ARCTIC
VOL. 52, NO. 3 (SEPTEMBER 1999) P. 244–256

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

CHRISTIAN M. GLAHDER[1]

(*Received 18 December 1997; accepted in revised form 19 December 1998*)

ABSTRACT. The Greenland white-fronted goose (*Anser albifrons flavirostris*) migrates about 3000 km from wintering grounds in Ireland and Britain to breeding grounds in West Greenland (64˚–72˚N). The migration route includes long flights over the ocean and over the Greenland ice cap. To obtain optimal reproduction output, it is important for 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 by 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 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) that covered the early spring period. A total of 35 potential spring staging areas between 63˚ and 70˚N were then examined on the ground (during May and June in 1994 and 1996) and surveyed from the air (during 9–12 May in 1995 and 1997). Between 1000 and 1500 geese were observed in 28 areas. However, 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 region (66˚29′N to 68˚21′N). It is recommended that eight spring staging areas in this region be designated as protected areas during the period 1–20 May.

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

RÉSUMÉ. L’oie rieuse du Groenland (*Anser albifrons flavirostris*) migre sur environ 3000 km depuis ses aires hivernales en Irlande et en Grande-Bretagne à ses aires de reproduction dans le Groenland occidental (64˚–72˚ N.) La route de migration comprend de longs survols de l’océan et de la calotte glaciaire groenlandaise. Afin d’obtenir un rendement optimal de reproduction, il est important pour ces oies d’accumuler des réserves à des aires de repos printanières spécifiques avant de se disperser vers les aires de reproduction. Deux de ces aires de repos ont été décrites antérieurement. Le but de cette étude était de trouver les plus importantes de ces aires printanières en vue de protéger les oies des perturbations causées par l’exploration minière, le tourisme, etc. Le nombre d’oiseaux reproducteurs qui se concentrent dans les aires de repos printanières n’est que de 6000 sur une population totale de 30000. Le nombre est donc petit comparé à celui d’autres populations d’oies sur la planète. On a sélectionné 50 zones à partir de cartes géodésiques (1:250000) et on les a appareillées avec la couverture de neige et un index de végétation obtenu d’images-satellites prises en 1985 et 1988 au cours du début du printemps. Ensuite, en mai et juin 1994 et 1996, on a étudié un total de 35 aires de repos printanières potentielles situées entre le 63˚ et le 70˚ N. sur le terrain même et, du 9 au 12 mai 1995 et 1997, du haut des airs. De 1000 à 1500 oies ont été observées dans 28 zones. Toutefois 75 p. cent des oies étaient concentrées dans huit de ces zones, dont quatre en contenaient plus de 50 p. cent. Parmi ces quatre zones se trouvaient les deux découvertes antérieurement. La plupart des oies (94,5 p. cent) ont été observées dans la région de Kangerlussuaq (de 66˚ 29' N. à 68˚ 21' N.). On recommande que huit aires de repos printanières soient désignées comme zones protégées durant la période allant du 1er au 20 mai.

Mots clés: oie rieuse du Groenland, zones de repos printanières, Groenland occidental, images-satellites de la NOAA, couverture de neige, indice de végétation par différence normative, gestion

Traduit pour la revue *Arctic* par Nésida Loyer.

INTRODUCTION

It is of considerable importance to arctic breeding geese to acquire adequate nutrient reserves for reproduction before 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; Johnson and Sibly, 1993; Ebbinge and Spaans, 1995). Goose

[1] National Environmental Research Institute, Department of Arctic Environment, Tagensvej 135, 4th floor, DK-2200 Copenhagen N, Denmark; cmg@dmu.dk

species adopt different strategies to obtain optimal condition, but most studied populations build up stores on the wintering grounds before the spring migration and then supplement their condition at one or more spring staging areas before they reach 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, 1995). Giant Canada geese (*Branta canadensis maxima)* probably build up condition only 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; 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 before 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*.

Greenland white-fronted geese feed in the 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. 1 and 2), the geese fed on perennating plant organs for 68% of the total diurnal activity, the females up to 80% of the time (Fox and Madsen, 1981b; Glahder, 1998). 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 nonstop 2200 km transoceanic flight and a further northward flight along the west coast (Salomonsen, 1950, 1967). However, few observations support this route. Only a relatively small proportion (c. 20%) of the total wintering population of 30000 Greenland white-fronted geese are potential breeding birds (Fox and Stroud, 1988; Stroud, 1992; Fox et al., 1998). The total population is small 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 countries within its range (United Kingdom, Ireland, Iceland, and Greenland/Denmark) in the 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 using 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 airplanes (Bélanger and Bédard, 1989). It was concluded that such disturbance can have significant energetic consequences for fall-staging greater snow geese (Bélanger and Bédard, 1990). Madsen (1994) 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 both the staging period and the most important spring staging areas.

This paper describes an efficient approach to identifying spring staging areas in remote areas of West Greenland. Information available from two known spring staging areas in West Greenland (Fox and Madsen, 1981a, b; Fox et al., 1983) was used to find similar sites 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. This paper identifies the most important areas, discusses factors that may determine the choice of the geese, and considers management implications. 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 have 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 (1:250000) (KMS, 1974–89). This ice-free 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 (Fig. 1, point B) to the north of Kangerlussuaq/Søndre Strømfjord (67°31′N; 50°34′W), and Itinneq (Fig. 1, point A) to the east of Sisimiut (66°59′N; 52°20′W). The characteristics of these two areas are that they are lowlands (below 200 m a.s.l.) of 10 to 20 km^2 and they contain a river, many small lakes, and a "sand and clay" signature. A total of 50 potential spring staging areas were selected (see Table 1; Fig. 1).

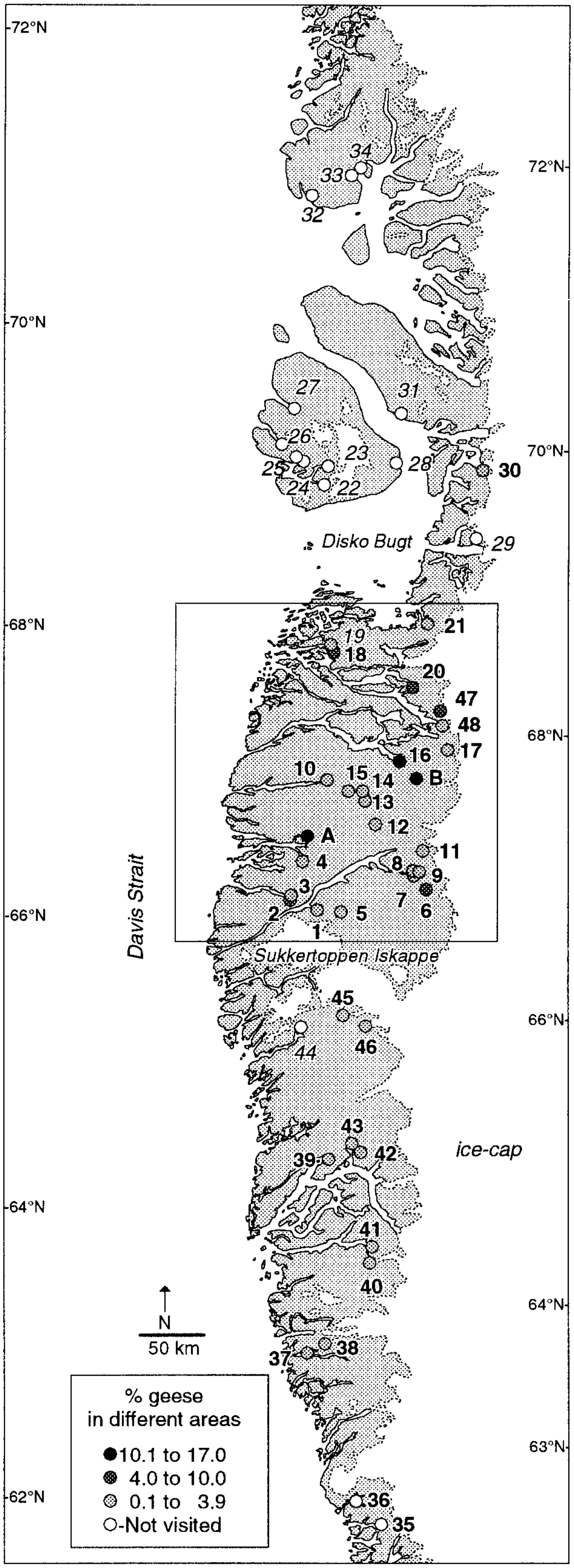

FIG. 1. Potential spring staging areas in West Greenland (62˚–72˚N). Of the 50 areas selected from topographical criteria (1–48, A and B), 14 (figures in italics) were rejected because of heavy snow coverage or lack of NOAA satellite scenes. Grey and black dots represent aerial surveys of 35 areas in 1995 and 1997. Dot colour indicates % geese in different areas (see Table 1). For area inside frame, see Figure 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 have 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 Normalised Difference Vegetation Index (NDVI) were calculated and corrected for clouds and haze (Hansen and Mosbech, 1994). Snow coverage was given four classifications: 1 = 20–40%, 2 = 40–60%, 3 = 60–80%, and 4 = 80–100% snow cover. Snow coverage less than 20% was included in the NDVI (< 0.1). The NDVI was given six classifications: < 0.1, 0.1–0.2, 0.2–0.3, 0.3–0.4, 0.4–0.5, and > 0.5. Higher values were associated with greater density and greenness of vegetation (Mosbech and Hansen, 1994).

The spring staging period is from 1 May to 28 May. Most observations of first arrival occur during the first week of May (Fox and Madsen, 1981a, b; Fox and Ridgill, 1985; K. Rosing-Asvid, pers. comm. 1996; Glahder, 1998). At the Kuuk spring staging area in West Greenland (Figs. 1 and 2, point B), the first geese were seen on 7 May; the number peaked (93 geese) on 12 May; and only a few birds were left on 17 May (Fox and Madsen, 1981a). A recent study in the same area (Glahder, 1998) observed a peak number of 470 geese on 3 May and 70 geese on 19 May. Normal clutch initiation is between 19 and 28 May (Fencker, 1950; Salomonsen, 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).

For an area to qualify as a potential spring staging area, its snow must have melted by early May under different weather conditions. During the period 1979 to 1992, precipitation (mm) and mean winter (December to February), and spring (March to 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 snowmelt in West Greenland is often characterized by periods of thick cloud cover. In 1985, snowmelt was earlier than normal, whereas in 1988 it 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 before the arrival of the geese, is shown in Figure 3.

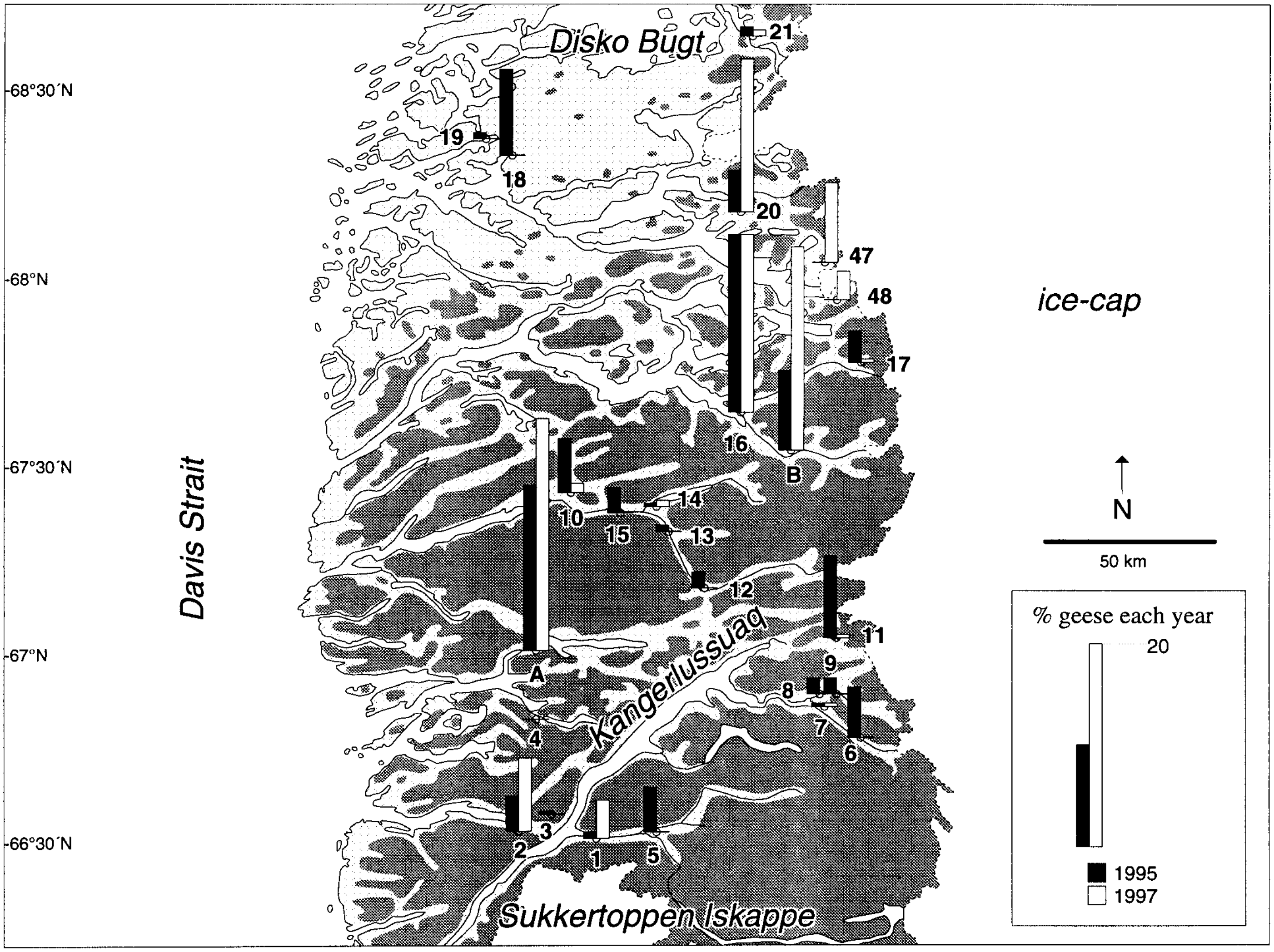

FIG. 2. Spring staging areas in the Kangerlussuaq area (66˚–69˚N). Black and white bars show % Greenland white-fronted geese observed on aerial surveys in 1995 and 1997 (see Table 1). Areas 47 and 48 were not visited in 1995, and areas 6, 18 and 19 were not visited in 1997. Light grey areas are below 300 m a.s.l., while dark grey areas are between 300 and 1500 m a.s.l.

The following criteria were used to select potential spring staging areas: A *potential area* must have had snow coverage of ≤ 20–40% on 23 April 1985 and a vegetation index of < 0.1 or higher on 12 or 16 May 1985 and 10 May 1988. An *uncertain potential area* must have had snow coverage of 40–100% on 23 April 1985, a vegetation index of < 0.1 or higher on 12 or 16 May 1985, snow coverage of ≤ 20–40% on 10 May 1988, and a vegetation index of < 0.1 or higher on 22 May 1988. Areas that still had snow coverage on 12 or 16 May 1985 and on 10 and 22 May 1988 were considered as *nonpotential areas*. Eleven areas were omitted in this way, 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. 1). 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 during 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 led to the more comprehensive aerial surveys earlier in May in 1995 and 1997. During 3 to 19 May 1996, feeding behaviour, habitat use, and goose numbers were studied on the ground at the staging area at Kuuk (Glahder, 1998). 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 optimal way

TABLE 1. Snow cover[1] and vegetation index[2] from NOAA satellite images during spring 1985 and 1988 for 50 areas in West Greenland,[3] showing evaluation as potential, uncertain potential, or nonpotential spring staging areas. Open cells indicate no NOAA scene was available.

No.	Name and co–ordinates	1985						1988			Evaluation[4]
		April 17	April 23	May 12	May 16	May 19	May 23	May 10	May 22	June 2	
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[5]		< 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		34	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°51′N, 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		(+)/÷ = (+)

[1] Snow cover classifications: 1 = 20 – 40%, 2 = 40 – 60%, 3 = 60 – 80%, 4 = 80 – 100%.

[2] NDVI (vegetation index) classifications: < 0.1, 0.1–0.2, 0.2 – 0.3, 0.3 – 0.4, 0.4 – 0.5, and > 0.5 (from low to high density and greenness).

[3] Areas A and B are the two known spring staging areas. The 48 numbered areas were chosen from geodetic maps.

[4] Evaluation (in 1985/in 1988 = final); + = potential area; (+) = uncertain potential area; ÷ = nonpotential area; ? = no evaluation possible.

[5] cl = clouds covering the area.

by following rivers and circling over lakes, marshes, and dwarf-scrubs. It is believed that all geese in the area were flushed, and only a few birds were 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 between areas as well.

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

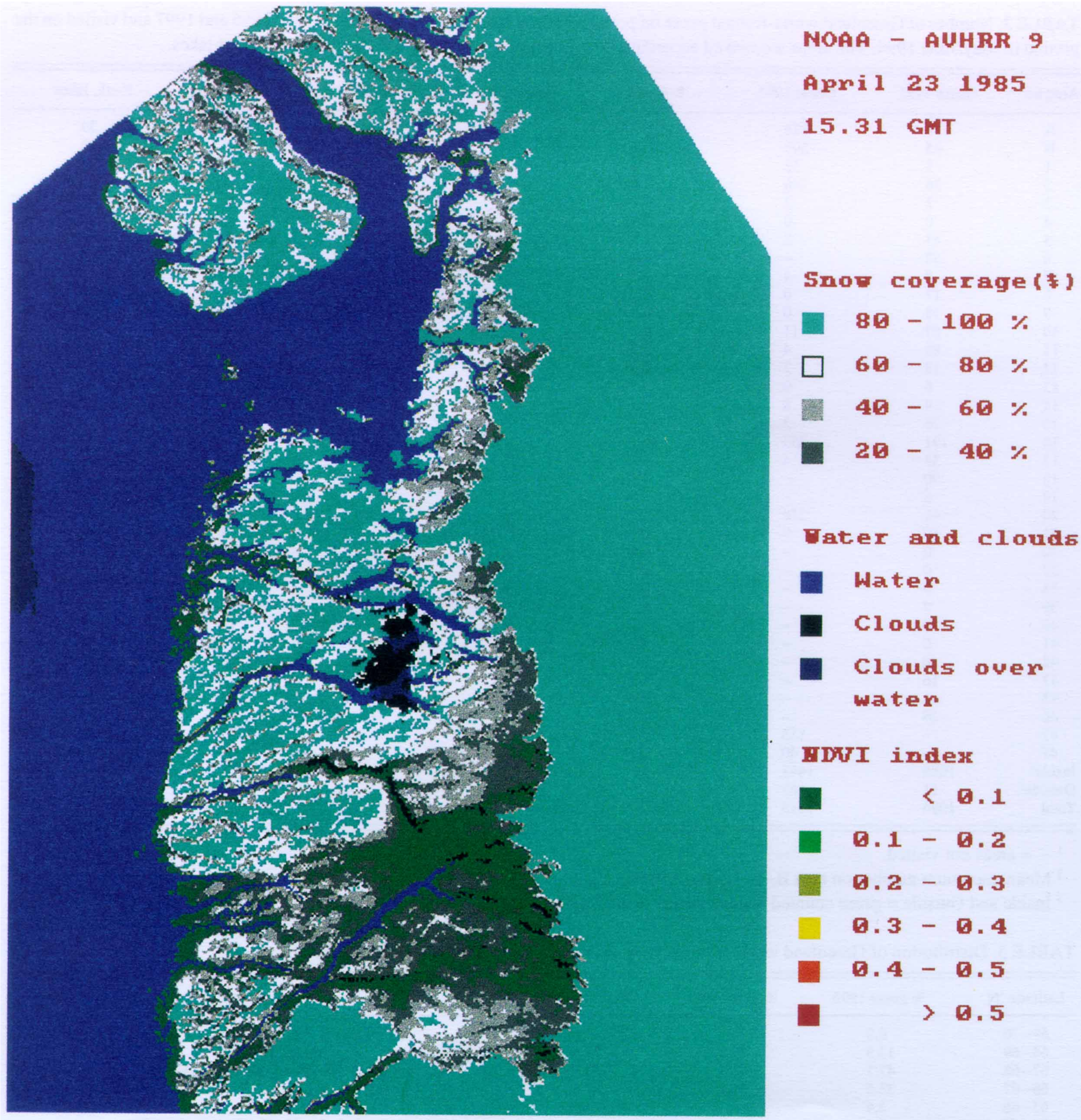

FIG. 3. Snow coverage in West Greenland (66˚–70˚N) on 23 April 1985. Snow coverage (%) is classified in four groups and vegetation (NDVI) index in six groups: < 0.1 to > 0.5. Snow coverage less than 20% is included in the NDVI group < 0.1.

RESULTS

Weather

In 1985, one of the years with satellite image coverage, mean spring temperatures in the area were slightly higher than normal (1–2˚C), but at Kangerlussuaq they were about 4˚C 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, precipitation was about double the normal (ASIAQ, 1995–97). Snowmelt in 1988 was much later than in 1985.

During the two aerial survey years, 1995 and 1997, mean spring temperatures in the area (62˚–69˚N) were normal to slightly above normal (1–2˚C), whereas

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 and according to the number of smaller lakes.

Area no.	Geese 1995	Geese 1997	% Geese	Rank, geese	Geese 1994	Lakes	Rank, lakes
A	178	328	16.9	35	–[1]	165	34
B	85	290	12.0	33	280[2]	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[3]	1085	1448					
Outside[3]	11	167					
Total	1096	1615					

[1] – = areas not visited.
[2] Mean maximum number on area B, 3–12 May 1996.
[3] Inside and Outside = geese counted inside or outside the staging areas.

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

Latitude ˚N	% geese 1995	% geese 1997	% geese total[1]	Area Numbers[2]
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

[1] – = % of total geese is adjusted to equal 100.
[2] All areas were covered during the 1995 aerial survey. In 1997, only areas between 66˚ and 69˚N (A, B, 1–5, 7–17, 20, 21, 47, 48) were surveyed.

temperatures at Kangerlussuaq were about 4˚C higher in 1995 and 2–3˚C higher than normal in May 1997. Precipitation in the area was normal in both years 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 and 1997.

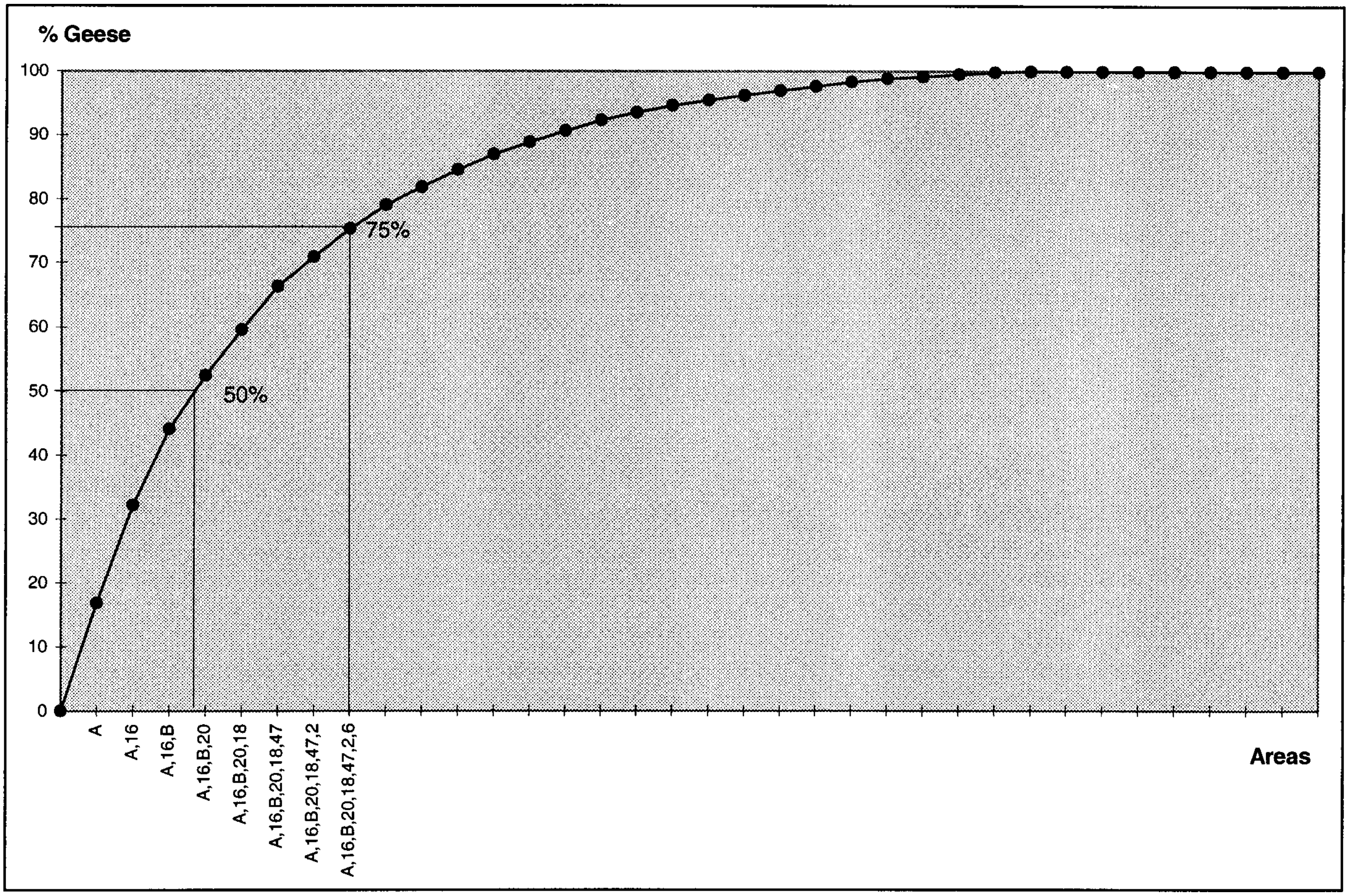

FIG. 4. Percentage of Greenland white-fronted geese observed on the 35 areas surveyed in 1995 and 1997. The % geese are summed over the ranked areas (see Table 2). More than 50% of all geese were counted in the four highest ranked areas (A, 16, B, 20), and 75% were within eight areas (A, 16, B, 20, 18, 47, 2, 6).

Aerial Survey

During the two aerial surveys, observers saw a total of 1096 geese in 1995 and 1615 geese in 1997. In 1995, 1085 geese were seen on 26 of the 33 areas visited; the remaining 11 were seen outside the areas. In 1997, 1448 geese were seen on 18 of the 22 areas visited, and 167 geese were seen outside the areas (Table 2, Figs. 1 and 2).

In 1995, the majority of the geese (94.5%) were observed between 66˚ and 69˚N, with a peak (47.1%) between 67˚ and 68˚N (Table 3). In 1997, geese were counted only in the area between 66˚ and 69˚N, but their distribution was similar to that of 1995 (Table 3). Number and distribution (in mean %) at each area are shown in Table 2. Because not all areas were visited in both years, the total mean percentage exceeded 100 (i.e., 115.9), so the mean percentages in Table 2 were adjusted proportionally 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), which included the two previously 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 were visited on the ground (Table 2, Geese 1994). 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 continuously from 3 to 19 May. On 3 May, 470 Greenland white-fronted geese were observed. This number had declined to 70 geese by 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 three-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: (1) the four most important areas include the two previously described spring staging areas; (2) of the ten highest-ranked areas, six ranked highest in both years; (3) the observation dates were later than the normal arrival period; and (4) only 1% (1995) and 10% (1997) of the geese 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 that extends from Sukkertoppen Iskappe north to Disko Bugt. In most years, early snow-free areas occur in the inner parts of this territory (the most extensive land in West Greenland, with 150–200 km from coast to ice cap). Figure 3 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 increase rapidly from March to May (ASIAQ, 1995–97). Also, the low precipitation is due to the Sukkertoppen Iskappe, where most precipitation falls on the southwest 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., those evaluated as potential or uncertain potential in both years (+ or (+) in 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, a comparison of snow coverage for the eight highest-ranked areas, which held about 75% of the geese, with that of the eight lowest-ranked areas, which held less than 1% of the geese, showed no differences. Obviously, early spring thaw is not the only condition important 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, as in 1984 (Fox and Stroud, 1988), must the geese 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, 1998), 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). 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 has been found to last 11–14 days (Ely and Raveling, 1984).

To evaluate the applicability of the described method for discovering spring staging areas in West Greenland, the number of Greenland white-fronted geese enumerated during the aerial surveys was 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 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 rate of predation, mainly by 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. Flooding 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 (55% average). The geese counted during the

1995 and 1997 aerial surveys were almost exclusively 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, 1998), and most were in pairs (Fox and Madsen, 1981b; Glahder, 1998).

How many staging geese the surveyed numbers of 1085 (1995) and 1448 (1997) represent can be calculated from the results of Øien et al. (1996), who studied lesser white-fronted geese (*Anser erythropus*) on a spring staging area in northern Norway. Over the five years of their study, 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 May and 12 May in 1995 and 1997 represent the maximum numbers on each staging area, it is possible that 2000 to 3000 geese, or up to 50% of the potentially breeding birds, will stage at the areas during the course of the whole spring staging period. This high proportion suggests that a relatively high number of important staging areas have been discovered in West Greenland. It is unknown whether the later-arriving immatures and nonbreeders use these staging areas, or whether they migrate directly to the breeding grounds, i.e., their summering areas.

MANAGEMENT RECOMMENDATIONS

In the late 1970s, the total Greenland white-fronted goose population was down to about 15 000 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). Today, the population is stable around this number, which is thought to represent an absolute minimum (Stroud, 1992). The international conservation plan (Stroud, 1992, 1993) initiated by the range states in the early 1990s addresses these various concerns for the long-term well-being of the population: the world population is small with a limited range; its 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 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 of which had more than 10% of the geese counted. Areas A and B meet the criterion set by the Ramsar Convention for wetlands of international importance, as they support 1% of the population of this species (Ramsar Convention Bureau, 1990). To protect a greater proportion of the breeding population and 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. 2).

The protection period should cover the period from the first arrival on 1 May to 20 May, when most geese, according to the Kuuk study (Glahder, 1998), have left for the breeding grounds. Studies at the Kuuk area (Glahder, 1998) 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 airplane flights below 500 m should be prohibited. Reactions to helicopters were not observed at the Kuuk area, but considering them would likely increase 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 already 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 with attached satellite transmitters, in addition to further confirmation of consistently used staging areas. Also, studies on disturbance reactions of the geese, especially to helicopters, are greatly needed. Most important to achieving the sustainability objective of the international conservation plan are probably studies of the different stress factors put on the population while it is staging during spring and fall in Iceland, where 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 protected by statute (Stroud, 1992; Fox et al., 1994).

ACKNOWLEDGEMENTS

Marianne K. Petersen of the National Environmental Research Institute (NERI) was observer at both ground truthing studies in 1994 and 1996. David Boertmann and Anders Mosbech (NERI) conducted the aerial surveys in 1995 and 1997 (only DB), and Leif Petersen was the pilot as well as observer in the Partenavia aircraft. Tony Fox and Preben Clausen (NERI) advised on studies in the Kuuk area in 1996, and Hanne Christoffersen and pilots from Grønlandsfly A/S Charter arranged and transported us in helicopters in 1994 and 1996. Jon Fjeldså, Tony Fox, and David Boertmann commented on earlier drafts of this paper, and three referees commented on the submitted manuscript.

REFERENCES

ANKNEY, C.D., and MacINNES, C.D. 1978. Nutrient reserves and reproductive performance of female lesser snow geese. Auk 95:459 – 471.

ASIAQ. 1995–97. Klima-Info, Grønlands Forundersøgelser 1995 –97. (Climatic information from 19 weather stations in Greenland).

BARRY, T.W. 1962. Effect of late seasons on Atlantic brant reproduction. Journal of Wildlife Management 26(1):19 – 26.

BÉLANGER, L., and BÉDARD, J. 1989. Responses of staging greater snow geese to human disturbance. Journal of Wildlife Management 53(3):713 – 719.

———. 1990. Energetic costs of man-induced disturbance to staging snow geese. Journal of Wildlife Management 54(1):36 – 41.

BUDEAU, D.A., RATTI, J.T., and ELY, C.R. 1991. Energy dynamics, foraging ecology and behaviour of prenesting greater white-fronted geese. Journal of Wildlife Management 55(4):556 – 563.

CHOINIÈRE, L., and GAUTHIER, G. 1995. Energetics of reproduction in female and male greater snow geese. Oecologia 103:379 – 389.

CRAMP, S., and SIMMONS, K.E.L., eds. 1977. The birds of the Western Palearctic. Vol. 1. Oxford: Oxford University Press.

DEL HOYO, J., ELLIOTT, A., and SARGATAL, J., eds. 1992. Handbook of the Birds of the World, Vol. 1. Barcelona: Lynx Editions.

EBBINGE, B.S. 1989. A multifactorial explanation for variation in breeding performance of brent geese *Branta bernicla*. Ibis 131:196 – 204.

EBBINGE, B.S., and SPAANS, B. 1995. The importance of body reserves accumulated in spring staging areas in the temperate zone for breeding of dark-bellied brent geese *Branta bernicla bernicla* in the High Arctic. Journal of Avian Biology 26: 105 – 113.

EBBINGE, B., ST. JOSEPH, L.A., PROKOSH, P., and SPAANS, B. 1982. The importance of spring staging areas for Arctic-breeding geese, wintering in Western Europe. Aquila 89:249 –258.

ELY, C.R., and RAVELING, D.G. 1984. Breeding biology of pacific white-fronted geese. Journal of Wildlife Management 48(3):823 – 837.

———. 1989. Body composition and weight dynamics of wintering greater white-fronted geese. Journal of Wildlife Management 53(1):80 – 87.

FENCKER, H. 1950. Den grønlandske blisgås (*Anser albifrons flavirostris* Scott & Dalgety) og dens ynglebiologi. Dansk Ornithologisk Forenings Tidsskrift 44 (2):61 – 65.

FOX, A.D., and MADSEN, J. 1981a. Pre-nesting feeding behaviour of the Greenland white-fronted goose. In: Fox, A.D., and Stroud, D.A., eds. Report of the 1979 Greenland White-fronted Goose Study Expedition to Eqalungmiut Nunât, West Greenland. Aberystwyth, United Kingdom: University College of Wales. 63 – 70.

———. 1981b. The pre-nesting behaviour of the Greenland white-fronted goose. Wildfowl 32:48 – 54.

FOX, A.D., and RIDGILL, S.C. 1985. Spring activity patterns of migrating Greenland white-fronted geese in West Greenland. Wildfowl 36:21–28.

FOX, A.D., and STROUD, D.A. 1988. The breeding biology of the Greenland white-fronted goose *Anser albifrons flavirostris*. Meddelelser om Grønland, Bioscience 27:1 – 14.

FOX, A.D., MADSEN, J., and STROUD, D.A. 1983. A review of the summer ecology of the Greenland white-fronted goose *Anser albifrons flavirostris*. Dansk Ornithologisk Forenings Tidsskrift 77:43 – 55.

FOX, A.D., NORRISS, D.W., STROUD, D.A., and WILSON, H.J. 1994. Greenland white-fronted geese in Ireland and Britain 1982/83 – 1993/94: The first twelve years of international conservation monitoring. National Parks and Wildlife Service, Ireland and The Greenland White-fronted Goose Study. Peterborough, United Kingdom: Joint Nature Conservation Committee. 54 p.

FOX, A.D., NORRISS, D.W., STROUD, D.A., WILSON, H.J., and MERNE, O.J. 1998. The Greenland white-fronted goose *Anser albifrons flavirostris* in Ireland and Britain 1982/83 – 1994/95. Population change under conservation legislation. Wildlife Biology 4:1 – 12.

FRANCIS, I.S., and FOX, A.D. 1987. Spring migration of Greenland white-fronted geese through Iceland. Wildfowl 38:7 – 12.

GANTER, B., and COOKE, F. 1996. Pre-incubation feeding activities and energy budgets of snow geese: Can food on the breeding grounds influence fecundity? Oecologia 106:153 – 165.

GAUTHIER, G., BÉDARD, J., HUOT, J., and BÉDARD, Y. 1984. Protein reserves during staging in greater snow geese. Condor 86:210 – 212.

GLAHDER, C.M. 1998. 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. PhD thesis. Department of Arctic Environment, National Environmental Research Institute, Copenhagen, Denmark. 142 p.

GLAHDER, C., FOX, A.D., and WALSH, A.J. 1996. Effects of fitting dummy satellite transmitters to geese: A pilot project using radio telemetry on wintering Greenland white-fronted geese. Technical Report No. 169. Copenhagen, Denmark: National Environmental Research Institute. 38 p.

———. 1997. Effects of fitting dummy satellite transmitters to Greenland white-fronted geese *Anser albifrons flavirostris*. Wildfowl 48:88 – 97.

———. 1998. Satellite tracking of spring migrating and summering Greenland white-fronted geese, 1998. Research Notes 91. Copenhagen: National Environmental Research Institute. 23 p.

GREENLAND HOME RULE 1995. Piniarneq 1996, with “Hunting seasons” in English (p. 10 – 12). Nuuk, Greenland: Direktoratet for Fiskeri, Fangst & Landbrug. 32 p.

GUDMUNDSSON, G.A., BENVENUTI, S., ALERSTAM, T., PAPI, F., LILLIENDAHL, K., and ÅKESSON, S. 1995. Examining the limits of flight and orientation performance: Satellite tracking of brent geese migrating across the Greenland ice cap. Proceedings of the Royal Society of London, Series B (Biological Science) 261:73 – 79.

HANSEN, B.U., and MOSBECH, A. 1994. Use of NOAA-AVHRR data to monitor snow cover and spring meltoff in the wildlife habitats in Jameson Land, East Greenland. Polar Research 13:125 – 137.

HOLM, C. 1997. Disturbance of dark-bellied brent geese by helicopters in a spring staging area. Dansk Ornithologisk Forenings Tidsskrift 91:69–73.

JOHNSON, I.P., and SIBLY, R.M. 1993. Pre-breeding behaviour affects condition, assessed by abdominal profile, and hence breeding success of Canada geese *Branta canadensis*. Wildfowl 44:60–68.

JØRGENSEN, P.V. 1993. Satellitbaseret kortlægning af snedække og vegetation på kystnære dele af det vestlige Grønland. Copenhagen, Denmark: Geografisk Institut, Københavns Universitet. 14 p.

KMS (NATIONAL SURVEY AND CADASTRE). 1974–89. Geodetic maps, 1:250 000. Copenhagen, Denmark: National Survey and Cadastre (KMS).

———. 1985. Aerial photos, 1:150 000, taken during July 1985 by National Survey and Cadastre (KMS), Denmark. Copenhagen, Denmark: National Survey and Cadastre (KMS).

MacINNES, C.D., DAVIS, R.A., JONES, R.N., LIEFF, B.C., and PAKULAK, A.J. 1974. Reproductive efficiency of McConnell River small Canada geese. Journal of Wildlife Management 38(4):686–707.

MADSEN, J. 1995. Impacts of disturbance on migratory waterfowl. Ibis 137S:67–74.

MADSEN, J., and FOX, A.D. 1981. The summer diet of the Greenland white-fronted goose. In: Fox, A.D., and Stroud, D.A., eds. Report of the 1979 Greenland White-fronted Goose Study Expedition to Eqalungmiut Nunât, West Greenland. Aberystwyth, United Kingdom: University College of Wales. 108–115.

MATHER, P.M. 1991. Computer processing of remotely-sensed images. An introduction. London: John Wiley & Sons. 352 p.

McLANDRESS, M.R., and RAVELING, D.G. 1981. Changes in diet and body composition of Canada geese before spring migration. Auk 98:65–79.

MILLER, M.W. 1994. Route selection to minimize helicopter disturbance of molting Pacific black brant: A simulation. Arctic 47(4):341–349.

MOSBECH, A., and GLAHDER, C. 1991. Assessment of the impact of helicopter disturbance on moulting pink-footed geese *Anser brachyrhynchus* and barnacle geese *Branta leucopsis* in Jameson Land, Greenland. Ardea 79:233–238.

MOSBECH, A., and HANSEN, B.U. 1994. Comparison of satellite imagery and infrared aerial photography as vegetation mapping methods in an arctic study area; Jameson Land, East Greenland. Polar Research 13:139–152.

MRA (MINERAL RESOURCES ADMINISTRATION). 1997. 1996 Annual Report from the Joint Committee on Mineral Resources in Greenland. Copenhagen, Denmark: Mineral Resources Administration for Greenland. 72 p.

NØRREVANG, A., and LUNDØ, J., eds. 1981. Danmarks Natur. Grønland. Politikens Forlag 11. 587 p.

ØIEN, I.J., AARVAK, T., LORENTSEN, S.H., and BANGJORD, G. 1996. Use of individual differences in belly patches in population monitoring of lesser white-fronted goose *Anser erythropus* at a staging ground. Fauna Norvegica, Series C, Cinclus 19:69–76.

OWEN, M. 1981. Abdominal profile: A condition index for wild geese in the field. Journal of Wildlife Management 45(1): 227–230.

PREVETT, J.P., MARSHALL, I.F., and THOMAS, V.G. 1985. Spring foods of snow and Canada geese at James Bay. Journal of Wildlife Management 49(3):558–563.

PROP, J., and DEERENBERG, C. 1991. Spring staging in brent geese *Branta bernicla*: Feeding constraints and the impact of diet on the accumulation of body reserves. Oecologica 87: 19–28.

RAMSAR CONVENTION BUREAU. 1990. Convention on wetlands of international importance especially as waterfowl habitat: Proceedings of the fourth meeting of the conference of the contracting parties. Vol. 1. Montreux, Switzerland: Ramsar Convention Bureau.

RAVELING, D.G. 1978. Timing of egg-laying by northern geese. Auk 95:294–303.

RUTTLEDGE, R.F., and OGILVIE, M.A. 1979. The past and the current status of the Greenland white-fronted goose in Ireland and Britain. Irish Birds 1(3):293–363.

SALOMONSEN, F. 1950. Grønlands Fugle. The birds of Greenland. Copenhagen: Munksgaard. 609 p.

———. 1967. Fuglene på Grønland. Copenhagen: Rhodos. 341 p.

———. 1979. Ornithological and ecological studies in S.W. Greenland (59°46′N–62°27′N). Meddelelser om Grønland 204(6). 214 p.

SECHER, K., BØCHER, J., GRØNNOW, B., HOLT, S., PETERSEN, H.C., and THING, H. 1987. Arnangarnup Qoorua. Paradisdal i tusinder af år. Pitersuiffik. 80 p.

SIGFUSSON, A. 1996. A new system of bag reporting from Iceland. Wetlands International Goose Specialist Group Bulletin 8:9–11.

STROUD, D.A. 1981. The distribution and abundance of Greenland white-fronted geese in Eqalungmiut Nunât. In: Fox, A.D., and Stroud, D.A., eds. Report of the 1979 Greenland White-fronted Goose Study Expedition to Eqalungmiut Nunât, West Greenland. Aberystwyth, United Kingdom: University College of Wales. 51–62.

———. 1992. Greenland white-fronted goose international conservation plan. Draft working document: Full plan (184 p.) and Executive summary (21 p.). Prepared for National Parks and Wildlife Service/International Waterfowl and Wetlands Research Bureau. Available from: Peterborough, United Kingdom: Joint Nature Conservation Committee, Monkstone House, City Road, Peterborough PE1 1UA, United Kingdom.

———. 1993. The development of an international conservation plan for *Anser albifrons flavirostris*, the Greenland white-fronted goose: In: Moser, M., Prentice, R.C., and van Vessem, J., eds. Waterfowl and wetland conservation in the 1990s: A global perspective. Proceedings of the IWRB Symposium, St. Petersburg Beach, Florida, U.S.A. IWRB Special Publication No. 26. Slimbridge, U.K. 142–148.

STROUD, D. A., and FOX, A. D. 1981. The status of the Greenland white-front in East Greenland. In: Fox, A.D., and Stroud, D.A., eds. Report of the 1979 Greenland White-fronted Goose Study Expedition to Eqalungmiut Nunât, West Greenland. Aberystwyth, United Kingdom: University College of Wales. 146–147.

VANGILDER, L.D., SMITH, L.M., and LAWRENCE, R.K. 1986. Nutrient reserves of premigratory brant during spring. Auk 103:237–241.

WARD, D.H., STEHN, R.A., and DERKSEN, D.V. 1994. Response of staging brant to disturbance at the Izembek Lagoon, Alaska. Wildlife Society Bulletin 22:220–228.

WILSON, J.R. 1981. The migration of high arctic shorebirds through Iceland. Bird Study 28(1):21–32.