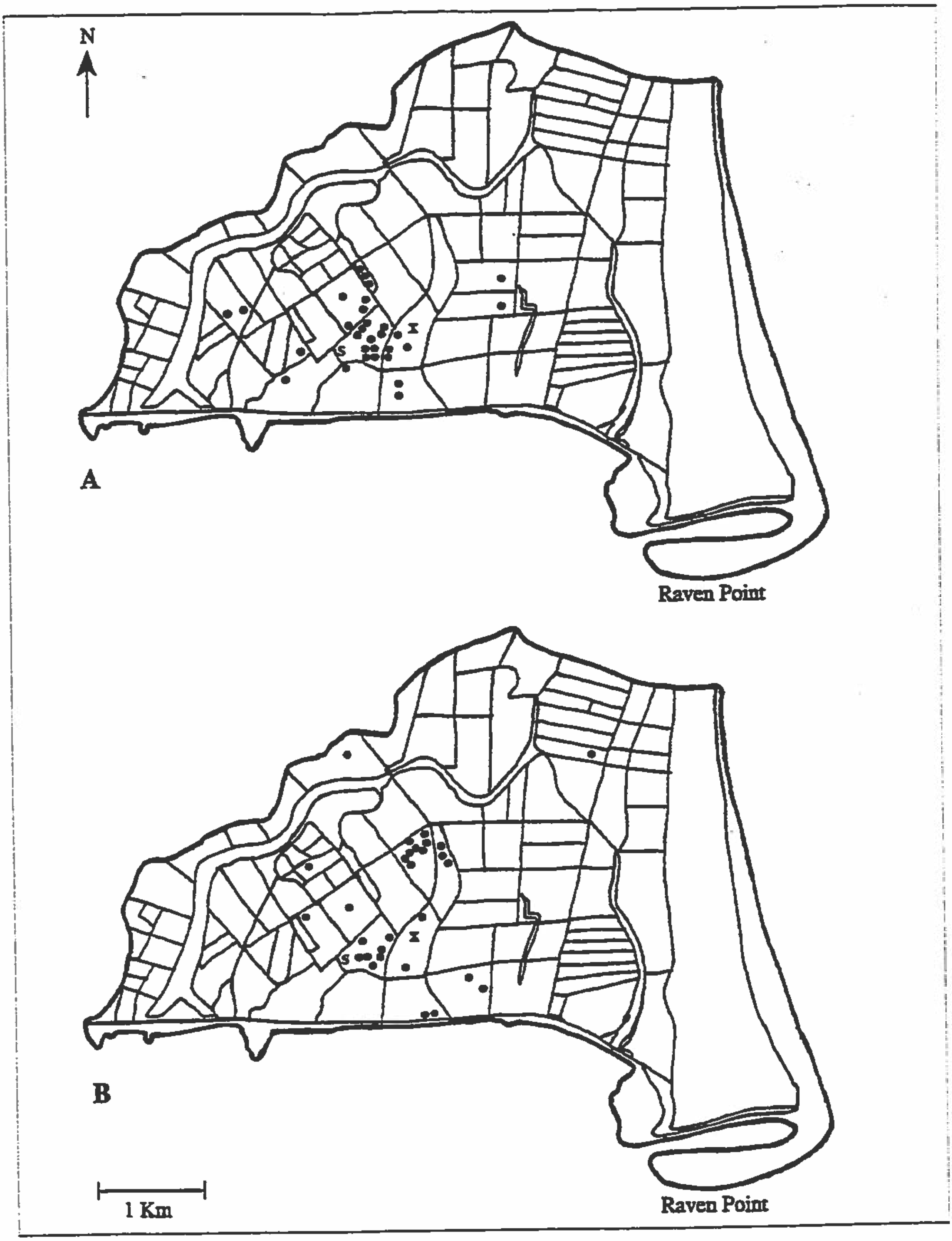
Table 2. The difference in abdominal profile index (29 February-5/8 April) for geese fitted with a light or a heavy dummy and for marked geese without a dummy (controls). The geese are grouped in API differences ≥+1.0 and <+1.0. (The χ^2-test showed no significant differences (P=0.07); the χ^2-test may not be valid, as most cells contain numbers below 5).

Abdominal index difference	Control geese	Geese with a light dummy	Geese with a heavy dummy
≥+1.0	8	3	1
<+1.0	2	3	4

Figure 1. Diagrams showing dummy attachments with knicker elastic (left) and neoprene (right) harnesses.

Figure 2. Sightings on Wexford North Slobs of Greenland White-fronted Geese with dummies attached with knicker elastic and neoprene harnesses. A shows sightings of six geese caught on 13 January 1996 and fitted with knicker elastic harnesses. B shows sightings of six geese caught on 19 January 1996, with five fitted with neoprene and one with a knicker elastic harness. Each circle represents a sighting. X: catching area, s: sugar beet field.


Back
Plastic tube
Radio transmitter
Antenna
Epoxy resin block
Belly - knicker elastic (one length)
Belly - Neoprene (two strings)
Two ends knotted and superglued
Four ends knotted and superglued


N
S
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Raven Point

11 Moulting Greenland White-fronted Geese: Distribution and concentrations in West Greenland

Moulting Greenland White-fronted Geese: Distribution and concentrations in West Greenland

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Abstract

During the moulting period Greenland White-fronted Geese *Anser albifrons flavirostris* (Dalgety and Scott) were censused from the air in July 1992 and 1995 in West Greenland between 67° and 72°N. A strip transect method was used in three areas in the southern part of this area, whereas route flights were used in the northern areas. Between 25 and 30% of the total wintering population was accounted for in the two surveys. Two different methods were used to calculate the population size in the whole West Greenland breeding and moulting area (64°-72°N). The one method scales up the densities derived from the transect censuses, the other scales up from goose densities inside groups of NDVI (Normalised Difference Vegetation Index) categories processed on NOAA satellite images from 1 July 1992 and 28 June 1995. The average numbers derived from the different estimates are between 22500 and 41000 geese and are comparable to the goose numbers of 27342 (1992) and 34442 (1995) counted on the wintering grounds. In spring and summer 1992, the weather was much colder than normal and more geese were probably forced to moult this year in the central area (66°-69°N). In 1995 the weather was warmer than normal with geese more numerous to the north and south according to the surveys and estimates. Also, productivity was affected in 1992 with a juvenile production of only 40% of that in 1995 which was comparable to the average production. It is recommended that eight areas be designated as protected areas during 25 June - 10 August with highest protection during 25 June - 10 July.

Keywords: Greenland White-fronted Goose, West Greenland, moult, aerial survey, NOAA satellite images, NDVI, population estimates, management implications

Introduction

The breeding range of the Greenland White-fronted Goose *Anser albifrons flavirostris* extends from 64° to 72°30'N in the low arctic West Greenland (Salomonsen 1950, 1967). The geese moult in the same area and no moult migration has been documented (Salomonsen 1968). Non-breeding geese moult from first to forth week of July, while breeders start to moult about two weeks later (Fox et al. 1983). The smaller flocks of moulting geese feed in general along the fringes of the lakes on young growth stages of sedges and grasses (Stroud 1981, Madsen & Fox 1981). The moulting geese use lakes, or rivers, as a refuge when disturbed; early in the moulting period they disappear in the opposite bank vegetation, later they swim to the middle of the lake or river (Stroud 1981). Different parts of the breeding range have been surveyed from the air or by foot (Joensen & Preuss 1972, Stroud 1981, Fox & Stroud 1988, Thing & Ettrup 1989, Bennike 1990, Frimer & Nielsen 1990, Ettrup 1991) and data are summarised in Stroud (1992). Combining the numbers from the different areas derived mainly from July and August 1988 and 1989 gives a total number of about 5200 geese. The total winter count in spring 1990 was 26090 geese (Fox et al. 1998).

The purpose of this study was to obtain a better knowledge of numbers and distribution of moulting Greenland White-fronted Geese in West Greenland. On the basis of the results measures can be taken to protect the relatively sensitive moulting Greenland White-fronted Geese from disturbances from, e.g., mineral exploration and tourism. Both mineral exploration and tourism have increased their activities over the last few years (Anon. 1997, MRA 1997). Two almost identical aerial surveys were performed during late July in 1992 and 1995. On the basis of these surveys, numbers and distribution of the Greenland White-fronted Goose were estimated for the whole summering range by the use of NDVI (Normalised Difference Vegetation Index) index on NOAA satellite images from the two years, and by scaling up densities derived from the transect and route flights.

Study area and methods

The aerial surveys were carried out between 67° and 72°N in the low arctic tundra of West Greenland. This area of about 550 km from south to north and a maximum width of 200 km from coast to the ice-cap, was divided in five subareas (Fig. 1). The southernmost area (1) is the huge area between Sukkertoppen Iskappe (a glacier) to the south and Naternaq to the north, including the inland area north to Ilulissat ice-fjord. The Nuuk area extending from Sukkertoppen Iskappe south to 64°N was included in area (1) when the total goose population was estimated. The coastal area was excluded because no or very few geese are reported from this area (Salomonsen 1950). The mountainous gneissic plateau rises from about 400 m a.s. l. in the northern part of area (1) to some 1000 m a. s. l. to the south. The area is intersected by large fjords, lowland valleys and contains large numbers of lakes, rivers and marshes. In the central part the climate is continental with low annual precipitation, while the Nuuk area has a more coastal climate with higher precipitation. The Naternaq area (2) south of Disko Bugt is a large clayey lowland plain with only few low mountains and with lots of smaller lakes and long meandering rivers. The area has a more coastal climate than area (1), but precipitation is low. The Disko area (3) includes the island and the inland between Ilulissat ice-fjord and Nuussuaq. The Disko island has a central glacier and basaltic mountains that rise to about 1500 m a. s. l. The island is intersected by fjords and large valleys. The climate is coastal with a high annual precipitation, and with the eastern part more sheltered. The Nuussuaq peninsula (4) including the inland north to Svartenhuk contains high basaltic (west) and gneissic (east) mountains rising to above 1500 m with only few lowland areas to the west, in the central valley and to the Southeast. The climate is similar to the west coast of the Disko island. Svartenhuk (5) is the most northern area with basaltic mountains between 500 and 1000 m a. s. l., large valleys and two big lowland plains, the eastern containing a huge delta area. Precipitation is probably low, but is not measured in Upernavik (72°47'N,56°10'W), the nearest weather station.

The two aerial surveys were performed on 20 to 26 July 1992 and on 27 July to 1 August 1995. The survey plane in both years was a Partenavia Observer with Plexiglas front and bubble windows on both sides. The plane had a four member crew with the pilot concerned with navigation, height and speed control, a navigator alongside the pilot helping the pilot and taking photos of goose flocks, and two observers in the rear seats. Ground speed was 85-90 knots (c. 160 km/h) and the altitude above ground about 250 feet (c. 75 m). The observations from navigator and observers were spoken to individual tape recorders and all three recorders were connected to an Epson computer that gave a time signal (hour/min./sec.) so that observations and time were combined. In 1992 the navigator announced start and end of transect lines or fix points along the route flights so appropriate positions of the observations could be calculated, whereas in 1995 the time signal was connected to the plane's GPS so that position, time and observation was connected. The crew was identical the two years except for the observer on the left side (JFR in 1992, ADF in 1995). Photos were taken with a Nicon 4F camera with a 35-135 mm zoom objective, shutter 1:2000 sec., the picture frame showing the time (hour/min./sec.), and films were 1000 RS AGFA professional. One to four pictures were taken of flocks of 10 or more birds. The observers were equipped with 10 x binoculars.

The two surveys were identical except that in 1995 the route on (3) Disko was extended with 83 km in the south-western part and that a new area, Nassuttuup Nunaa, Southwest of Eqalummiut Nunaat, area (1), was included (Fig. 1). The areas were censused in three different ways according to Table 1. Strip transects were placed parallel to each other and 2 km (areas 1b and 2) or 4 km (area 1b) apart, and in this census method it is assumed that all geese are detected inside the transect area (Buckland et al. 1993). Routes were flown in areas not suited for transect surveys, such as areas with high mountains and narrow valleys (Table 1). For each strip transect area censused mean densities (number of geese pr. km^2) and 95% confidence limits were calculated. These mean densities were then used to estimate the total moulting population by simple extrapolation inside the five main areas (1-5). Total areas were found by rejecting the coastal zone in the southern part (south of 68°N, Fig. 1) and by the use of the NDVI index (see below).

As an alternative method of estimating the total moulting population the NDVI index derived from NOAA satellite scenes were used. The NOAA satellite images covered West Greenland (63°-72°N) on the dates 1 July 1992 and 28 June 1995. The reason for choosing dates around 1 July was that this date is about the latest the geese are able to fly in their search for optimal moulting grounds. The satellite scenes were chosen after consulting cloud coverage on quicklook satellite images between 25 June to 10 July. The satellite data has a spatial resolution of about 1 km (at Nadir), a swath width of c. 3000 km and five channels that measure reflected solar radiation and infrared radiation (Mather 1991). The data were geometrically corrected and the NDVI index was calculated and corrected for clouds and haze (Hansen & Mosbech 1994). The NDVI index from < 0.0 (no vegetation, but ice, snow, water) to 3.0, was classified in 32 categories (separated by colours and signatures), with highest categories corresponding to highest NDVI index. The higher NDVI values are associated with greater density and greenness of vegetation (Mosbech & Hansen 1994). With the use of MapInfo 4.5 Professional, flocks of geese were matched with NDVI categories of the corresponding pixel (smallest unit of about 1x1 km). In 1992 flocks were placed on geodetic maps (1:250,000, KMS 1974-89) during or after the survey and each flock was therefore associated with the NDVI category of the pixel it lies within. In 1995 the flock was placed on the position of the plane with the information to which side of the plane it was observed. Therefore the flock was associated with the mean of the NDVI categories of the pixel it lies within and one or two pixels away from the plane and perpendicular to the route. Two pixels were used when the transect was 2 km wide, three pixels with a width of 4 km. The number and flocks of geese in each NDVI category were then calculated, and one to three uniform groups were made for each area. For example, at Naternaq in 1992, 99% of the geese and 97% of the flocks were represented by one group of the NDVI categories 16-21 (Table 5); and at Eqalummiut Nunaat/Nassuttuup Nunaa in 1995, 91% of the geese and 90% of the flocks were represented by one group of the NDVI categories 15-26, and 5% geese and 4% flocks were represented by another group of the NDVI categories 13-14 (Table 5). Inside each area (1-5) the area of each uniform group was calculated by counting pixels with the defined NDVI categories. Goose densities in the groups could then be calculated. Scaling up was made by counting pixels with the defined NDVI categories in the areas not censused. Because geese in the northern areas (3-5) were associated with NDVI categories often below 0.0 it was not possible to distinguish potential goose areas from areas not suitable to geese, such as mountain slopes with flowing water. Therefore only lowland areas below 300 m were used to calculate geese numbers outside the surveyed areas.

Results

Weather

The weather in West Greenland (64°-72°N) during the period January to July in the two survey years 1992 and 1995 was derived from seven weather stations (Asiaq 1992/1995) and from weather maps showing temperature anomalies (DMI 1992/1995). The two years were very different in mean temperatures, with much lower temperatures in 1992 than normal, whereas precipitation in both years was lower than normal.

In 1992 precipitation was low during the period, except for the most northern weather station (Uummannaq, 70°40'N, 52°10'W) with high January precipitation. In 1995 precipitation from

January to April/May was low, and normal during the rest of the period. In 1992, the mean temperatures were during the entire period 1° to 8°C below normal (1961-1990), with 5°C below normal in May and 1° to 3°C below normal in June and July. In 1995 mean temperatures were during January to March 3° to 8°C below normal and during April to July 1° to 4°C above normal temperatures.

Number of geese

In 1992, 6060 geese were counted in the five areas, with an average flock size of 25.3 geese (SD=34.1, n=240), with 3.6 juveniles (juv.) pr. family (SD=1.2, n=24 families), and with 1.6% juv. of the total number counted (SD=0.9, n=6). The percentage of first year birds in the wintering population was 6.0% (Fox et al. 1998). Corrected for differences in field observations and corresponding photos would give a total of c. 7120 or 26% of the total winter population of 27342 (Fox et al. 1998)(Table 2).

In 1995, 7312 geese were counted in the same five areas, with an average flock size of 22.5 (SD=26.0, n=325), with 4.5 juv. pr. family (SD=1.2, n=66 families) and with 3.9% juv. of the total number counted (SD=2.3, n=6). The average number of juv. pr. family in 1992 was significantly lower than in 1995 (t-test, $p<0.01$, df=88) and also the percentage of juveniles of the total number counted was lower in 1992 than in 1995 (t-test, $p<0.02$, df=10). The juvenile percentage of the wintering population was 16.5% (A. D. Fox, pers. comm.). Corrected for differences between field observations and photos would give a total of c. 8590 or 25% of the winter population of 34442 (A. D. Fox, pers. comm.). A new area, Nassuttuup Nunaa, was added in 1995, and this would change the above figures to a total of 8699 geese, average flock size of 20.9 (SD=24.1, n=416), photo corrected c. 10220 or 30% of the wintering population; number of juv. pr. family would be 4.3 (SD=1.4, n=83)(Table 2).

Photo correction

On the basis of 52 observations (26 in both years) with valid photos (2711 geese noted in the field as against 3185 geese on photos) the equation:

log(photo)= -0.050 + log(field) x 1.04, (SE(intercept)=0.19, SE (log(field))=0.05) , or

photo=0.95 x field $^{1.04}$,

does express the connection between field observations and real numbers (i.e., read on photos).

Strip transect flights

Five areas were surveyed with the use of strip transect flights and goose densities pr. km^2 was calculated for each area and year, and 95% confidence limits given (Table 3). Densities varied between 0.32 (Eqalummiut Nunaat, 1995) and 2.60 (Svartenhuk, 1992) and 95% confidence limits varied between 23 and 128% (Table 3).

Route flights

Route flights were performed in three areas north of 69°N (Disko, Nuussuaq and Svartenhuk) and goose densities pr. km^2 were calculated (Table 4). Densities in 1992 were significantly lower than densities in 1995 (paired t-test, $p<0.05$, df=2).

Ground truthing

On 2 and 3 August 1995 ground truthing was performed by three persons (ADF, DAS and the author) in an area of about 102 km^2 in the south-eastern part of Nassuttuup Nunaa. A total of 176 Greenland White-fronted Geese was counted which is 36% more than the 129 geese counted on the aerial census (transect width of 2 km) on 1 August 1995. This percentage would fall to 27 if the censused flocks are photo corrected (139 geese).

Densities in different groups of NDVI categories

In the five surveyed areas densities of geese pr. km^2 in 1992 and 1995 were calculated for the different uniform NDVI groups (Table 5). Densities varied between 0.52 (Eqalummiut Nunaat, 1995) and 4.40 (Nuussuaq, 1995).

Estimates on the total moulting population

In both 1992 and 1995 estimates on the total moulting population was calculated on the basis of densities derived either from the NDVI categories or from the transect/route flights (Table 6). The estimates in Table 6 are based on average figures only, but the magnitude of the uncertainty in the transect/route flight estimates can be seen from Table 3 (95% confidence limits).

Discussion

The two aerial surveys in 1992 and 1995 performed in almost identical parts of West Greenland between 67° and 72°N has contributed greatly to the knowledge of distribution and densities of moulting Greenland White-fronted Geese. Estimates on distribution based on two different techniques, i.e., (1) transect/route and (2) NDVI density calculations, are in the range of the winter population counts. Weather conditions in the two years differed much from normal, 1992 being much colder, 1995 warmer than normal. These different weather conditions indicates that the population in cold years concentrate more in the central summer range (66°-69°N) whereas in warm years the population is more widely distributed to the north and south of the central area.

Estimates based on transect/route flights

Transect surveys were performed in four areas where conditions were reasonable good for this counting method, i.e., plains (Svartenhuk areas and Naternaq) or hilly plateau's (Eqalummiut Nunaat and Nassuttuup Nunaa). Since strip transects were used the density calculations are less precise than calculations from line transect counts (Buckland et al. 1993). The wider the strips are chosen the lower densities can be expected because more animals are overlooked (Norton-Griffiths 1978). In this study, strip width was either 2 km (Svartenhuk, Naternaq and part of Nassuttuup Nunaa) or 4 km (Eqalummiut Nunaat and part of Nassuttuup Nunaa). It is believed that most flocks were discovered when the strips were 2 km wide, whereas there are indications that flocks in the 4 km strips were missed; at Nassuttuup Nunaa densities were 0.86 goose pr. km^2 at 2 km strips and 0.46 goose pr. km^2 at 4 km strips (Table 3). In late July, when the censuses were conducted, moulting geese swim to the middle of lakes and rivers when disturbed; with a mean flock size of about 25 geese the area of a dense flock would cover c. 2.5 m^2 and therefore be rather conspicuous.

Moreover flocks will almost always be in contrast to the surrounding water. These are the reasons why it is believed that most flocks are discovered when the distance from observer to goose flocks is ≤ 1 km on rather flat terrain. With a distance of ≤ 2 km to the flocks in more mountainous areas it is more likely that flocks are missed. It is believed that a smaller part of the geese is overlooked, because some flocks were discovered swimming out from the banks after the plane had crossed, and in this census 7% of all geese were discovered on the ground. Again it is believed that more geese are overlooked at the 4 km strips, because the disturbance from the plane is less pronounced at these wider strips.

These differences in transect width and terrain are insignificant when densities are compared for the same areas in the two different years, as long as the other factors such as effort, crew and period are the same, which they were the two years. However, when the densities are used to estimate the total moulting population it is important to know the reliability of the calculated densities. Since the densities calculated for Eqalummiut Nunaat and Nassuttuup Nunaa are used to estimate numbers for the whole area (1) (64°-68°N; c. 35 000 km^2) the estimate is likely to be too low.

On the other hand it is believed that the estimates based on the route flights in the northern areas (Disko, Nuussuaq and Svartenhuk) are overestimated. The reason is that many of the routes are flown in areas known to hold moulding geese. Densities calculated from these routes are therefore higher than if routes were chosen at random among lowland areas. One route of 142 km^2 flown in lowland areas on the island Alluttoq (area 3, Disko, inland) confirms this assumption, because no geese were observed.

Estimates based on NDVI categories

The use of the NDVI categories to estimate the number of moulting Greenland White-fronted Geese is based on the assumption that the geese prior to the moulting period search for optimal moulting grounds. A moulting area must contain a lake or a river big or wide enough to serve as a refuge, and the area of 200-250 m from the water must contain enough fresh grasses and sedges to sustain the geese during the four weeks period. The extension of the area along the lake or river is not known in the Greenland White-fronted Goose, so the width is derived from moulting Pink-footed Geese *Anser* *brachyrhynchus* in East Greenland (Madsen & Mortensen 1985). The NDVI index is for vegetation between 0.1-0.9 (in this study max. 0.3), around zero for rock and bare ground, and negative for water and snow (Mosbech & Hansen 1994). The NDVI index for the pixel containing a moulting habitat must therefore be between 0.0 and 0.3 (or between NDVI categories of 13-32 in this study), because the habitat must contain both a lake or river and a vegetated area. This was true for the areas south of 69°N (i.e., Naternaq, Eqalummiut Nunaat and Nassuttuup Nunaa) where ≥ 95% of the geese both years were associated to NDVI categories 13-26 (NDVI index: 0.0-0.2). For the northern areas (Disko, Nuussuaq and Svartenhuk) the percentage of geese inside these NDVI categories gradually decreased to the north with most geese on Svartenhuk associated with NDVI categories between 7-12. In these northern areas the vegetation around 1 July is still sparse and melt-water covers many areas, with the result that the NDVI index is often below 0.0. Therefore it is difficult on the NOAA satellite images to distinguish moulting habitats in the northern areas from non suitable areas. As with the transect/route estimates the NDVI estimates in the northern areas are probably too high, so again an alternative estimate based only on counted areas was made.

Usefulness of NOAA satellite images and the NDVI index

The NOAA satellite images with the calculated NDVI index are useful, especially in the moulting range south of 69°N, to delimitate the possible moulting areas. The NOAA images were also used in the transect/route estimates to delimitate areas where to calculate densities, so in this way the two types of estimate were not entirely independent. The NDVI categories that covers possible moulting areas are not fixed values, but differs from year to year and area to area; so, the more geese that are counted, geographically positioned and associated to the NDVI categories in different parts of the range, the more precise the estimates will be. The NOAA satellite image with pixel sizes of about 1x1 km is a coarse method compared to Landsat and SPOT satellite images with pixel sizes of 80x80 m to 20x20 m (Mosbech & Hansen 1994). A moulting habitat of, e.g., a lake of 100x100 m and a vegetated fringe of 200 m would cover only one quarter of a pixel. In this example other ground characteristics can contribute more to the NDVI category of the pixel than the habitat itself. The advantage of the NOAA satellite images is that they cover huge areas compared to the Landsat/SPOT images.

Weather conditions

The spring and early summer temperatures were very different the two years, which gave extremely good possibilities to evaluate goose distribution following a cold (1992) and a warm (1995) spring and early summer. In 1992, goose numbers in the northern areas were significantly lower than in 1995, they were congregated in the outer delta parts of the valleys and the geese seemed to form bigger flocks. Even at Naternaq, the geese seemed to concentrate in the southern parts in 1992 compared to 1995 where geese were more evenly distributed. The opposite distribution was seen in Eqalummiut Nunaat where the goose concentration in 1992 was twice as high as in 1995. In the Nuuk area in the southernmost part of the range, which was not censused in this study, the potential moulting area in 1992 was only about one third of that in 1995 (Table 6). So, in cold years moulting geese are likely to concentrate in the central part of the breeding range with the northern and southern areas being able to support only half the numbers they can support in warm years. Also, productivity was affected in 1992 with a juvenile production of only 40% of that in 1995, the latter production being close to the mean of c. 17% (1970-1994)(Fox et al. 1998). Interspecific competition from the recent influx of moulting Canada Geese *Branta canadensis* is another factor that can decrease the moulting areas of the Greenland White-fronted Goose (Fox et al. 1996).

Management implications

In general, Greenland White-fronted Goose flocks are widespread over the entire summer range with less than 1 goose pr. km^2 or about 1 flock pr. 35 km^2. So, generally speaking, geese are well protected during their moult. In the northern areas - and perhaps also in the southern - geese are more concentrated, in some valleys and deltas well above 1 goose pr. km^2. On Svartenhuk these areas are the delta and plain north-west of Itsako, the Narsaq plain to the west and the south-western valley, on Nuussuaq the central valley, and on East Disko, Sullorsuaq and the valley south of Sullorsuaq, and on West Disko, Kuussuaq. Moreover the Naternaq area holds a stable number of geese of about 10% of the total wintering population and with a rather high density of about 1 goose pr. km^2. Sullorsuaq and Naternaq are designated as Ramsar sites (Jepsen et al. 1996) and the remainder areas should be given a similar protection. Eqalummiut Nunaat and Nassuttuup Nunaa are both parts of a Ramsar site (Jepsen et al. 1996). The protection period should cover 25 June to 10 August, with the most important period being 25 June to 10 July where the geese search for optimal moulting areas. Geese would likely abandon the moulting grounds if disturbed during this period, and helicopters are probably the source that can cause most disturbance during the moulting period (Mosbech & Glahder 1991).

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Table 1 Aerial survey methods and effort in different West Greenland areas.

Transects are strip transects with a width of either 2 or 4 km.

Area	Name	Transect 2 km	Transect 4 km	Route 2 km	Km flown in 1992	1995	Time used in 1992	1995
1b	Eqalummiut Nunaat		+		419.4	403.6	2h45min	3h15min
1b	Nassuttuup Nunaa	+	+		-	692.9	-	4h11min
2	Naternaq N	+			517.7	517.7	3h36min	4h17min
2	Naternaq S	+			445.2	445.2	3h30min	3h30min
3	Disko			+	556.2	638.8	2h58min	3h51min
4	Nuussuaq			+	174.3	174.3	1h01min	0h53min
5	Svartenhuk			+	425.2	425.2	3h55min	3h50min

Table 2. Number of Greenland White-fronted Geese, flock sizes, families and juveniles, in different areas of West Greenland between 67° and 72°N.

Naternaq N, S and T: Naternaq North, South and Total (North + South).

Eqalum Nu: Eqalummiut Nunaat; Nassutt Nu: Nassuttuup Nunaa; Eqal+Nass: Eqalummiut Nunaat + Nassuttuup Nunaa.

Area	Svartenhuk		Nuussuaq		Disko		Naternaq N		Naternaq S		Naternaq T		Eqalum Nu		Nassutt Nu		Eqal+Nass		Total	
Year	1992	1995	1992	1995	1992	1995	1992	1995	1992	1995	1992	1995	1992	1995	1992	1995	1992	1995	1992	1995
No of geese (field)	820	1348	634	1003	855	1788	520	845	2068	1717	2588	2562	1163	611	-	1387	-	1998	6060	8699
Mean flock size	30.4	24.5	48.8	35.8	38.9	25.5	20.0	15.1	27.9	22.9	25.9	19.6	14.9	14.9	-	15.2	-	15.1	25.3	20.9
No of flocks	27	55	13	28	22	70	26	56	74	75	100	131	78	41	-	91	-	132	240	416
SD	39.1	29.1	89.0	31.3	45.2	35.0	17.4	12.4	24.1	21.5	22.8	18.6	15.1	11.8	-	14.0	-	13.3	34.1	24.1
No of families	4	13	5	1	2	14	3	14	7	20	10	34	3	4	-	17	-	21	24	83
No of juv/family	3.0	4.5	3.8	4.0	3.0	4.9	4.3	4.3	3.6	4.7	3.8	4.5	3.7	3.5	-	3.6	-	3.6	3.6	4.3
SD	1.2	1.5	0.4	0.0	1.0	0.9	0.5	1.3	1.6	1.0	1.4	1.1	1.2	1.1	-	1.8	-	1.6	1.2	1.4
% juv. of total no	1.5	4.3	3.0	0.4	0.7	3.9	2.5	7.1	1.2	5.4	1.5	6.0	0.9	2.3	-	4.4	-	3.8	1.6	4.0

Table 3. Transect flights. Densities of Greenland White-fronted Geese in different West Greenland areas between 67° and 72°N.

Naternaq N, S and T: Naternaq North, South and Total (North + South).

Eqalumm Nuna: Eqalummiut Nunaat; Eqalum+Nassutt: Eqalummiut Nunaat + Nassuttuup Nunaa.

Area	Svartenhuk		Naternaq N		Naternaq S		Naternaq T		Eqalumm Nuna		Nassuttuup Nunaa			Eqalum+Nassutt	
Year	1992	1995	1992	1995	1992	1995	1992	1995	1992	1995	1995	1995	1995	1995	1995
Transect width (km)	2	2	2	2	2	2	2	2	4	4	2	4	2/4	2/4	4
Density (geese/km^2)	2.60	0.75	0.34	0.80	1.70	1.40	0.91	1.06	0.69	0.32	0.86	0.46	0.66	0.49	0.36
95% Confid. limit ±	2.54	0.96	0.21	0.46	0.73	0.61	0.36	0.37	0.31	0.22	0.37	0.30	0.25	0.17	0.17
95% Confid. l. (%) ±	97.6	127.6	61.3	42.6	42.7	43.6	39.5	22.5	45.1	69.3	43.7	65.0	38.7	35.4	45.7
Area covered (km^2)	241	241	1035.4	1035.4	890.4	890.4	1925.8	1925.8	1677.6	1677.6	526.4	1718.8	2245.2	3922.8	3396.4
No of geese	481	181	490	748	1988	1574	2478	2322	1114	542	418	815	1233	1775	1357

Table 4. Route flights. Densities of Greenland White-fronted Geese in different West Greenland areas between 67° and 72°N.

Alluttoq (69°40'N, 51°10'W) is part of the inland Disko area (3)(Fig. 1).

Area	Svartenhuk		Nuussuaq		Disko		Alluttoq
Year	1992	1995	1992	1995	1992	1995	1995
Density (geese/km^2)	0.40	1.37	1.82	2.88	0.77	1.40	0.0
Area (km^2)	850.4	850.4	348.6	348.6	1112.4	1277.6	141.6
No of geese	339	1167	634	1003	855	1788	0

Table 5. NDVI categories and densities of Greenland White-fronted Geese in different West Greenland areas between 67° and 72°N

Area	Svartenhuk			Nuussuaq			Disko					Naternaq				Eqalummiut + Nassuttuup			
Year	1992	1995		1992	1995		1992		1995			1992	1995			1992		1995	
Total area (km^2)	1091	1091		349	349		1112		1278			2141	2141			1828		4240	
NDVI categories	10-13	12-16	7-9	13-17	20-21	10-16	13-17	8-9	21-26	13-18	7-12	16-21	23-26	15-22	13-14	16-26	13-14	15-26	13-14
Area (km^2)	350	307	246	200	31	221	340	143	321	375	232	947	1455	565	59	1319	342	3396	116
Densities (geese/ km^2)	2.07	2.27	2.24	2.47	4.4	3.9	2.02	0.97	1.75	2.54	1.07	1.85	1.37	0.87	1.36	0.60	0.92	0.52	0.91
No of geese	725	696	552	493	136	825	687	139	562	953	249	1753	1991	491	80	793	313	1769	106

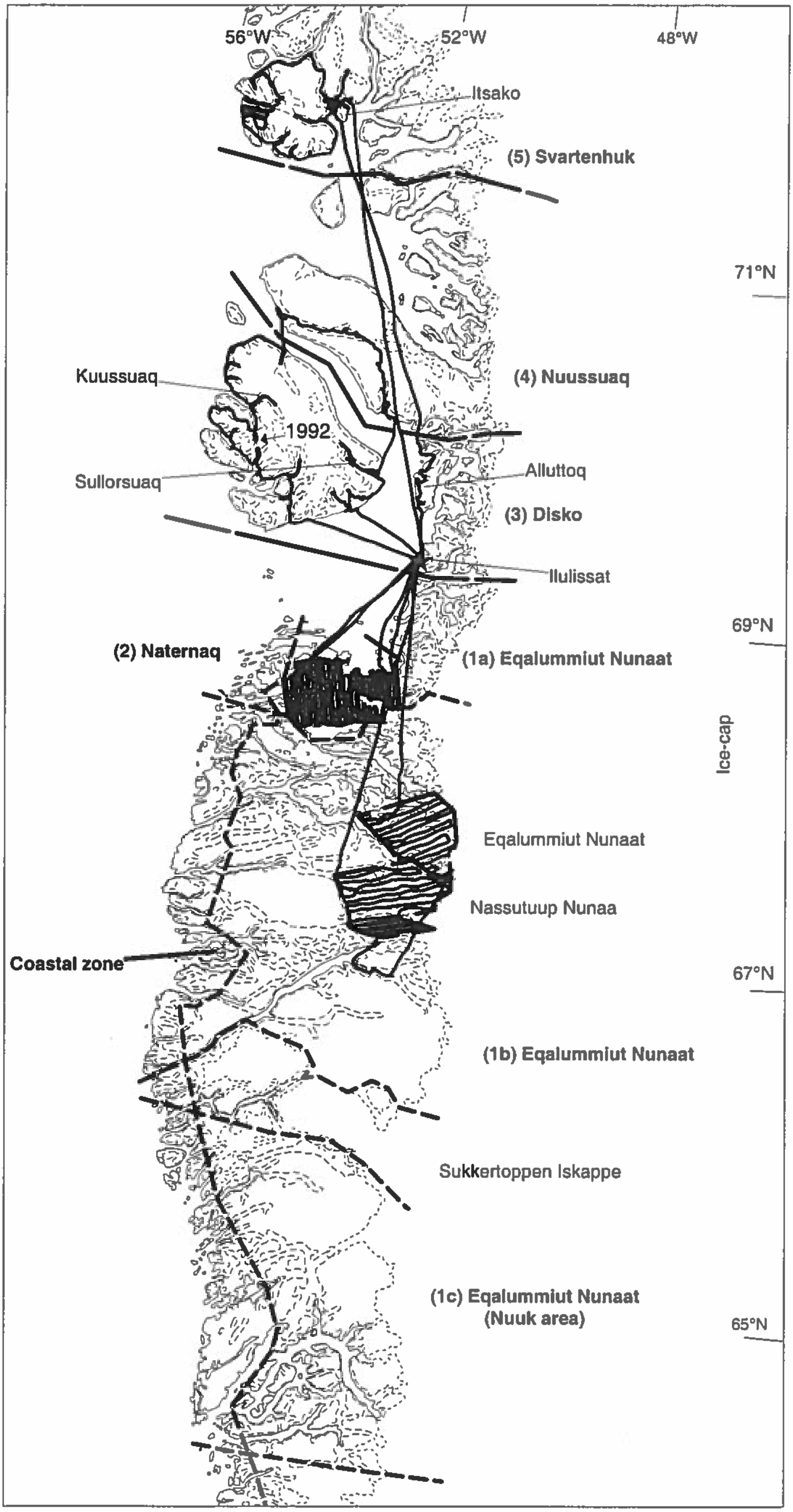
Table 6. Estimates on the total moulting goose population in West Greenland (64°-72°N)
The estimates on number of geese in the subareas are based on densities calculated for different NDVI categories (Table 5) and from transect/route counts (Tables 3 and 4). Figures in brackets are areas (km^2) not censused. Winter population: 1992 (Fox et al. 1998), 1995 (A. D. Fox, pers. comm.). c: aerial count; e: estimate. Eqalum Nu: Eqalummiut Nunaat; Nassuttuup N: Nassuttuup Nunaa; Eqalu+Nassu: Eqalummiut Nunaat + Nassuttuup Nunaa.

Year	1992		1995	
Estimate based on:	NDVI	Trans/route	NDVI	Trans/route
5. Svartenhuk c	820	820	1348	1348
5. Svartenhuk e	(543) 1124	(543) 217	(578) 1301	(578) 792
4. Nuussuaq c	634	634	1003	1003
4. Nuussuaq e	(884) 2183	(884) 1609	(882) 3467	(882) 2540
3. Disko c	855	855	1788	1788
3. Disko e	(1474) 2978	(1474) 1135	(2437) 4569	(2437) 3412
2. Naternaq c	2588	-	2562	-
2. Naternaq e	(424) 784	(3314) 3016	(991) 988	(3314) 3513
1a. Qasigiannguit e	(1874) 1454	(1999) 1379	(2022) 1113	(1999) 980
1b. Eqalum Nu c	1163	-	611	-
1b. Nassuttup N c	-	-	1387	-
1b. Eqalu+Nassu e	(17705) 11811	(22716) 15674	(17353) 9564	(22716) 11130
1c. Nuuk e	(3370) 2522	(3370) 2325	(9044) 5234	(9534) 4672
A. Total	28916	27664	34935	31178
A. Total + (photo)	33976	32505	41049	36634
B. Total - (3-5 e's)	22631	24703	25598	24434
B. Total + (photo)	26591	29026	30078	28710
Winter population	27342	27342	34442	34442

Fig. 1 Survey transects and routes in different West Greenland areas (1-5) in 1992 and 1995.

Fig. 2 Number and distribution of the Greenland White-fronted Goose in West Greenland in 1992 and 1995.

Dashed lines (long): Areas ≤ 300 m a.s.l. Dashed lines (short): delimitate glaciers or the ice-cap.



56°W
52°W
48°W
Itsako
(5) Svartenhuk
71°N
Kuussuaq
(4) Nuussuaq
1992
Sullorsuaq
Alluttoq
(3) Disko
Ilulissat
69°N
(2) Naternaq
(1a) Eqalummiut Nunaat
Ice-cap
Eqalummiut Nunaat
Nassutuup Nunaa
Coastal zone
67°N
(1b) Eqalummiut Nunaat
Sukkertoppen Iskappe
(1c) Eqalummiut Nunaat
(Nuuk area)
65°N


56°W
54°W
52°W
71°N
69°N
1992
1 to 11
11 to 51
51 to 400
1995
1 to 11
11 to 51
51 to 400

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