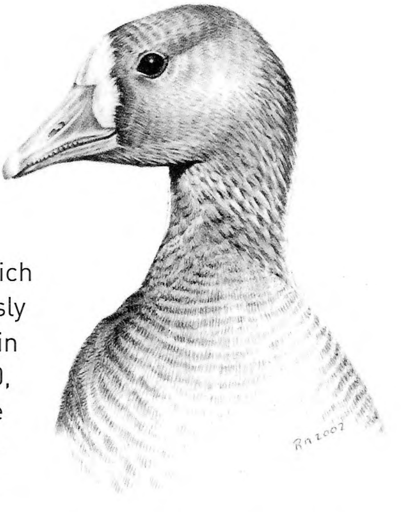
Spring staging areas of White-fronted Geese in West Greenland; results from aerial survey and satellite telemetry

[1]C. M. Glahder, [2]A. D. Fox & [3]A. J. Walsh

[1]National Environmental Research Institute, Department of Arctic Environment, P.O. Box 358, Frederiksborgvej 399, DK-4000 Roskilde; Email: cmg@dmu.dk
[2]National Environmental Research Institute, Department of Coastal Zone Ecology, Grenåvej 12, Kalø, DK-8410 Rønde; Email: tfo@dmu.dk
[3]Dúchas, The Heritage Service, National Parks & Wildlife, Wildfowl Reserve, North Slob, Wexford, Ireland; Email: alynwalsh@eircom.net



During spring 1998 and 1999, 10 Greenland White-fronted Geese fitted with satellite transmitters on the wintering grounds at Wexford, Ireland, migrated to West Greenland and provided new information on spring staging areas and staging periods. The geese staged at 11 different areas, of which eight were new and three were previously known from aerial surveys performed in 1995 and 1997. On May 15 and 16 2000, 3,177 Greenland White-fronted Geese were counted from aircraft at 28 of 34 staging areas in West Greenland between 66°30'N and 70°N. Three areas held more than 50% of all geese counted and c.75% of which were counted in six areas. The average minimum staging period was 11.2 days, but the staging period in 1998 was significantly shorter (7.2 days) than in 1999 (13.3 days). This difference may have been linked to a 4°C higher mean May temperature in 1998 compared to 1999. Seven of the 10 tagged geese used northern staging areas (north of 68°N) before continuing northwards, and this distribution differed significantly from the distribution of all geese counted on the staging areas. Although 11 known spring staging areas fall within territories designated as Ramsar Wetlands of International Importance, only two of the six best sites are designated in this way.

Key Words: Greenland White-fronted Goose, migration, stopover sites, Wexford-Ireland, Ramsar sites

Female arctic-nesting geese in good body condition lay larger clutches and fledge more young than females in poorer condition (Ankney & MacInnes 1978; Ebbinge *et al.* 1982; Ebbinge 1989; Prop & Deerenberg 1991; Johnson & Sibly 1993; Warren 1994; Ebbinge & Spaans 1995). Supplements to the reserves of a female goose on arrival at the breeding grounds will maintain or improve her general nutrient status and enhance her reproductive success, as long as no costs are incurred during the period between arrival and the first egg date. Given the significance of spring staging and pre-nesting feeding to the nutrient status of breeding females, conditions at the areas utilised can have a substantial influence on reproductive outcomes. Knowing the number, distribution and extent of spring staging sites used by this goose population, as well as the average staging period and numbers of birds using such sites, is therefore of high conservation utility. Such information provides an understanding of the relative importance of different sites, as well as the potential impact of threats (eg increased human activity or habitat destruction). Studies of patterns in the number of birds using sites within and between seasons is also important, as they contribute to an understanding of how geese can switch between different sites in response to a variety of environmental factors.

The world population of the Greenland White-fronted Goose *Anser albifrons flavirostris* declined from c.23,000 in the late 1950s to c.15,000 in the late 1970s (Fox *et al.* 1999a). Following conservation measures in the UK and other range states, combined with several good breeding seasons, numbers recovered to over 30,000 by the late 1990s (Fox *et al.* 1999a). Despite this, the population remains a Species of European Conservation Concern, listed on Annex 1 of the EC Birds Directive. Continued contraction of the wintering range remains an issue of conservation concern. Following a run of years with low reproductive success in the 1990s, it is essential that critical periods in the annual cycle (such as spring staging) are adequately understood in order to support the development of effective conservation mechanisms. Until the late 1990s, very few traditionally used spring staging areas for the Greenland White-fronted Goose were known from West Greenland (Fox *et al.* 1983; Glahder 1999). Two aerial surveys during May 1995 and 1997 discovered 28 staging areas in West Greenland (66°-69°N), of which eight areas supported 75% of all geese counted (Glahder 1999). During 1998 and 1999, a total of ten paired adult male Greenland White-fronted Geese were fitted with satellite transmitters and tracked to West Greenland where they provided new information on spring staging areas (Glahder *et al.* 1999a). During May 2000, an aerial survey covered the previously known staging areas as well as those areas used by the geese fitted with satellite transmitters. This paper compiles different sources of information about spring staging areas, summarising information for the future regulation of hunting, mineral exploration and exploitation in West Greenland (BMP 2000).

Methods

Study area

The study area comprised 28,000km^2 of ice-free land in West Greenland, situated between the ice cap and the coast (66°30'N to 70°N) (**Figure 1**). In the north (69°-70°N), the ice-free area extends 50km to the coast, consisting of mountain areas rising to 700m, with large fjord systems, river valleys, and lakes with restricted lowland areas dominated by dwarf shrub heath. South of Disko Bugt, the coastal landmass broadens and rises from about 100m at the plains of Naternaq to about 500m north of Kangerlussuaq, and up to c.800m in the southern part of the area. There is a climatic gradient from the humid coastal areas to the drier, more continental areas close to the ice cap. The dominant vegetation is dwarf shrub heath intersected by grassland further inland. Snow-free areas occur earlier in the south of the study area, which is characterised by low annual precipitation (149mm in Kangerlussuaq, 67°01'N), and rapid increases in temperature between March and May (-18°C to +2°C, Kangerlussuaq, Asiaq 1998-99).

Satellite telemetry

During late March 1998 and 1999, 14 satellite transmitters were attached to adult male Greenland White-fronted Geese on their wintering grounds in Wexford, southeast Ireland. All the tagged males proved to be paired, based on observations at Wexford after their release. The satellite transmitters (Microwave Telemetry PTT 100, 30g version) were back-mounted, secured by an elastic harness (Glahder *et al.* 1997), and programmed to transmit for eight hours, followed by a 29 hour dormant 'rest' period. During transmission, signals were transmitted every 60 seconds (1999) or 90 seconds (1998), and provided information on transmitter temperature, battery voltage and goose activity. Argos, CLS,

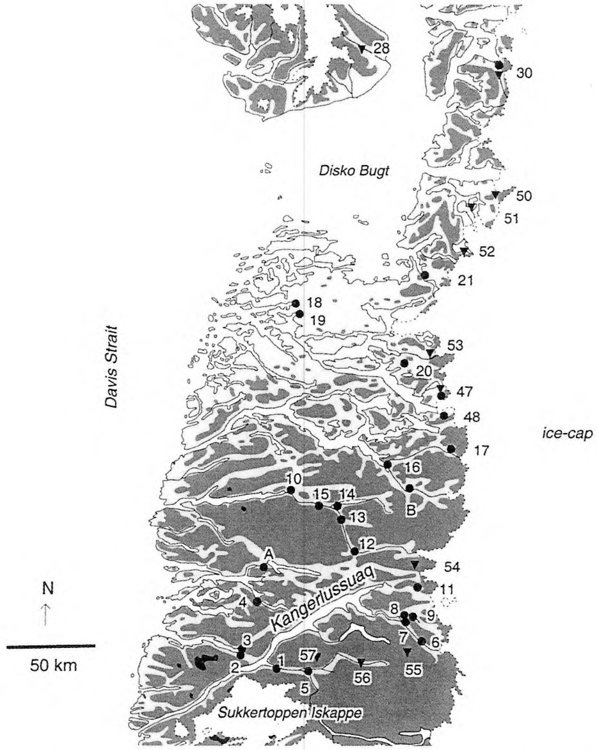


Figure 1: Currently known spring staging areas of Greenland White-fronted Geese in West Greenland (66°-70°N). The areas were surveyed from the air in 1995, 1997 and 2000. New areas were identified on the basis of geese attached with satellite transmitters having identification numbers 50-57 (triangles), while previously identified areas have numbers below 50 (dots). See also **Appendix 1** and **Figure 2** for site details. Pale grey land areas are those <300m a.s.l., darker grey land areas are 300-1,500m a.s.l. and dotted line shows the extent of permanent ice.

France, calculated ground positions of transmitters by measuring Doppler shift on the transmitted frequencies. Co-ordinates were generated in thousandths of a degree in the World Geodetic System (WGS 84) (Argos CLS 1996). Ground positions were assigned to the following accuracy classes: 3 (<150 m), 2 (150-350m), 1 (350-1000m) and 0 (>1000m). This was done on the basis of at least four signals being received during a polar orbiting NOAA satellite pass (Glahder *et al.* 1999a). Positions calculated from only three and two signals per pass were assigned to classes A and B, respectively, with no estimate of location accuracy (Argos CLS 1996). The average minimum number of locations per goose per day during the staging periods was 3.3 in 1999 (excluding K4L because of its movements between two staging areas) and 3.7 in 1998.

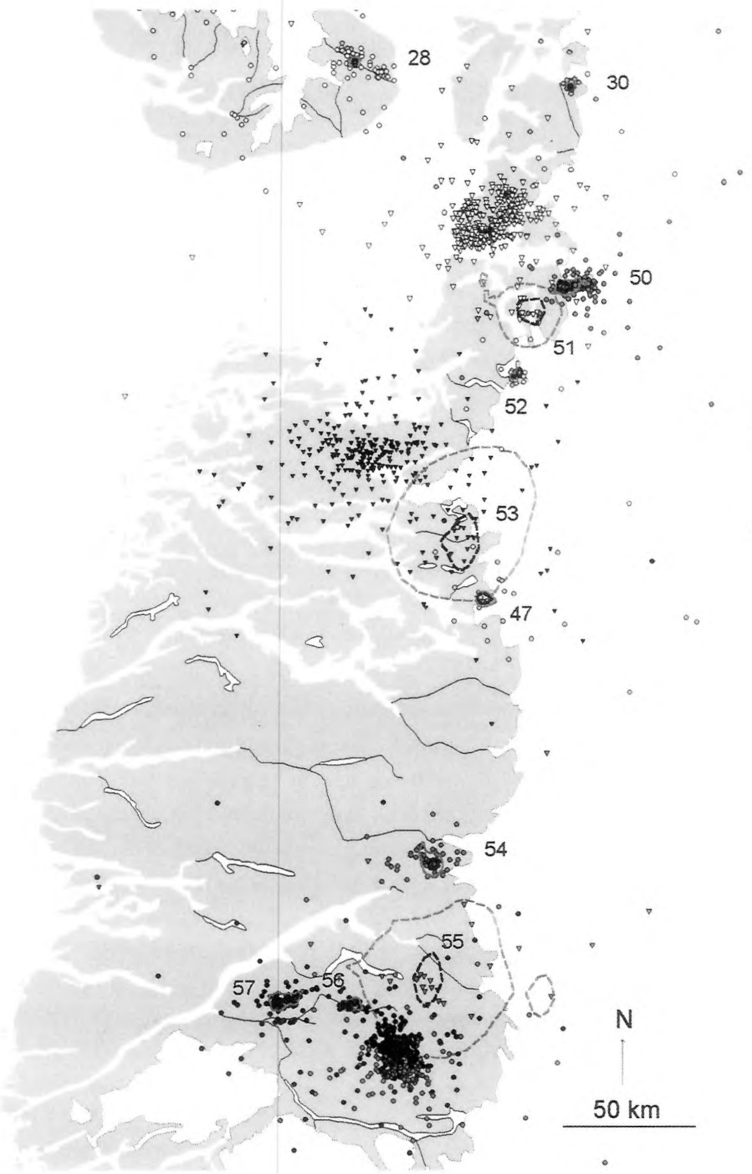


Figure 2: Spring staging areas in West Greenland (66°-70°N) identified by Greenland White-fronted Geese fitted with satellite transmitters in southeast Ireland in 1998 (triangles) and in 1999 (circles). See also **Appendix 1** and **Figure 1** for site details. New areas have codes 50-57, while 28, 30 and 47 represent previously identified staging areas from 1995 and 1997 surveys. Dispersion ranges are shown as "core areas" (inner black pecked line) and "whole area" (outer grey pecked line). Dotted lines represent dispersion ranges calculated on the basis of classes 0-3, solid lines on 1-3 classes.

Two major sources of variation explain changes in position between subsequent transmitter positions: (1) birds may change location and (2) changes may occur in fix error, which represents the difference between the true location and the position derived from the standard algorithms used to calculate the position. To define the point at which an individual moved onwards in Greenland, the degree of scatter of locations derived during a period when the tagged goose remained in a relatively small area was determined. The degree of dispersion of positions (dispersion ranges) for each of the 10 staging geese was calculated as harmonic means (with outliers removed and cell sizes optimised), using Range Manager (1998 Data Solutions, a MapInfo Professional application). Positions assigned to accuracy classes 1, 2 and 3 were used for the seven geese deployed with a transmitter in 1999, whereas accuracy classes 0, 1, 2 and 3 were used in the three 1998 geese, due to too few positions in the 1-3 accuracy classes. The positions provided in 1999 resulted in far smaller dispersion ranges than 1998 (**Figure 2**). For each staging area, 50% and 90% dispersion ranges were calculated, and regarded as 'core areas' and 'whole areas', respectively. Average distances between all successive used positions of each dispersion range were calculated. A staging area was defined as the area used by the goose immediately after spring arrival in West Greenland, but before movement to the final summering area. Distances to positions immediately before and after the staging period had to be at least ten times the average distance between positions inside the whole area dispersion range. If this criterion was not fulfilled, then no overlap was accepted between core areas of the staging site and the subsequent summering area.

Minimum and maximum staging periods were calculated for each location. The difference between the two periods results from the resting period of the transmitter. The minimum staging period was calculated from the first to the last position (classes 0-3) obtained from the staging area. The maximum staging period was calculated from positions (classes 0-3) immediately before and after the positions used to calculate the minimum staging period, minus the distances to and from the staging area to these outside positions. These distances were converted to time by assuming the ground speed of a flying goose to be 60 km/h (Owen 1980; Glahder *et al.* 1999a).

Aerial survey

The aerial survey was conducted in 2000 on May 15 and 16. An MD500 helicopter was used with a single observer on board. Counts were carried out at the 34 different areas at ground speeds of 150-175 km^{-1} and at an approximate altitude of 60 m. The 34 areas comprised the 26 areas resurveyed from 1995 and 1997, supplemented by the eight areas located from data derived from the satellite telemetry study. Aerial coverage was similar to that of the previous surveys and utilised the same routes. Searches for geese were made between the more intensive surveys of staging areas. On these transit routes, a ground speed of 185 km^{-1} was maintained, and an altitude of 150m. In 1995 and 1997, a fixed winged aircraft (Partenavia Observer) was used, and the surveys conducted on May 9 and 10 in 1995, and May 12 in 1997. In each of these years, the number of areas surveyed totalled 33 and 20, respectively (Glahder 1999).

The extent of suitable habitat at the surveyed staging areas (n=34) was defined from the air and transferred onto maps. Topographical features, such as fjords, rivers, large lake shorelines and glaciers, within which geese were observed during the aerial surveys (in 1995, 1997 and 2000) were used to delimit the geographical extent of these areas. In some areas, the habitats used by geese extended approximately to the 200m contour, while upland staging areas (ie above 200m) could be mapped using other salient topographical features. The density of small lakes km^{-2} inside the defined staging areas (ie number of lakes less than 10,000 m^2) were counted from aerial photos (1:150,000, KMS 1985), ranked, and correlated with the number of geese, using the Spearman rank correlation coefficient (**Appendix 1**).

Mean May temperature (based on one hour mean temperatures) and May precipitation sum (based on one hour accumulated weight, Belfort meter) from 1998 and 1999 were derived from six weather stations in West Greenland (Asiaq 1998-99): Sisimiut (66°57'N, 53°40'W), Kangerlussuaq (67°01'N, 50°42'W), Aasiaat (68°43'N, 52°52'W), Qasigiannguit (68°49'N, 51°12'W), Qeqertarsuaq (69°15'N, 53°32'W) and Ilulissat (69°58'N, 51°06'W).

Results

Climatological conditions

The weather during the three aerial surveys in May 1995, 1997 and 2000 did not differ markedly. Temperatures in the area were average to slightly above average in all three years, and precipitation was average in 1995 and 1997 and below average in 2000. During May 1998 and 1999, when the geese fitted with satellite transmitters arrived in West Greenland, mean May temperatures in 1998 were average to above average (+1.3°C, SD=0.9, n=6 weather stations) and in 1999 below average (-2.6°C, SD=1.0, n=6). In both 1998 and 1999 precipitation was above the average.

Satellite telemetry

Of the 14 Greenland White-fronted Geese fitted with a satellite transmitter, ten reached West Greenland with functioning transmitters. In 1998, three of six satellite transmitters stopped functioning after 1, 16 and 24 days, whilst still in Ireland. In 1999, one goose doubled back whilst crossing the

Table 1: Details of West Greenland spring staging areas used by ten Greenland White-fronted Geese fitted with satellite transmitters in spring 1998 and 1999. Individuals are identified by the code engraved on their neck collars fitted at capture. See text for definitions of minimum and maximum staging periods. Spring staging area codes (see **Figures 1 and 2**) refer to either previously identified staging areas (codes <50, Glahder 1999) or areas located by satellite telemetry data (codes 50-70).

Goose code	Arrival date	Spring staging area (code)	Position, centre	Minimum period (days)	Maximum period (days)	Position, summer area
K4L	09.05.1999	Ivnajuagtoq (57)	66°35'N,51°25'W	9.8	10.0	66°29'N,50°26'W
K4L	22.05.1999	Ivnajuagtoq (57)	66°35'N,51°25'W	11.8	13.0	66°29'N,50°26'W
K4L	03.05.1999	Arnangarngup kuua (56)	66°36'N,50°50'W	5.9	6.8	66°29'N,50°26'W
K4L	19.05.1999	Arnangarngup Kuua (56)	66°36'N,50°50'W	2.9	2.9	66°29'N,50°26'W
K1D	09.05.1999	Isungua (54)	67°08'N,50°20'W	19.7	21.6	66°29'N,50°29'W
K7N	13.05.1999	O. Nordenskjöld Dal (47)	68°01'N,50°20'W	12.9	14.9	72°22'N,53°54'W
K4N	15.05.1999	Naqerlut (52)	68°46'N,50°20'W	12.7	15.1	69°58'N,54°12'W
K1J	13.05.1999	Isua, Kangia (50)	69°04'N,50°05'W	11.3	(13.6)*	-
K3L	14.05.1999	Aqajarua (28)	69°42'N,52°20'W	14.5	16.8	72°15'N,54°51'W
K6N	20.05.1999	Qimmilivik (30)	69°45'N,50°15'W	8.6	9.8	70°00'N,54°05'W
Average (excl K4L)	1999	-	-	13.3 (SD=3.7,n=6)	15.6 (SD=4.2,n=5)	
K2A	10.05.1998	Qaamarngit Aussivaa (55)	66°41'N,50°15'W	7.1	12.8	72°23'N,52°29'W
K3A**	10.05.1998	Qallutuup Nunaa (53)	68°13'N,50°35'W	9.0	11.8	68°27'N,51°32'W
K3F	11.05.1998	Qallunaat Nunaat (51)	69°00'N,50°20'W	5.6	8.4	69°18'N,51°01'W
Average	1998	-	-	7.2 (SD=1.7,n=3)	11.0 (SD=2.3,n=3)	
Overall average (excl. K4L)	1998/99	-	-	11.2 (SD=4.3,n=9)	13.9 (SD=4.2,n=8)	

* The activity recorder stopped sensing movement on 26 May, suggesting that the satellite transmitter had either fallen off or the goose had died. Transmissions continued from the same site until September.

** during the staging period the goose explored the summering area c.50km to the northwest for a minimum period of 1.7 and maximum of 3.0 days. This period is included in the staging period.

Greenland ice cap, and remained in East Greenland throughout the summer, migrating to Iceland on 5 September and continuing to Ireland during late October. The ten geese staged on 11 areas in spring of which eight were new, and three were already known from aerial surveys performed in 1995 and 1997 (**Table 1, Figures 1 and 2**).

The average minimum staging period (**Table 1**) was significantly shorter in 1998 (7.2 days) than in 1999 (13.3 days, t_{10} = 2.1, P<0.05, adjusted for unequal variances). The average maximum staging period (less well defined than the minimum staging period) was 2.5-4 days longer than the minimum average (**Table 1**).

Following the staging period, geese moved between 40 and 570km north to northwest to their summering areas. Two individuals moved 50-75km to the south or southeast. K3A ranged over its summering area for a period of two to three days in the middle of the staging period, and K4L used two areas c.30km apart, before it finally settled for the summer c.50km to the southeast. K7N, K3L and K2A summered furthest north in the breeding range, and had stop-over sites 170-430km north of their initial staging area in West Greenland.

Aerial survey of spring staging areas in May 2000

A total of 3,177 geese was counted on major staging areas and 303 geese (8.7% of all geese observed, **Appendix 1**) were seen elsewhere. Over half were observed in three areas (A, 57 and B) and c.75% of the geese were counted on six areas (A, 57, B, 16, 51 and 2, **Figure 1**). There was a significant positive correlation between the number of geese and density of small lakes in the staging areas (Spearman rank correlation r_s=0.5862, n=34, P<0.01).

Of the eight areas supporting highest numbers of birds in 1995 and 1997, five (A, B, 16, 2 and 6) were among the eight highest ranked areas in order of abundance in 2000. The remaining three areas were ranked tenth (area 47), 11th (20) and 25th (18) in 2000. The two 'best' new areas found by satellite telemetry in 2000, ranked second (area 57) and fifth (51). Area 14 ranked 12th in 1995/1997 and was eighth in year 2000. Based on the survey in 2000, the ranking of the spring staging areas changed little despite the incorporation of the two new important areas.

The 11 staging areas used by geese fitted with satellite transmitters were situated between 66°N and 70°N. Most geese in 2000 were observed between 66°N and 68°N and the majority (53.3%) observed between 66°N and 67°N (**Table 2**). One of the areas identified by satellite telemetry (28) on Disko Island was not surveyed in 2000 due to logistical reasons. The remaining 10 areas held a total of 1,191 geese (37.5% of all geese counted on staging areas). The average rank of these ten areas (18.7±10.2) was similar to the average rank of all 34 surveyed areas (17.5±9.9) suggesting their abundance class distribution was

Table 2: Distribution of Greenland White-fronted Geese on staging areas in 1995, 1997 and 2000 in West Greenland (63°-70°N) segregated by 1 degree latitude bands. In 1995 the whole area was covered 66°-70°N, in 1997 66°-69°N and in 2000 66°-70°N. New areas discovered in 1997 are italicised, those in 2000 emboldened. Area codes are those mapped in **Figures 1** and **2**. Full details for the 1995 and 1997 surveys are given in Glahder (1999).

Latitude band (°N)	% of all geese counted 1995	% of all geese counted 1997	% of all geese counted 2000	Area Codes
69-70	0.0	-	7.7	30,**50**,**51**
68-69	13.9	23.5	7.5	18,19,20,21,*47*,**52**,**53**
67-68	47.1	42.5	31.4	B,10,11,12,13,14,15, 16,17,*48*,**54**
66-67	33.5	34.1	53.3	A,1,2,3,4,5,6,7,8,9, **55**,**56**,**57**
65-66	3.4	-	-	45,46
64-65	2.3	-	-	39,40,41,42,43
63-64	0.0	-	-	37,38

not dissimilar. Seven of the 10 geese fitted with a satellite transmitter staged between 68°N-70°N and three 66°N-68°N; this distribution differed significantly from the distribution of all geese counted on the staging areas: 15.2% between 68°N-70°N and 84.7% between 66°N-68°N (χ^2=23.09, df=1, P<0.0001).

Discussion

The satellite telemetry investigation added eight new sites not previously found from aerial survey (including two supporting one third of all geese counted). The surveys also confirmed the use of three previously known sites. Of all the identified spring staging areas, eight (sites 12, 13, 14, 15, 16, 17, 54 and B) fall within the existing Eqalummiut Nunaat and Nassuttuup Nunaa Ramsar site, site 28 falls in the Ajajarna and Sullorsuaq Ramsar sites and sites 18 and 19 are in a proposed extension to the existing Naternaq Ramsar site (Egevang & Boertmann, 2001). However, only two (B and 16) of the six most important known spring staging areas currently have such designation. Of the remaining four areas, A and 57 support more than 1% of the population of the Greenland White-fronted Goose, the criteria set by the Ramsar Convention for wetlands of international importance (Ramsar Convention Bureau 1990).

Twice as many geese were counted in 2000 compared with 1995 or 1997 (of which over 900 were contributed by two new areas discovered by the satellite tracking study), but this was probably partly due to the 3-6 day delay in the survey that year. More geese were found in the southern part of the staging range in 2000, but generally the study confirmed the overall picture derived from the 1995 and 1997 aerial surveys. Despite the higher goose encounter rate, the 2000 survey still only located 10% of the entire wintering population in spring. Greenland White-fronted Geese are dispersed during the spring. Indeed it is known that small groups and pairs intending to breed, separate from the large spring aggregations in mid May to feed at smaller wetlands immediately prior to nesting (Stroud 1981). Observations suggest that paired adults are the first to arrive in West Greenland during spring (Stroud 1981; Fox & Madsen 1981; Fox *et al.* 1983, Glahder *et al.* 1999b), and with an estimated 6,000 such potential breeders (Glahder 1999), a much higher proportion were located during the 2000 aerial survey. Without intensive aerial surveying involving regular line transects and distance sampling techniques (Buckland *et al.* 2001), accurate census of this potentially very large element of the spring population lies beyond the realms of logistic feasibility. In addition, geese at spring staging areas are easily flushed and displaced by approaching aircraft, making line transects and distance sampling techniques difficult in practice. This also means that aerial counts such as presented here undoubtedly underestimate true numbers present, even at the visited staging areas. Given these potential explanations for the low total numbers located at staging areas, we remain confident that, whilst other important staging areas undoubtedly still remain undetected, the survey has been successful in locating internationally important spring staging areas which are used consistently by the population.

The staging areas discovered by the satellite telemetry study were at higher latitudes than the general distribution of those discovered by aerial survey. A possible explanation could be that all geese fitted with satellite transmitters were caught at the southernmost wintering area, Wexford Slobs, southeast Ireland. This wintering area holds c.9,000-10,000 geese or nearly one third of the total wintering population (Fox *et al.* 1999a). Salomonsen (1967) and Kampp *et al.* (1988) showed that geese wintering further south in Ireland and Britain tend to summer further north in West Greenland and this leapfrog tendency could also hold for spring staging areas (Fox *et al.* 2002). Of the ten geese attached with a satellite transmitter, seven staged on areas situated between 68°N and 70°N, six of which moved further north after staging; the seventh presumably died during staging. The remaining three staged between 66°N and 68°N, and of these one moved further north to its summering area. It seems likely therefore, that staging areas between 66°N and 68°N (and perhaps further south) may be under-represented in the sample of those located by aerial survey. Given the leapfrog tendency to obtain the best coverage of spring staging areas in West Greenland used by the entire population, geese wintering at sites in the northern part of the winter range should be fitted with satellite transmitters. One suggestion would be to attach satellite transmitters to geese wintering in Scotland, in the north of the wintering range (eg on Islay, which supports some 9,000-12,000 geese, Fox *et al.* 1999a). This would be especially useful if such a study could be carried out concurrently with another Irish site (other than Wexford), so as to contrast the timing, duration and geographical nature of the spring migration between differing wintering elements of this population.

The geese attached with satellite transmitters provided high utility data on the length of the staging period. Upon arrival in West Greenland, the geese staged on average for about 11 days at spring staging areas covering on average 24.8km^2 (SD=19.9, n=34). Repeated readings of neck collar codes of individually marked geese have been used to estimate the staging period during spring (Fox *et al.* 1999b; Glahder *et al.* 1999b), but this method is time-consuming, dependant on good observation conditions and on geese showing predictable behaviour. The one study on a West Greenland staging area (Glahder *et al.* 1999b), showed the estimated average staging period to be only 2.2 days, suggesting such methods grossly underestimate the true staging times of individuals.

In order to save battery power, a resting period of 29 hours was chosen for the transmitters. This meant that the true staging period at any one site could potentially be up to two days and nights longer than estimated. The quality of the calculated geographic positions derived during spring staging was much improved from 1998 to 1999. In 1998, an accuracy of 1,000m or less (classes 1-3) was obtained in about 21% of the calculated locations; in 1999 this accuracy increased to 42%. Since the transmitter design had not changed, the establishment of a new additional satellite, NOAA-K, in orbit during 1999 was probably responsible for the improvement in signal detection. This satellite has a more sensitive onboard receiver that enables up to 50% more messages from low-power transmitters to be received and thereby enable more accurate location calculation (Argos newsletter 1999).

On arrival in West Greenland during the first or second week of May, satellite telemetry has shown that Greenland White-fronted Geese stage for one to two weeks before they either fly directly to their summering areas or migrate to a more northerly stop-over site en route. Although the tagged birds were males, they were all paired on the wintering grounds and were therefore accompanied back to the breeding areas with potentially fecund female partners. For these females, the staging period probably equates to the period of rapid oocyte growth which in the Greater White-fronted Goose *Anser albifrons frontalis* lasted 11-14 days (Ely & Raveling 1984). Following the staging period, geese in Greenland are ready to start nesting between May 19 and 28 (Salomonsen 1950; Fencker 1950). During 1998, the staging period was 7-11 days, so geese probably commenced oocyte growth on staging areas and completed on the breeding grounds. The reason for the significantly shorter staging period in 1998 compared to the staging period in 1999 of 13-16 days, may be linked to the almost 4°C difference in mean May temperature on the staging areas between 1998 (+1.3°C) and 1999 (-2.6°C). During periods of prolonged sub-zero temperatures, geese will have difficulties finding feeding ponds that have thawed sufficiently to enable extraction of plant material. In such shallow lakes, warmed by solar insolation, geese up-root the rhizomes of their preferred food plant, common cotton grass *Eriophorum angustifolium*. Therefore, sub-zero conditions will probably delay further northward migration. The mean spring temperature (March-May) in the main staging range (66°-68°N) of the Greenland White-fronted Goose has increased by 0.5-3.5°C per decade based on data from 1979 to 1997, whilst the northern part (69°-72°N) has become colder by 0.5-2.5°C per decade (Rigor *et al.*, 2000). Assuming this trend continues, the later thaw in the northern area will force geese to stay longer at their staging areas, undergo delayed breeding chronology and hence potentially reduced productivity. However, there is a considerable need for long-term data on the effects of weather during the pre-nesting phase on reproductive success, and to test the hypothesis that delayed onset of Spring is responsible for recent declines in reproductive output. It is especially important to test this against the competing hypothesis that increases in local goose density may have contributed to this process.

There is considerable evidence to suggest that the ability of female geese to accumulate nutrient stores at the earliest stage prior to the onset of breeding, has an influence on their ability to reproduce successfully in a given year. Theoretical considerations suggested that, for the Lesser Snow Goose *Anser caerulescens caerulescens* the fat stores available on arrival were only sufficient to account for 46% to 70% of the lipid and 14% to 55% of the protein requirements for clutches of 3-6 eggs (Meijer & Drent 1999). From this standpoint, female geese arriving at the breeding grounds must supplement stores with substantial amounts of dietary fat and protein in order to attempt reproduction at all. Few arctic nesting geese are complete capital breeders, in the sense that all reproductive material invested in clutches was derived from stores accumulated by the female in areas remote from the breeding areas. Many populations exploit spring staging areas close to, but not necessarily at, breeding sites and hence have the potential to supplement stores after the main spring migration and prior to first egg date. These include the Lesser Snow Goose (Ganter & Cooke 1996) and high arctic Greater Snow Goose *Anser caerulescens atlanticus*, thought originally to breed soon after arrival on the nesting areas (Choiniére & Gauthier 1995), although the Lesser Snow Geese of Karrak Lake sustain minimal food intake rates during pre-incubation (Gloutney *et al.* 2001). White-fronted Goose populations in particular are known to rely upon pre-nesting feeding on the nesting grounds to supplement stores for investment in reproduction (Fox & Madsen 1981; Ely & Raveling 1984; Budeau *et al.* 1991; Carriere *et al.* 1999). Even arriving non-breeders (eg young unpaired birds not intending to breed) need to recoup depleted stores and reserves on arrival after the sea and ice cap crossing to West Greenland. For this reason, identification of the number of spring staging areas represents an important contribution to our understanding of the population and its conservation needs at this point in the annual cycle. At Wexford, the percentage of young and the number of pairs of geese returning with young have shown significant declines over the period 1982-2000 (unpublished data). It is therefore increasingly important to monitor the number, quality and availability of spring staging sites for this population in West Greenland, and to understand the relationship between the use of these by different wintering and summering sub-populations. This is especially important to provide best advice on conservation management strategies and site-safeguard networks in the face of potential changes brought about by global climate change.

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Appendix 1: Number of geese counted on spring staging areas in West Greenland (66°-70°N) May 2000. Area codes refer to either previously identified staging areas (codes <50, A and B, Glahder 1999) or new areas (codes 50-57, shown in **Figures 1 and 2**). Percentage geese column contains the percentage of the total number of geese (3,177) observed at each staging area. The staging areas were ranked in descending order according to (i) number of geese observed and correlated with (ii) density of lakes ≤10,000m^2.

Area Code	Area km^2	Goose Numbers	% Geese	Rank Geese	Lakes Numbers	Lake Density no/km^2	Rank Lake Density
A	31.40	695	21.9	34	165	5.25	33
B	17.11	460	14.5	32	62	3.62	31
1	11.59	8	0.3	12	7	0.60	7
2	19.85	103	3.2	29	52	2.62	26
3	9.78	6	0.2	9	5	0.51	6
4	6.68	0	0.0	3.5	9	1.35	16
5	26.69	0	0.0	3.5	28	1.05	13
6	20.36	94	3.0	27.5	29	1.42	18
7	11.38	0	0.0	3.5	0	0	1
8	18.77	0	0.0	3.5	27	1.44	19
9	13.63	2	0.1	7	6	0.44	3
10	17.69	34	1.1	19.5	31	1.75	22
11	44.62	0	0.0	3.5	14	0.31	2
12	12.94	14	0.4	14	13	1.00	12
13	3.83	6	0.2	9	3	0.78	8.5
14	14.48	95	3.0	27.5	7	0.48	5
15	5.13	36	1.1	19.5	4	0.78	8.5
16	21.87	230	7.2	31	75	3.43	30
17	26.61	55	1.7	22.5	67	2.52	25
18	22.48	6	0.2	9	52	2.31	24
19	11.41	16	0.5	16	110	9.64	34
20	70.60	58	1.8	24	198	2.80	27
21	8.95	16	0.5	16	14	1.56	21
30	74.80	25	0.8	18	35	0.47	4
47	29.28	80	2.5	25	43	1.47	20
48	40.23	52	1.6	21	53	1.32	15
50	31.82	0	0.0	3.5	41	1.29	14
51	14.17	220	6.9	30	29	2.05	23
52	23.21	9	0.3	12	23	0.99	11
53	44.36	54	1.7	22.5	62	1.40	17
54	90.10	17	0.5	16	79	0.88	10
55	15.25	10	0.3	12	52	3.41	29
56	14.59	90	2.8	26	57	3.01	32
57	17.15	686	21.6	33	55	3.21	28
Inside Areas		3,177					
Outside Areas		303					
Total		3,480					