Greenland White-fronted Geese:
Investigating causes of low reproductive output in Greenland

Spring 2010 fieldwork – report to Scottish Natural Heritage

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Summary

- Greenland White-fronted Geese *Anser albifrons flavirostris* have been of conservation concern since the late 1970s when sharp declines triggered protection from hunting on the wintering grounds, which led to their recovery through the 1990s. Since the mid 1990s however, the population has again declined sharply.

- Since monitoring began in the 1960s, Greenland White-fronted Geese wintering in Ireland and Britain have shown levels of reproductive success below that of many similar low-arctic nesting geese (e.g. 27.5% amongst continental White-fronted Geese *A. a. albifrons* breeding in Russia during 1957-2009, compared to just 13% amongst Greenland birds during 1982-2007). Since 1995, levels of breeding success amongst the *flavirostris* population have been even lower (mean 9.4% on Islay in the Inner Hebrides and 8.9% at Wexford in southeast Ireland during 1999-2007 inclusive), falling well below those necessary to balance annual mortality at that time.

- Several potential hypotheses have been put forward to explain these patterns, of which weather seems amongst the most important, especially increased late winter/early spring snow on the nesting grounds since 1995, which likely has affected the ability of females to attain condition prior to investment in egg-laying. In addition, Atlantic population Canada Geese *Branta canadensis interior* appear to have colonised west Greenland in large numbers since the early 1980s. Numbers have increased rapidly since the 1980s and there were thought to be more than 42,000 by summer 2007 and so outnumber Greenland White-fronted Geese (estimated to be 23,000 at that time), where the latter were formerly the only species present. The two species undoubtedly compete for resources during the moult when they are confined to feeding areas close to open water to escape from predators, but if these two species compete for food and resources throughout the summer cycle, the presence in west Greenland of increasing numbers of Canada Geese could be another possible explanation for the decline in reproductive success in the Greenland White-fronted Geese.

- Investigation into the causes of low reproductive success on the breeding grounds was considered the most urgent priority by an international flyway management plan endorsed by an international workshop of interested parties organised by the Greenland White-fronted Goose Study (GWGS) and Scottish Natural Heritage (SNH) in February 2009. Actions to address this were proposed including fieldwork to study the behaviour, feeding ecology and reproductive success of both species on the breeding grounds.

- Fieldwork to investigate the arrival phenology, distribution and pre nesting behaviour of Greenland White-fronted Geese was carried out in Isunngua, west Greenland during late April to early June 2010 by six fieldworkers for a total of 115 man-days.

- The first Greenland White-fronted Geese seen after 26 April were on 1 May, with major arrivals on 5 May and 6-9 May (similar dates to those previously documented). Apart from one early arriving individual, Canada Geese began to arrive at least one week later with influxes on 12 May and 19-20 May. This staggered arrival pattern may have been influenced by weather patterns.

- Median first egg date from nine Canada Goose nests, for which the date of the first egg laid was known, was 29 May (mean 27 May), seven days after previously documented first egg dates of Greenland White-fronted Geese.

- No Greenland White-fronted Goose nests with eggs were found.

- A total of 34 Canada Goose nests was found, including one from a previous year. Twenty eight nests contained eggs. Nests in Isunngua had identical mean first egg dates (27 May) but greater mean clutch size (4.57 vs. 3.80) than ancestral stock breeding in Ungava Bay, northern Québec, 1,300 km further south.

- Detailed behavioural observations of Greenland White-fronted Geese feeding alone concurred with previous studies which showed females spend more time feeding than males; whilst males spent more time vigilant than females.

- There was evidence from the activity budgets that, when feeding sympatrically, Greenland White-fronted Geese spent more time feeding and less time being vigilant, suggesting that they may have benefitted from the vigilance of male Canada Geese.

- From mid May onwards, Greenland White-fronted and Canada Geese were observed in valleys generally lower than 500 m and were mostly associated with waterbodies and adjacent marshes. Nearest neighbour analysis revealed that white-fronts tended to avoid Canada Goose nest territories.

- Single and small groups of Greenland White-fronted Geese fed closer to Canada Geese than pairs and perhaps appeared more tolerant of feeding sympatrically. Pairs of white-fronts, although their breeding status could not be confirmed, tended not to feed sympatrically.

- Very few aggressive encounters between Greenland White-fronted Geese and Canada Geese were witnessed (on eight occasions out of 25 hours of observations).

- Disturbance events in Isunngua were rare with no other humans recorded in the study area from mid May to early June. However, Greenland White-fronted Geese

reacted to the presence of observers (ultimately leading to flight) at a greater distance than Canada Geese.

- In spring 2010, weather conditions in Isunngua and many other parts of west Greenland were warmer and drier than in recent years. Observations in the autumn and early winter suggest that 2010 was a good breeding season for Greenland White-fronted Geese with 22.9% young in sample flocks on Islay, the highest since the record season of 1985. Such benign spring conditions may have contributed to the high breeding success.

- Despite the lack of evidence for competition, aggressive encounters or displacement between the two species, it may remain the case that Greenland White-fronted Geese have abandoned the area as a breeding ground, and that displacement through these mechanisms may have occurred at some time in the last twenty years.

- The study in spring 2010 provided useful logistical and observation experiences to guide future fieldwork opportunities in west Greenland.

Photo 1. Sanningasoq on 16 May, 2010 showing >95% ice cover (H. Thomas)

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1 Introduction

Greenland White-fronted Geese *Anser albifrons flavirostris* have been of conservation concern since the late 1970s when sharp declines triggered protection from hunting on the wintering grounds, which led to their recovery through the 1990s. Since the mid 1990s however, the population has again declined sharply (Figure 1).

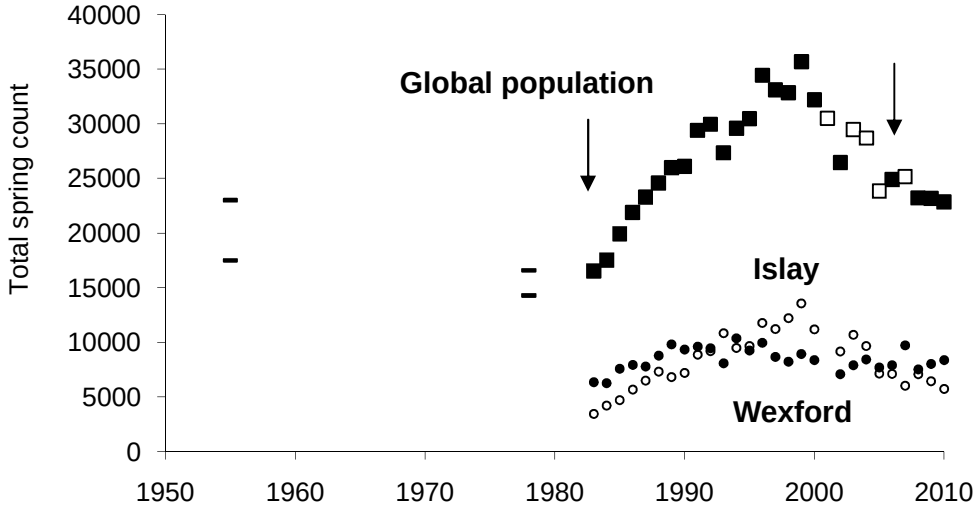

Figure 1. Change in the global population size of Greenland White-fronted Geese since the 1950s. Maximum and minimum estimated global population size in the 1950s and late 1970s (horizontal lines). Solid dots show total population size based on coordinated annual spring counts, open symbols show estimates resulting from missing counts in some years. Open squares show spring counts from Islay (the most important Scottish site) and solid triangles those from Wexford (SE Ireland). Vertical arrows indicate protection from hunting on winter quarters in 1982 and in Iceland in 2006.

Since monitoring began in the 1960s, Greenland White-fronted Geese wintering in Ireland and Britain have shown levels of reproductive success below that of many similar low-arctic nesting geese. For instance, the proportions of first year birds amongst those sampled on the winter quarters were 27.5% amongst continental White-fronted Geese *A. a. albifrons* breeding in Russia during 1957-2009, compared to just 13% amongst Greenland birds during 1982-2007 (Figure 2, Fox *et al.* 2010). This is in spite of the fact that the mean brood size of Greenland White-fronted Geese sampled on the wintering grounds is actually greater than those amongst other races of Greater White-fronted Geese. It is therefore the case that a much smaller proportion of the sexually mature potentially breeding population of the Greenland White-fronted Goose breed successfully in most years in this population (Fox *et al*. 2009), although those that do seem to return with large families.

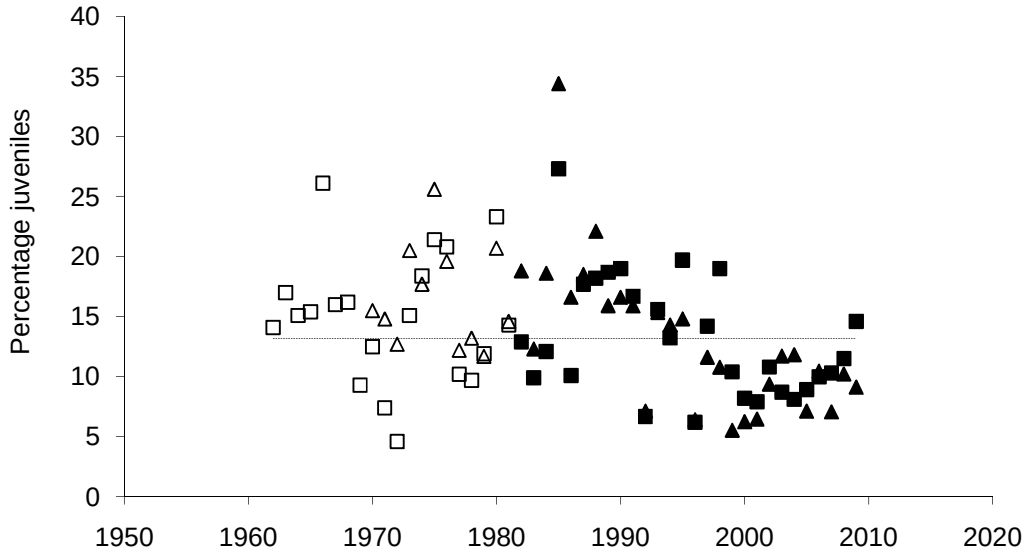

Figure 2. Annual percentage young amongst Greenland White-fronted Geese sampled at Islay (squares) and Wexford (triangles) during 1962-2009. Unfilled symbols indicate data prior to protection from hunting on the winter quarters, dotted line indicates overall mean.

However, since 1995, levels of breeding success amongst the *flavirostris* population have been even lower (mean 9.4% on Islay in the Inner Hebrides and 8.9% at Wexford in southeast Ireland during 1999-2007 inclusive), falling well below those necessary to balance annual mortality at that time, resulting in a rapid decline in population size since 1999 (Fox *et al.* 2006).

Since then, the Greenland White-fronted Goose has been protected from hunting in Iceland (where up to 3,500 birds were shot annually) effective from autumn 2006 and in Greenland (where a few hundred were shot annually) from 2009. Furthermore, productivity during the summer of 2009 and especially 2010 was better than in previous years, with the result that the global population size has levelled out since 2006 (Figure 1). Nevertheless, there remains the need to understand the main drivers of population change in this population, so it is important that we understand the factors that have constrained reproductive success during 1995-2007.

Several potential hypotheses have been put forward to explain these patterns, of which weather seems amongst the most important, especially increased late winter/early spring snow on the nesting grounds since 1995, which likely has affected the ability of females to attain condition prior to investment in egg-laying (Boyd & Fox 2008, see also Figure 3).

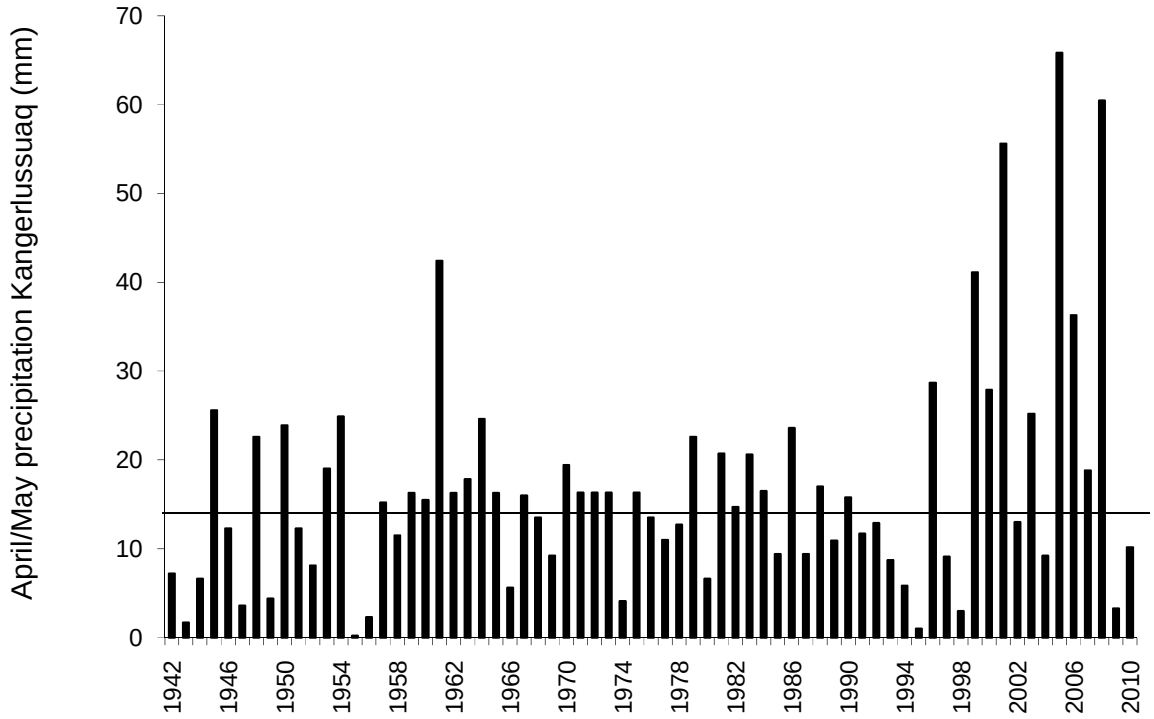

Figure 3. Annual precipitation in April and May combined from Kangerlussuaq, west Greenland since 1942 when records began. Solid line indicates overall annual mean. Note that nine out of the 13 years 1995-2008 inclusive lie well above the mean.

Atlantic population Canada Geese *Branta canadensis interior* have colonised west Greenland in large numbers since the early 1980s (Fox *et al.* 1996); genetic analysis and satellite telemetry suggests they originate from northern Canada (Schribner *et al.* 2003). Numbers have increased rapidly since the 1980s and there were thought to be more than 42,000 by summer 2007 (Fox & Glahder 2010) and so outnumber Greenland White-fronted Geese (estimated to be 23,000 at that time), where the latter were formerly the only species present. The two species undoubtedly compete for resources during the moult when they are confined to feeding areas close to open water to escape from predators (Kristiansen & Jarrett 2002), but if these two species compete for food and resources throughout the summer cycle, the arrival in west Greenland of Canada Geese could be another possible explanation for the decline in reproductive success in the white-fronts. In Isunngua the number of Canada Geese has risen from c.10 birds in 1988 to over 400 birds in 2008 (Figure 4, Stroud 2011).

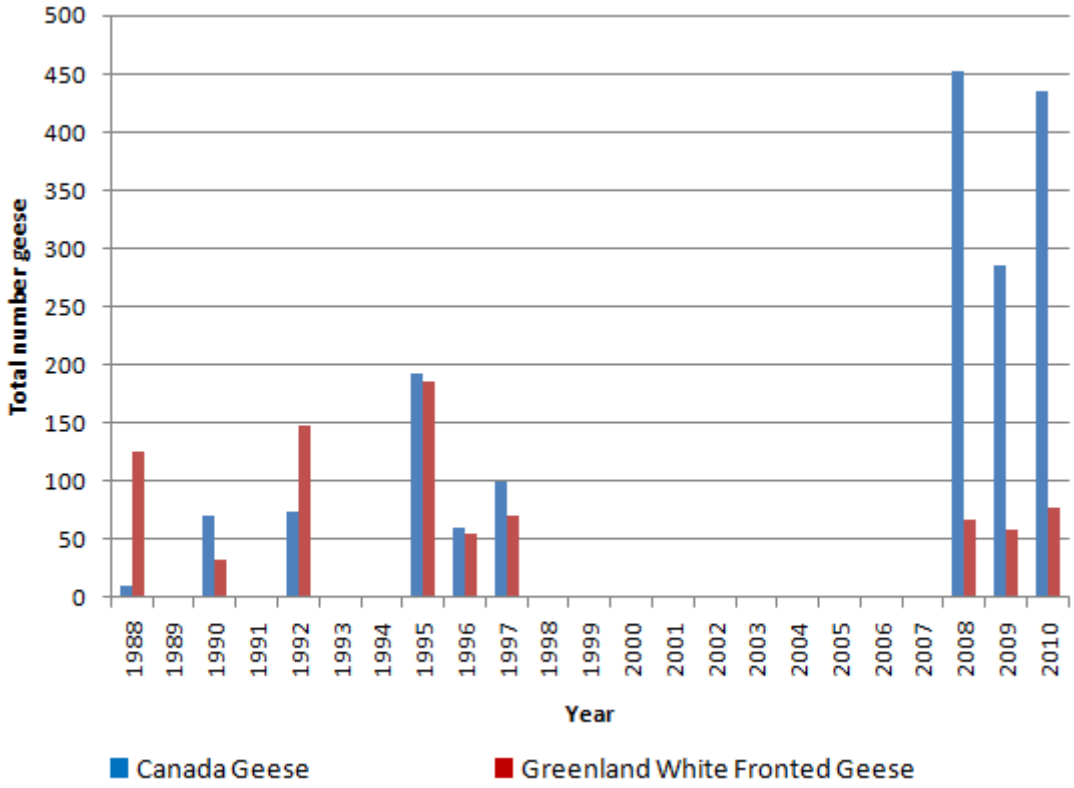

Figure 4. Numbers of Greenland White-fronted and Canada Geese in core areas of Isunngua, West Greenland during 1988-2010. Data only available for 1988, 1990, 1992, 1995, 1996, 1997, 2008, 2009, 2010. (Figure taken from Stroud 2011, with permission).

Investigation into the causes of low reproductive success on the breeding grounds was considered the most urgent priority by an international flyway management plan endorsed by an international workshop of interested parties organised by the Greenland White-fronted Goose Study (GWGS) and Scottish Natural Heritage (SNH) in February 2009 (Anon. 2009, Stroud *et al.* 2011). Actions to address this were proposed including fieldwork to study the behaviour, feeding ecology and reproductive success of both species on the breeding grounds. The results were to inform potential management actions (if possible) to address the problems faced by the population.

There was broad agreement at the workshop that factors inhibiting reproductive success were most likely manifest on the breeding areas, and so to this end, GWGS and the Wildfowl & Wetlands Trust (WWT) organised a project to study arrival phenology and nesting ecology during the pre-breeding and early nesting period in west Greenland to assess whether there were obvious reasons for the recent downturn in breeding success. SNH commissioned GWGS and WWT to report on preliminary research carried out in spring 2010 into the causes of low reproductive output of Greenland White-fronted Geese in Greenland. The results of these preliminary investigations will provide some context for prioritisation of conservation actions by SNH and the Scottish Government over the coming years.

The main objectives for the project in spring 2010 were as follows:

- To determine the contemporary arrival times of the two species on the breeding grounds in west Greenland to assess the potential for competition between Greenland White-fronted and Canada Geese at this critical time, especially for the

earliest arriving females that are likely to require undisturbed feeding in limited foraging habitat (dependent on exposure from snow cover).

- Establish key differences in broad and local distributions of the two species.
- Assess the potential for competition between the two species.
- Report on the observed effects of human disturbance, based on currently prevalent access levels in the general area, and contrast between levels of disturbance where feasible.

Photo 2. Looking southeast over marsh and pool complex at eastern end of Sanningasoq. Base camp was along the eastern shore (H.Thomas).

2 Background

The population of White-fronted Geese that breed in Greenland, winter in Scotland and Ireland and migrate through Iceland in spring and autumn, is one of the smallest goose populations in the world. Recent rapid declines in numbers have led to the population being identified in Scotland as a Species Action Framework (SAF) species requiring management for species conservation and being red-listed in the recently published third assessment of UK's Birds of Conservation Concern (Eaton *et al.* 2009), as well as being assessed as Endangered against IUCN's global Red-List criteria (Eaton *et al.* 2009, Boertmann 2007).

In light of this decline, an international workshop on the conservation of Greenland White-fronted Geese under the auspices of the Species Action Framework was convened by SNH and GWGS on Islay, Scotland in February 2009. Fifty participants from Ireland, UK (including Scotland, England, Wales and Northern Ireland), Iceland, Greenland, Denmark and Germany attended, with preparatory inputs from Canada. The workshop objective was to share information and assessments of current threats, and develop an international Action Plan summarising means to reduce or eliminate these.

It was agreed at the Islay Workshop (Anon 2009, Stroud *et al.* 2011) that urgent action needs to be taken to halt and reverse the current decline and concluded that the cause of the population decline was low recruitment. Numbers of birds hatched each year (recruitment) had been low and consistently less than the numbers dying (mortality), especially during 1995-2005. Since annual rates of survival had not changed at that time, it was likely that low levels of reproductive success had been responsible for declines in population size during that period.

The causes of low recruitment remain unknown, but may relate either to consequences of increased snow-fall in April and May during 1995-2008, and/or the consequences of inter-specific competition with rapidly increasing numbers of breeding Canada Geese in Greenland (which have colonised west Greenland from Canada). Other unknown factors may also be of significance (e.g. disease, parasite infestation or changes in nest predation rates) but there is little support for these alternative hypotheses despite thorough review and assessment in recent years.

The long-term goal of the International Action Plan, as agreed at the workshop, is to restore the Greenland White-fronted Goose to favourable conservation status and maintain this throughout its range. The short term aim is to identify the causes of current low productivity responsible for recent rapid declines in the population, and (where feasible) establish measures to halt the decline. The top priority action is to investigate the factors acting on geese on the breeding grounds responsible for the known current reduction in annual production of young. It is acknowledged that the factors which limit reproduction are most likely to manifest on the nesting grounds in Greenland. Consequently, to address the top priority action of the International Action Plan there is a pressing need to undertake research there.

A project to investigate the factors was initiated, led by GWGS and WWT. In spring 2010, preliminary research was undertaken on the breeding areas in west Greenland to better understand potential factors constraining reproductive output. The work in 2010 was a precursor to a three year PhD project, funded by WWT and Exeter University, which will begin in autumn 2011 and provide a platform for the continuation of the project. The SAF Implementation Plan identifies the facilitation and contribution to this project as a high priority task. SNH have provided financial support to WWT and GWGS for the reporting of the results of work undertaken in spring 2010, enabling preliminary results to be used to inform conservation actions in advance of reporting the results of future work, which will take several years.

3 Fieldwork in spring 2010

Greenland White-fronted Geese were studied in an accessible area close to Kangerlussuaq (Isunngua) on the breeding areas in west Greenland as a pilot study in spring 2010 to better understand potential factors affecting reproductive output and develop a more detailed research plan for the future. Isunngua was chosen due to its proximity to Kangerlussuaq airport, its history of previous fieldwork (going back to the 1980s) and because it is an easily accessible area with a known breeding population of both species. Emphasis was placed on the critical pre breeding period, late April to early June, when feeding opportunities can be highly restricted by snow cover and when females acquire energy and nutrients for investment in egg-laying.

3.1 Fieldwork methodology

This report documents the collation of data and analysis of results from the following work:

3.1.1 Assessing the timing of arrival of the two goose species

One important objective of the project was to attempt to track the arrival of Greenland White-fronted and Canada Geese to Isunngua, to assess the degree to which there could be inter-specific competition during the crucial period after arrival. Both species are likely to have completed journeys in excess of 1,000 km across inhospitable terrain (white-fronts from Iceland over the sea and Greenland ice cap, Canada Geese over the sea from Canada) and the females of both species need to recoup depleted energy stores in preparation for laying (and completing) a clutch. Clearly any competition for food at this important time could have implications for the weaker species. For this reason, we undertook observations of all flying geese and recorded species, flock size, position and direction of flight during the earliest parts of the fieldwork (late April to mid May). These data were then pooled to plot an overview of numbers. Clearly geese fly all the time, but it was found to be the case that there were dramatic changes in the numbers of flying geese which could be confidently related to the major arrival periods of both species. All times were recorded in local time (three hours ahead of GMT).

3.1.2 Assessing the degree of spatial overlap at the landscape, site and habitat scale

The distribution and abundance of both goose species was mapped in two separate study areas (north and south of Kangerlussuaq) causing as little disturbance as possible on a c.5 day basis. Results were analysed to assess habitat use and spatial overlap of the two species.

3.1.3 Assessing the behaviour of both goose species with and without the other

We attempted to compile activity budgets for both species to assess the degree of time spent investing in key activities likely to affect individual fitness (particularly feeding and feeding efficiency), especially with regard to any possible effects on Greenland White-fronted Geese and the presence or absence of Canada Geese. For this reason some effort was made to find white-fronts feeding in allopatry as well as sympatry.

We followed standard methods for data collection undertaking observations every two or five minutes (Altmann 1974). Each focal bird was allocated to a unique activity (Table 1). Any period of observation less than 30 minutes was excluded. For periods of 30 minutes up to 1 hour, data were allocated to an hour long block (00h00 to 00h59, 01h00 to 01h59 etc). Where several hour long observation periods were undertaken, the weighted mean proportion of time (0 to 1) spent undertaking an activity and standard errors (SE) were calculated. For some hour long periods, only one observation watch was undertaken and no SE could be calculated. Activity categories were lumped as follows:

Table 1. Activities recorded during fieldwork (left hand column) and lumped (composite) activity categories used in the results summary.

Activities recorded in the field	Composite Activity
Feed (whilst swimming) Feed (whilst standing or walking)	Feed
Alert (standing or sitting) Stand (but not feeding)	Alert/Sentinel
Preen Sleep Wing stretch Bathe Rest (sitting)	Comfort
Drink Swim (but not feeding) Walk (but not feeding) Aggression to others Aggression from others Up end (but not feeding) Head dip	Other

In addition, detailed observations were made of encounters between white-fronts and Canada Geese. Focal birds were followed between the two or five minute observations for activity budgets, and at times when time budgets were not undertaken, and detailed notes were kept of any interactions.

3.1.4 Assessing the effects of human disturbance on both goose species
There has been some increase in subsistence hunting and recreational human activity in the Isunngua area, with published recommended walking routes indicated on maps, and more guided tours in the area. Although increases in human disturbance is, and likely always will be, highly geographically restricted within west Greenland, it is nevertheless useful to monitor and to assess the differential responses of the two goose species to see if one or the other is disproportionately affected by such disturbance.

Background data on the numbers, activities and distributions of humans encountered in the study area and the response of geese to these were collated. Assessment of surveyor movements on the behavioural responses of geese in the field were recorded throughout the study, measuring response distance, rates and reactions of both species for comparisons.

4 Results

4.1 Fieldwork timetable and logistics

4.1.1 General fieldwork narrative

Kangerlussuaq airport provides a convenient entry point to the southern end of the Greenland White-fronted Goose breeding range, and the area in the immediate vicinity holds many breeding Canada Geese. Fieldwork was undertaken from 26 April until 15 June (with a gap in observer coverage on 10-11 May), a total of 49 days, with between one and four fieldworkers in the field for a total of 115 man-days. Due to the turnover of personnel, sightings of geese, and study areas covered, the study period was split into two phases; 'early' (26 April until 10 May) and 'late' (11 May to 15 June).

Fieldworkers flew from Copenhagen to Kangerlussuaq. A taxi was used on occasions to travel approximately 9 km along a gravel road east of the town. From there, fieldworkers (with kit) walked c 9 km to a base camp established at the eastern end of Sanningasoq (Figure 5, Photo 2). The team was extremely fortunate in negotiating the assistance of a research crew who had the use of a helicopter and who kindly agreed to fly all the food supply out to the base camp on 15 May. Bicycles were also hired in the early phase, although there are few tracks.

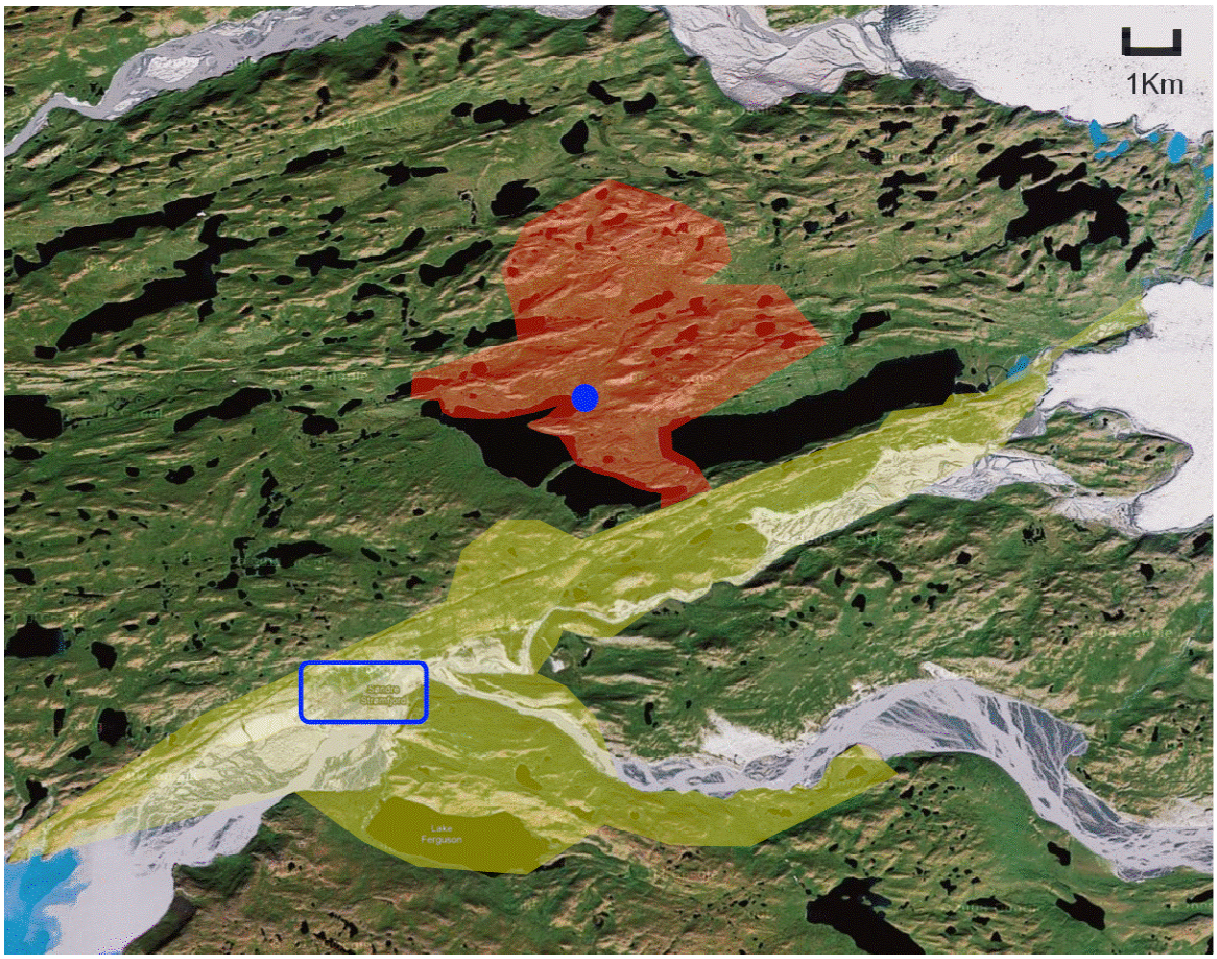

Figure 5. Fieldwork area, spring 2010. Yellow shaded area indicates early phase study area (end April to mid May). Red shaded area indicates late phase (or main) study area (mid May to mid June). Blue dot shows location of late phase base camp (see Photo 2). Blue rectangle shows location of Kangerlussuaq and airport.

By the end of April, 2010, much winter snow cover had disappeared and the thaw was well underway – conditions were already potentially suitable in some lowland areas for geese to find feeding (and nesting) sites, however, no geese were present. The first Greenland White-fronted Geese were seen on 1 and 2 May – just a few advanced breeding pairs, presumably the fittest individuals. There was little more activity until 6-8 May, when more white-fronts began to arrive, again apparently composed predominantly of breeding pairs, with larger groups of over 20 geese only evident from 8 May. This arrival timing is interesting, as it is essentially the same as arrival dates in 1979 and 1984 (Fox & Stroud 1988) and also in 1998 and 1999 (as shown from movements of satellite tagged birds - Glahder *et al.* 1999, Fox et al. 2003). It was expected that birds might have arrived earlier, since departures from the UK and Ireland have advanced 10-14 days in the last 25 years (A.J. Walsh and GWGS unpublished data). This observation suggests that birds are staying longer on their Icelandic staging grounds rather than arriving earlier in the breeding areas.

On arrival in 1979 in Eqalummiut Nunaat, white-fronts immediately settled on marshes along the glacial melt rivers that were the very first to thaw. These held below ground bulbs of the marsh arrow grass *Triglochin palustris* and the saltmarsh grass *Puccinellia phryganodes* which is eaten by arriving geese around much of the polar north.

In 2010, the geese fed first in small groups in low-altitude marshes and were probably exploiting cottongrass *Eriophorum* species and mare's-tail *Hippuris vulgaris* in pools; such wetland features were very important in 1979 and 1984 in Eqalummiut Nunaat, 50 km further north, but were exploited only after protracted feeding on the glacial melt river wetlands at lowest altitudes which thawed before the cotton-grass bogs and *Hippuris* pools. These latter resources had thawed earlier in May 2010 than in 1979, with the result that geese had no need to exploit the glacial melt river wetlands, and almost certainly allowed arriving females to accumulate nutrient stores for investment in clutches. Typically, the males stood guard, highly attentively, while females fed, in widely separated pairs. Exploratory flights by pairs and small groups to higher altitude areas where the lakes were still mostly frozen at this time were observed. These were presumably birds checking potential breeding and foraging areas near traditional nest sites.

During the initial two weeks, much time was spent checking suitable marshes and watching for arriving geese (as 'visible migration'). It was also expected that a later wave of non-breeders would arrive, at some unknown stage. Although some skeins of moving white-fronts were seen, they were usually small in number, and few large groups of presumed non-breeders had arrived by 9 May. The movements of white-fronts were in a range of directions, including frequently directly north-south. These may have been birds re-orienting themselves having crossed the ice cap. By 9 May, an estimated 450 white-fronts had been counted, within an effective survey range of 10-15 km around Kangerlussuaq. Two white-fronts tagged with satellite transmitters earlier in the winter at Loch Ken, Scotland (by WWT) crossed the Greenland icecap on 8 May and one of those marked at Wexford, Ireland (by Susan Schaeffer of the Livingston Ripley Waterfowl Conservancy) was crossing the ice cap at 22h00 on 8 May arriving at Svartenhuk in west Greenland by 20h00 next day.

Canada Geese arrived relatively late: On 2 May, three collared birds from Isunngua were still known to be present in Quebec, Canada. One lone Canada Goose was seen on 6 May, but the main arrival in west Greenland did not occur until the middle of May. During the rest of May to mid June, lakes were surveyed in areas where white-fronts are known to breed. From 20 May, the more obvious migratory movements of Canada Geese had mainly ceased with some small skeins flying higher overhead from south to north. More often, smaller groups or pairs were moving west to east up the valleys of the study area presumably searching for new feeding sites as the thaw continued apace. With temperatures as high as the low twenties (centigrade), ice cover on nearly all of the study lakes receded to zero from mid to

late May, with ice only remaining on the more substantial water bodies (see 4.1.2.1 below). A few aggressive interactions were seen between pairs of Canada Geese establishing territories and nest sites on lake shores, peninsulas, spits or islands mostly many hundreds of metres apart.

During 10-23 May, observations of white-fronts were largely of pairs or small groups (<5 individuals) in flight. Only on four occasions during this period was it possible to observe pairs actually on the landscape. Here, they seemed anxious and were present for less than two hours at any given time, often flying after just ten minutes on the ground. It appeared as if most white-fronts were searching for suitable foraging and/or resting areas.

The first active Canada Goose nest with one egg already present was found on 23 May. At this point, the route counts following set transects around the study area covering groups of lakes mainly recorded pairs or small feeding groups of Canada Geese, sometimes with occasional white-fronts. Most lakes checked held white-fronts during previous years. The white-fronts however were highly unpredictable as to whether or not they utilised a specific feeding area from one day to the next, which made them very difficult to observe. One pair that did regularly turn up for a couple of mornings, male (bearing the collar J5F) and female (J3F), appeared to start a nesting attempt on a fairly steep tussocky hillside at the east end of Sanningasoq, about 50 m above the water, although the nest was never completed. Both birds were ringed at a nearby lake on 14 July 2008 and were seen during the winter at Drumlemble, Kintyre in 2008/09 but not in 2009/10.

On at least two occasions, single adult white-fronts were seen with presumed family groups of yearlings, the dark nail and lack of belly bars still being evident. On the rare occasions that white-fronts were found feeding or resting with Canada Geese in a dispersed flock, detailed observations on the behaviours of the birds were collected. During these periods aggressive encounters were rare; however, these groups were mainly non-breeding birds. Judging from the disturbance distances of lone white-fronts or pairs of white-fronts compared to those in mixed flocks, it appeared that the presence of Canada Geese made white-fronts more tolerant and less flighty; white-fronts also appeared to spend more time with their heads down feeding rather than with their heads up and alert.

By the beginning of June, encounters with white-fronts in the Isunngua study area were less frequent with only c.10-20 birds present. Copulation was seen on one occasion and nest building was again attempted, suggesting that nesting was likely to occur in the area, although no completed white-front nests were located. Behavioural observations continued to be undertaken whenever geese were found. Although relatively few mixed flocks were recorded, competition for resources appeared negligible with, in most cases, white-fronts and Canada Geese feeding side by side.

4.1.2 Environmental phenology

4.1.2.1 Weather

Weather conditions in spring 2010 were relatively warm and stable with mean daytime temperatures above zero degrees centigrade almost throughout the study period (Figure 6). The mean May temperature (8.1℃) was 4.5℃ higher t han the 10 year (2000 to 2009) mean (3.6℃). The mean May precipitation (4.6 mm) was 8. 5 mm lower than the 10 year (2000 to 2009) mean (13.1 mm). Precipitation, mostly in the form of light rain or light snow, fell on three days (2.03 mm on 5 May, 2.54 mm on 13 May and 3.05 mm on 8 June). Heavier snow was recorded as falling on four days (4-5 May and 12-13 May).

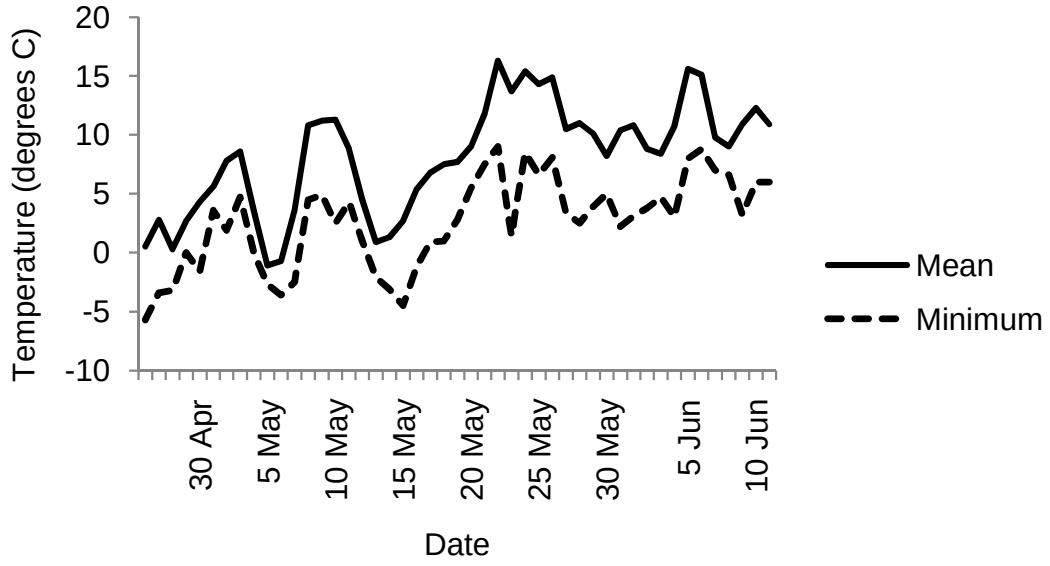

Figure 6. Mean and minimum temperature (℃) experie nced during the study period. Data recorded at Kangerlussuaq (http://www.tutiempo.net/en).

4.1.2.2 Ice cover on waterbodies

The percent ice cover on waterbodies of different sizes melted at different rates (Figure 7) with smaller waterbodies (<20 ha) becoming free from ice quicker than the larger ones. By the first week of June, except for the very largest waterbodies of Sanningasoq and Aajuitsup Tasia, very little ice remained on any waterbodies.

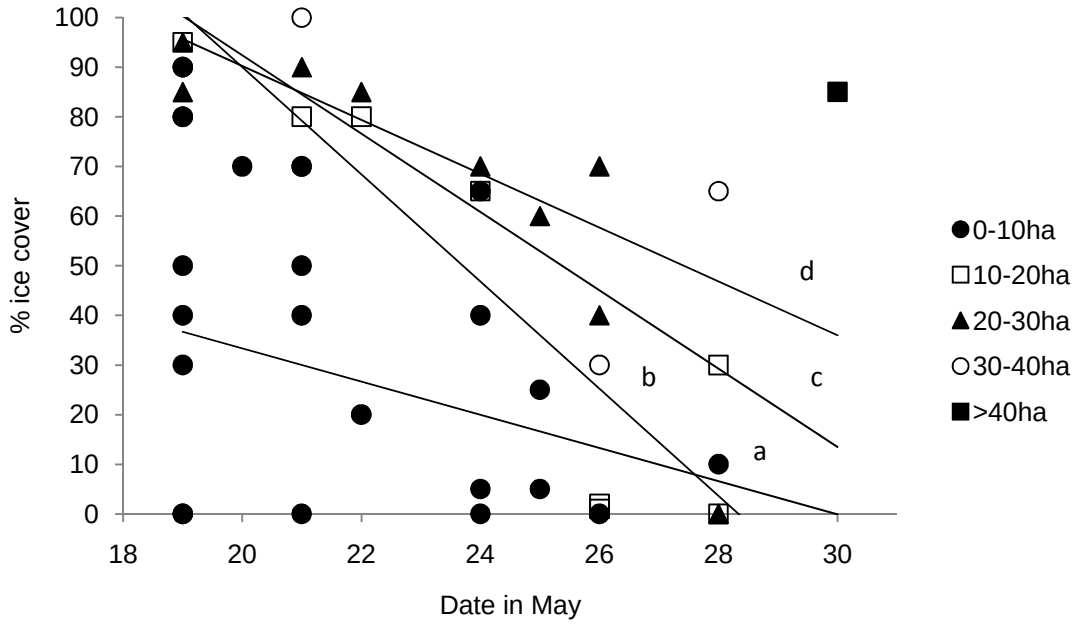

Figure 7. Decline in percent ice cover on lakes in Isunngua during May 2010. Trend lines shown for lakes of sizes 0-10ha (a), 10-20ha (b), 20-30 ha (c) and 30-40ha (d).

Photo 3. Looking northwest from the eastern end of Sanningasoq on 24 May, 2010. Base camp to right of photo. Note extent of ice cover (H. Thomas)

4.1.2.3 Flora/fauna

Casual observations of insect emergence and state of ground vegetation were noted. Arrival dates for common migrant birds, first emergence records for some invertebrates and the state of vegetation were recorded (Table 2, see also Appendix 1).

Table 2. Arrival dates for common migrant birds, first emergence records for some invertebrates and the state of vegetation, Isunngua, 2010.

Common migrant birds		Emerging invertebrates		Vegetation	
Species	First record	Species	First record		
Greenland White-fronted Goose	1 May	Mosquito Cuculidae	22 May	Dwarf Birch *Betula nana* budburst and leafing	18 May
Northern Wheatear *Oenanthe Oenanthe*	1 May	Bumble Bee Bremidae	22 May	Purple Saxifrage *Saxifraga oppositifolia* flowering	21 May
Lapland Bunting *Calcarius lapponicus*	5 May	Whirlygig beetle Gyrinidae	24 May	Arctic Willowherb *Chamerion latifolium* flowering	23 May
Canada Goose	6 May[1] (12 May)	Hoverfly Syrphidae	24 May	Sporulating puffball fungus	25 May
Ringed Plover *Charadrius hiaticula*	6 May	Lepidopteran caterpillars	27 May	*Vaccinium uliginosum* bushes now in leaf	25 May
Long-tailed Duck *Clangula hyemalis*	22 May	Butterfly (probably *Colias hecla hecla*)	6 June	Lousewort *Pedicularis* spp.starting to leaf up	27 May
Red-necked Phalarope *Phalaropus lobatus*	24 May			Labrador Tea *Ledum palustre* flowering	27 May

[1] A lone Canada Goose was seen on 6 May; the next arrivals were seen on 12 May.

The distribution of sightings of birds (other than geese) and mammals are shown in Appendix 1.

4.2 Assessing the arrival times of pre nesting Greenland White-fronted Geese and Canada Geese

4.2.1 Arrival times from observations of flying geese

The first Greenland White-fronted Geese seen during continuous observations from 26 April 2010 onwards were three adult birds without neck collars flying west over the Sugar Loaf area at 18h50 on 1 May. There followed two sets of pairs at 02h08 and 04h28, then a group of six at 10h09 on 2 May which together constituted the first arrivals of the species.

No more geese were seen until a pair passed southwest at 08h12 on 5 May, followed by 81 more birds during the rest of that day (mean flock size 4.2). After this second influx, there followed another major arrival from 14h22 on 6 May, with 97 more white-fronts arriving (mostly small groups; mean flock size 4.4) until 20h19. White-fronts continued to arrive in the following days, but in less dramatic numbers, conspicuously in flocks of up to 23 individuals, but by 9 May, the arrival had slowed and fewer and fewer flying birds were noted (Figure 8).

The first Canada Goose was seen at 14h49 on 6 May, but no others were seen until 12 May when there was a major arrival, some three days after the numbers of white-fronts observed appeared to plateau. An additional peak of arrivals occurred on 19-20 May (Figure 8). Note

that the first Canada Goose egg was found on 23 May (see below), but the median date of the first egg laid from nine followed nests was 29 May.

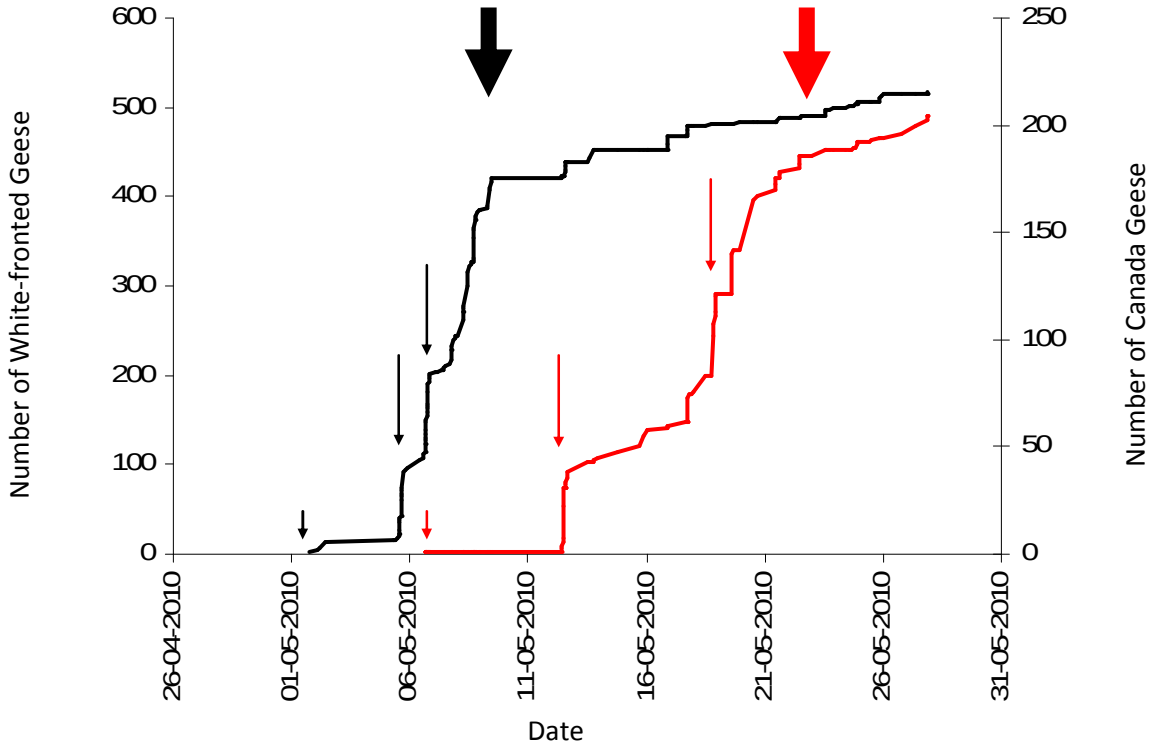

Figure 8. Cumulative observations of flying Greenland White-fronted Geese (black line, left axis) and Canada Geese (red line, right axis) observed in Isunngua, 26 April – 31 May 2010 as an index of migratory arrival times in the two species. We infer that the plateau in the numbers observed reflects the reduction in genuinely over flying migrant birds and increasingly reflects local movements. Small arrows indicate first sightings, long thin arrows indicate particular arrival times for both species and thick arrows infer when the main arrival was deemed to be over.

The arrival times were compared to pressure charts available for these periods[1]. For Greenland White-fronted Geese migrating from Iceland to Greenland, conditions were favourable on 1-2 May but deteriorated on 3-4 May with a less favourable wind direction and more weather fronts along the migratory route (Figure 9). Despite this, the majority of birds arrived during 5-7 May. Winds did not look favourable for migration on 5 May but pressure built up from the south of Iceland with good conditions for migration from 7-10 May (Figure 10). It is noteable that two white-fronts that wintered in the Loch Ken area of Scotland, and fitted with GPS satellite tags, crossed the Greenland ice cap independently from Iceland on 8 May, heading to sites within 50 km of the study area.

[1] Pressure charts obtained from http://www.wetterzentrale.de/topkarten/tkfaxbraar.htm

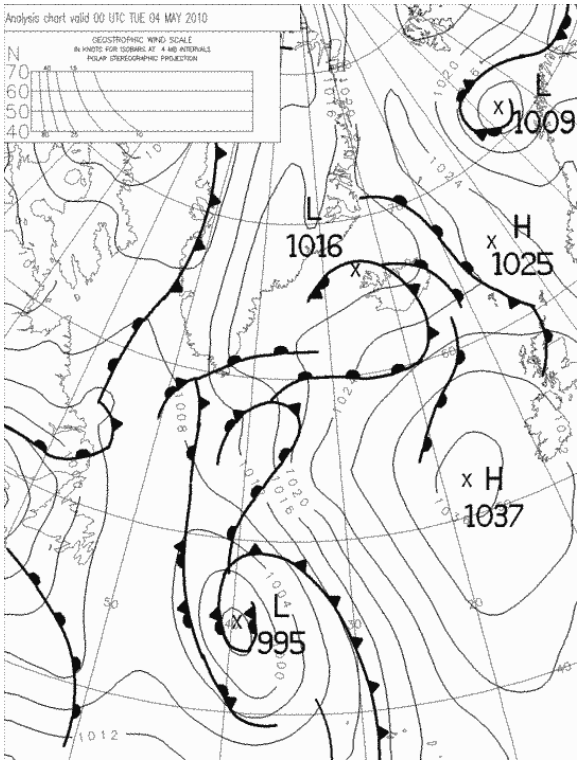

Figure 9. Synoptic weather chart for 4 May 2010.

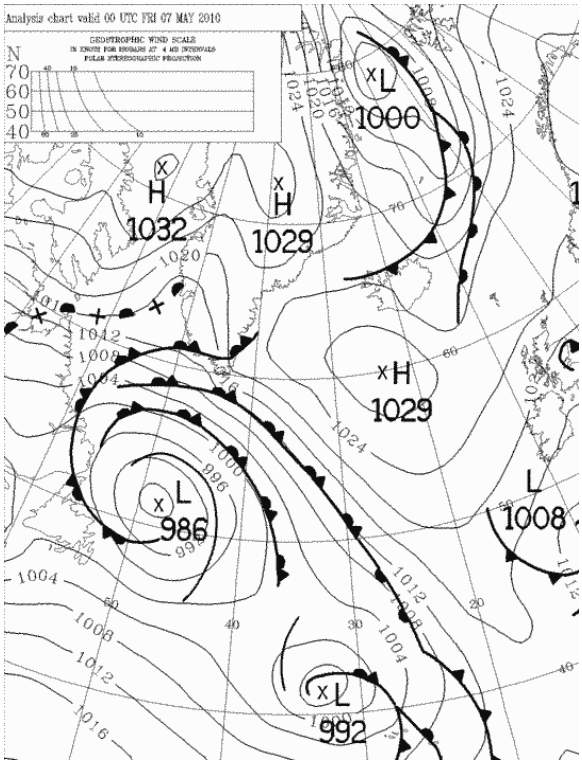

Figure 10. Synoptic weather chart for 7 May 2010.

The Canada Geese breeding in west Greenland would be expected to depart from Newfoundland and Quebec and from 4 May onwards a low pressure system began to deepen in that area with associated weather fronts meaning the wind direction for these birds was not favourable. By 10-13 May, conditions began to improve (Figure 11), however these deteriorated on 16-17 May but improved again by 18 May (Figure 12). Thus, favourable migration conditions for Canada Geese migrating from north west Canada to west Greenland were best around 11-12 May and 18-19 May. This generally fits with the observed arrivals on 12 and 19 May.

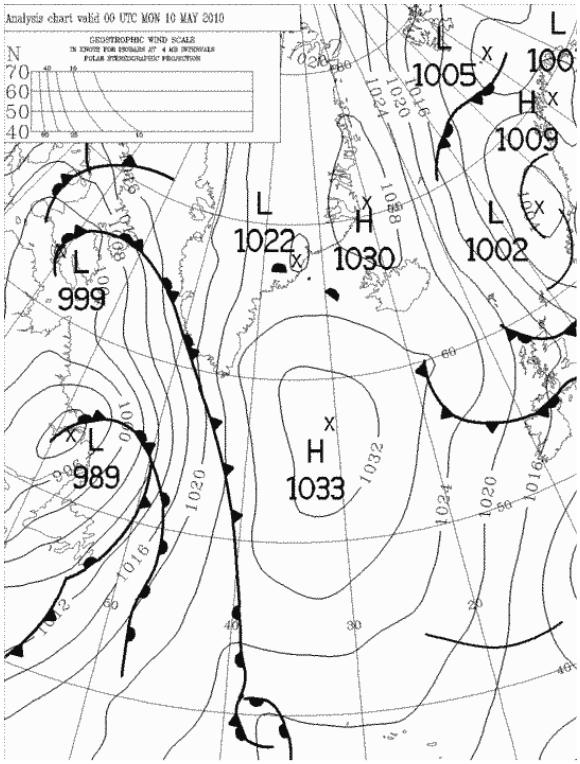

Figure 11. Synoptic weather chart for 10 May 2010.

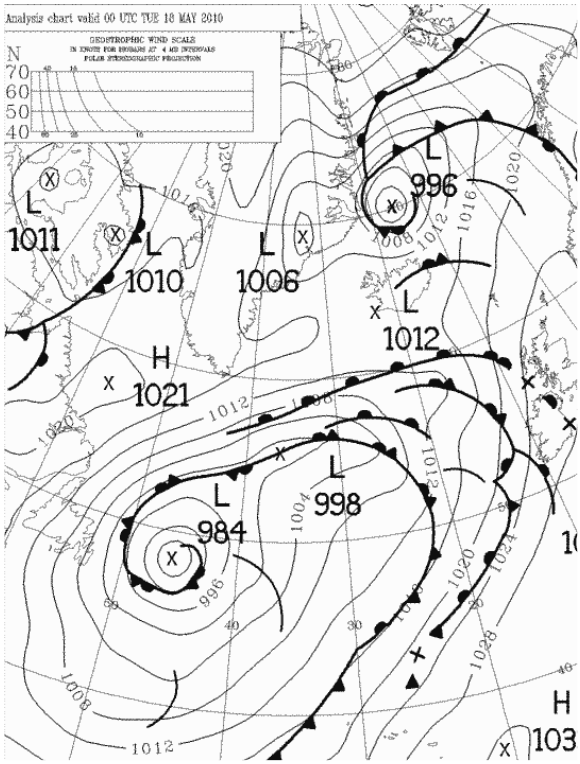

Figure 12. Synoptic weather chart for 18 May 2010.

4.2.2 Arrival times from observations of marked individuals

Too few individually marked Greenland White-fronted Geese were seen in the field to allow analysis (all observations of marked birds are given in Appendix 2). An un-read neck collared individual was seen on 7-9 May, and a pair with neck collars J3F and J5F was first seen on 18 May. Independent data from two white-fronts tagged with satellite transmitters earlier in the winter at Loch Ken, Scotland (by WWT) crossed the Greenland icecap on 8 May and one marked at Wexford, Ireland (by Susan Schaeffer of the Livingston Ripley Waterfowl Conservancy) crossed the ice cap at 22h00 on 8 May arriving at Svartenhuk in west Greenland by 20h00 on 9 May. The arrival date of these three geese fitted with satellite transmitters fits the general arrival pattern shown in Figure 8.

Cumulative counts of all Canada Geese encountered (flying and those recorded on the ground) corresponded well to first sightings of neck collared Canada Geese (Figure 13). This suggests that the arrival of Canada Geese into the study area was staggered and spanned the period from the middle of May until the end of May. Thus, Canada Geese were still arriving into the area up to three weeks after the white-fronts had arrived and up to the time that the first Canada Goose eggs had been laid (median date of first egg 29 May).

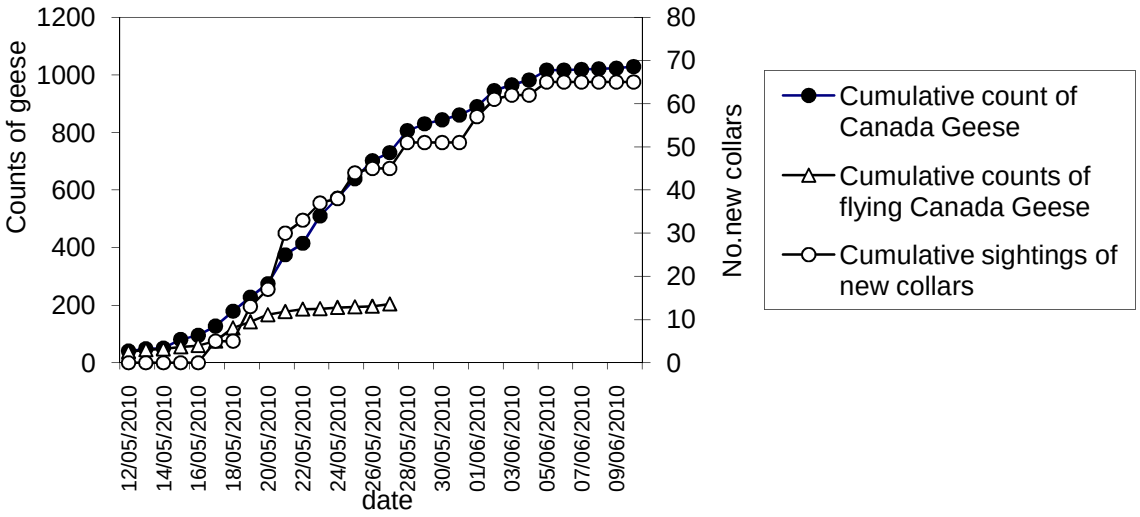

Figure 13. Cumulative counts of Canada Geese (both flying and on the ground) shown together with cumulative sightings of newly observed neck collared individuals. Also shown for reference, is the cumulative counts of Canada Geese seen flying (latter data from Figure 8).

Some of the newly arrived neck-collared Canada Geese that were seen for the first time before 29 May (the median date first eggs were laid) were not seen in the study area after that date. These included early birds that may have moved out of the study area, or birds that had moved to areas that were not checked. For example, nine neck-collared Canada Geese seen for the first time on 21 May, were not seen after 28 May, and further, five birds seen for the first time on 28 May were not seen subsequently (Figure 14). In total, 25 neck-collared Canada Geese, or approximately one-third of the total number of collared individuals seen, arrived before 29 May and were not seen subsequently. This suggests a turnover of Canada Geese in the study area and movements of early arriving birds either outwith the study area or to areas not regularly checked.

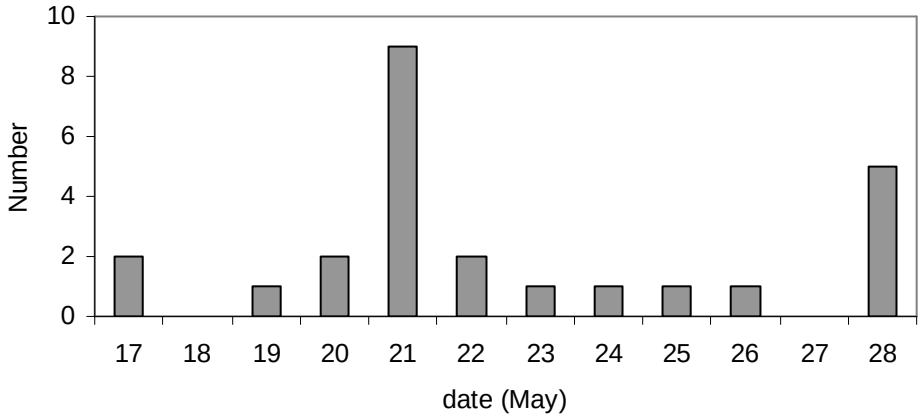

Figure 14. The number of newly arrived neck-collared Canada Geese that were not seen after 28 May (median date first eggs were laid).

4.3 Distribution of Greenland White-fronted Geese and Canada Geese

From 12 May to 11 June Greenland White-fronted Geese and Canada Geese were recorded in the late (main) study area (Figure 15). Circuits were covered in a systematic pattern, leading from base camp to as many different lake areas as possible so that observers covered up to 20 km per day, a distance that was often shorter if geese were encountered *en route* in a situation useful for observation. The broad circuits established were surveyed approximately every five days and most areas were covered two or three times during the fieldwork with some areas closer to camp being visited more than 20 times from 16 May to 11 June as summarised in the survey effort map (Appendix 3, Figure 33).

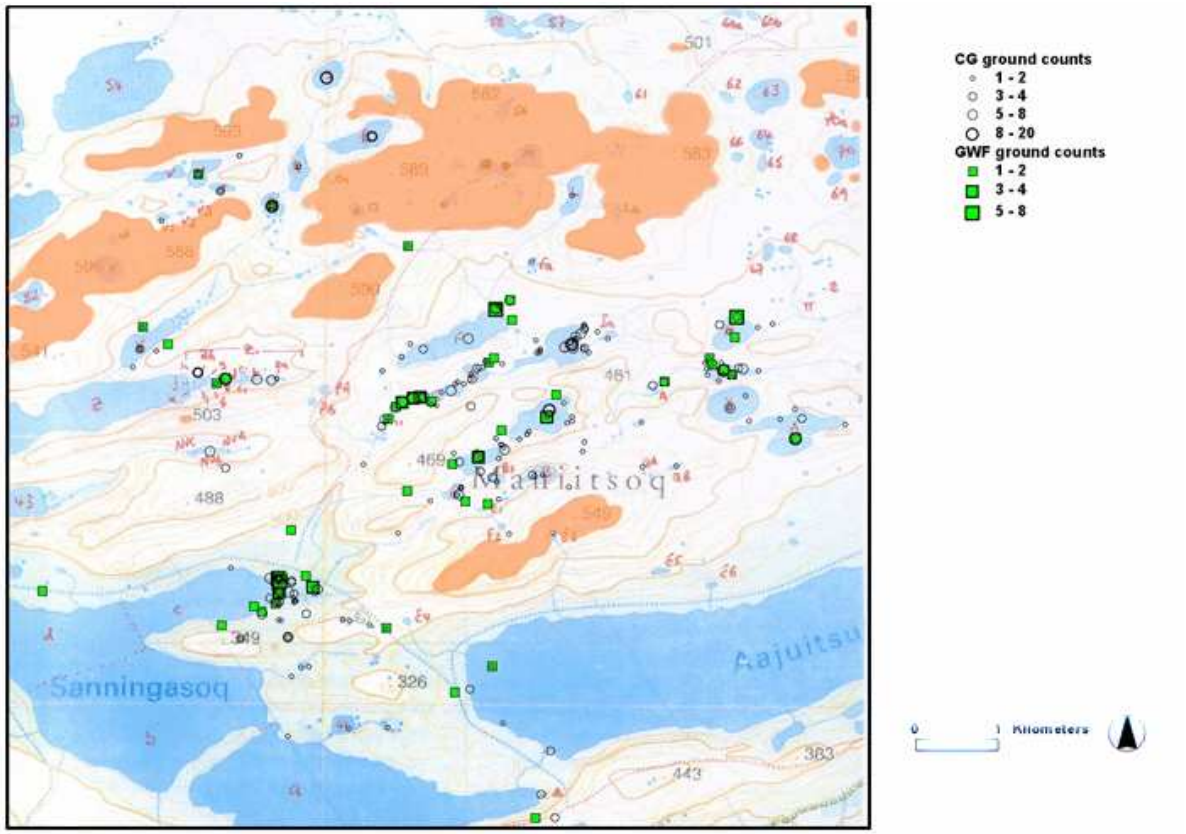

Figure 15. Distribution of all sightings of Greenland White-fronted Geese and Canada Geese in Isunngua, mid May to early June, 2010. Land over 500 m asl shaded orange.

The spatial distribution of geese (Figure 15) suggests that pairs of Greenland White-fronted Geese tended not to use the feeding areas used by Canada Geese. Single white-fronts or larger aggregations showed a greater tendency to overlap with the areas used by larger aggregations of Canada Geese. The nearest neighbour distances between all white-fronts and Canada Geese during a single day were calculated using the Haversine formula (the shortest distance between two points "as the crow flies" over the Earth's surface), with white-fronts classified as singletons, pairs or groups. There was a significant difference between the mean nearest neighbour distances of pairs versus singletons (t_{59} = -2.24, P = 0.014), pairs versus groups (t_{55} = 2.43, P = 0.009) but singletons versus groups was not significantly different (t_{38} = 0.99, P = 0.160; Figure 16).

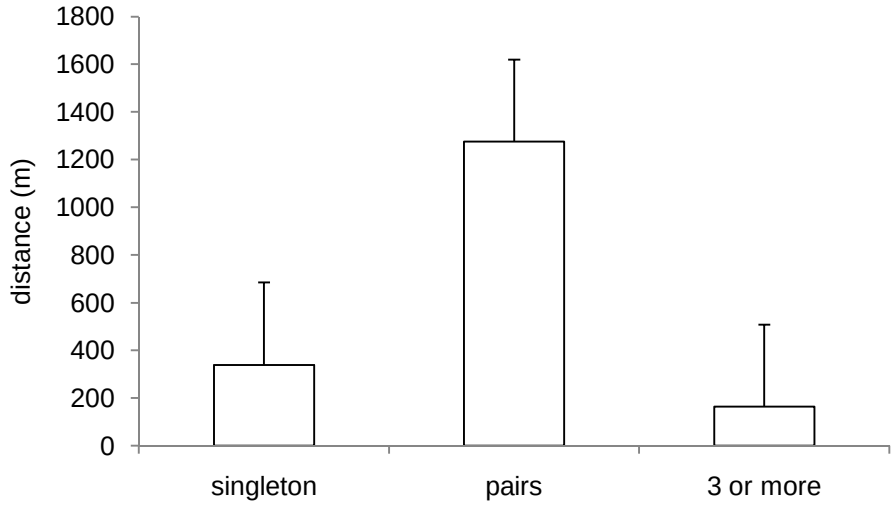

Figure 16. Mean nearest neighbour distances (with SEs) between single Greenland white-fronts, pairs and flocks of three or more birds from the nearest Canada Geese.

The median nearest neighbour distances between Canada Goose nests was 250 m (range 100-2,030 m), although the frequency distribution was heavily skewed towards smaller distances (Figure 17). Due to the skewed nature of the frequencies, the median figure of 250 m was halved to give an indication of what might represent a typical radius of a defended Canada Goose territory. A buffer of this radius is shown in Figure 18 together with the locations of observed white-fronts recorded during the main pre and post egg laying periods. It can be seen that Greenland White-fronted Goose pairs and small flocks tended to overlap very little with the positions of active Canada Goose nests (note that the northernmost Canada Goose nest shown at base camp was abandoned prior to egg laying).

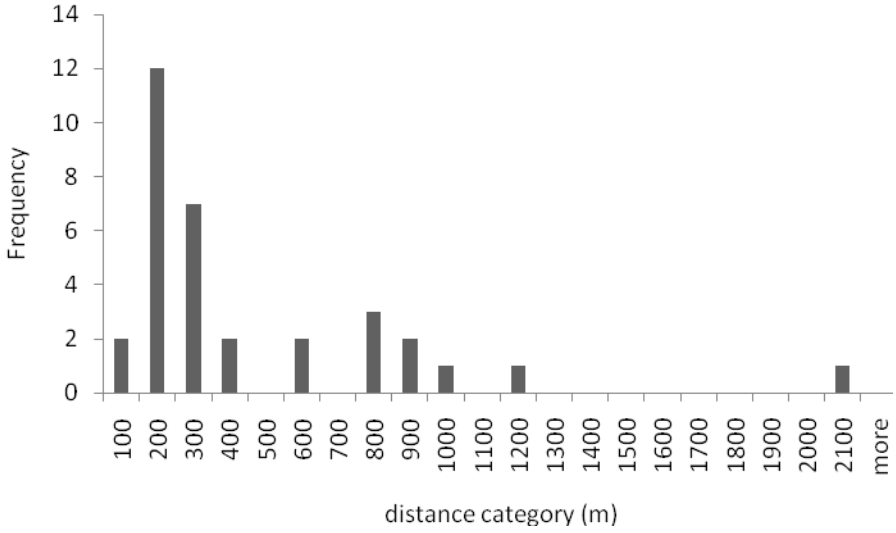

Figure 17. Frequency of nearest neighbour distances between Canada Goose nests in Isunngua, west Greenland in spring 2010.

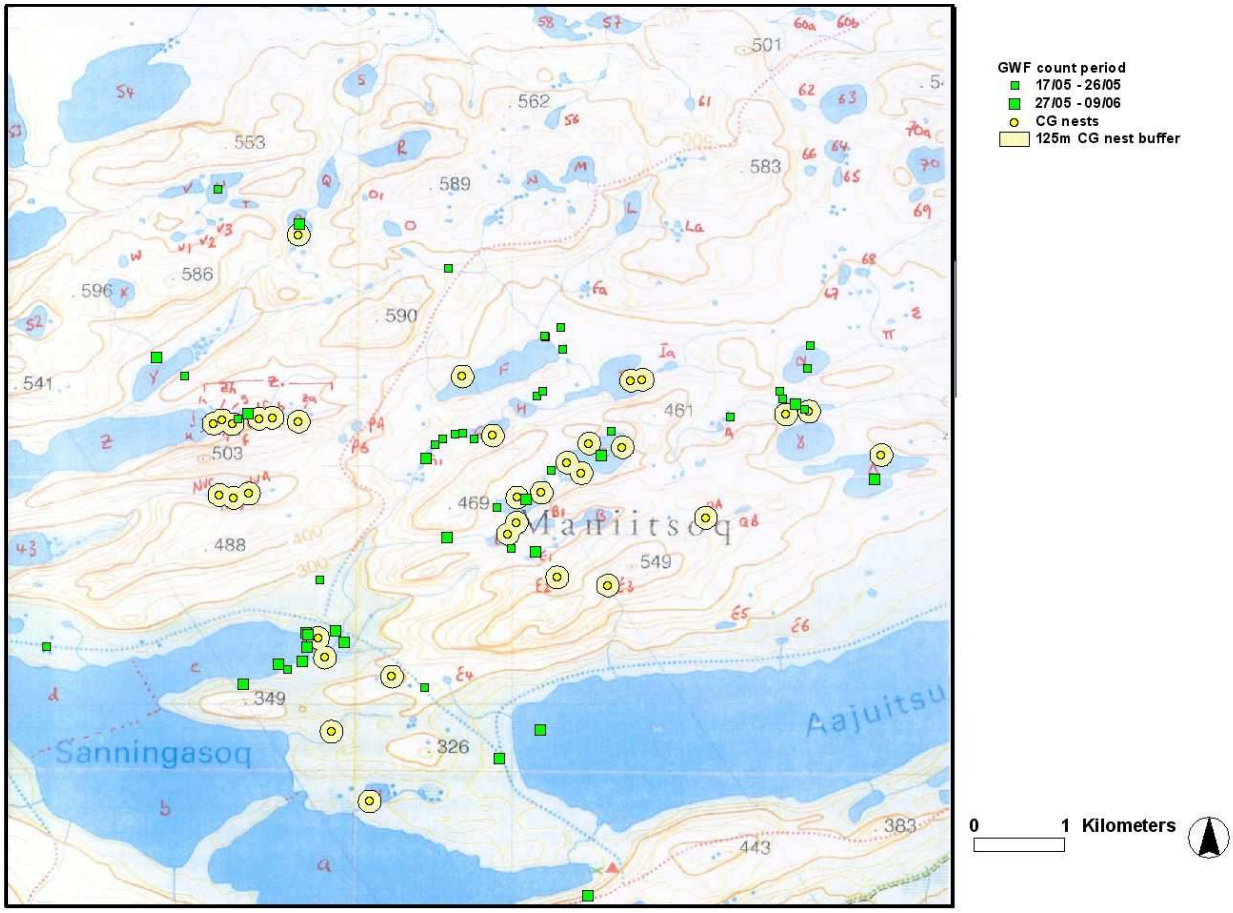

Figure 18. Location of Canada Goose nests (small yellow circle) together with a 125 m buffer around each active nest (larger yellow circle) and sightings of Greenland White-fronted Geese, Isunngua, west Greenland, spring 2010.

4.4 Behaviour of Greenland White-fronted Geese and Canada Geese

4.4.1. Activity budgets of Greenland White-fronted Geese encountered alone (allopatric)

A total of 9.5 hours of activity budgets of Greenland White-fronted Geese was undertaken during 6-9 May. At this time, no Canada Geese were present so no records of interaction between the two species were possible.

Male Greenland White-fronted Geese spent the majority of time feeding (0.446) and alert (0.349), whilst females spend the majority of time feeding (0.683) and engaged in comfort movements (0.166; Figure 19, Table 3).

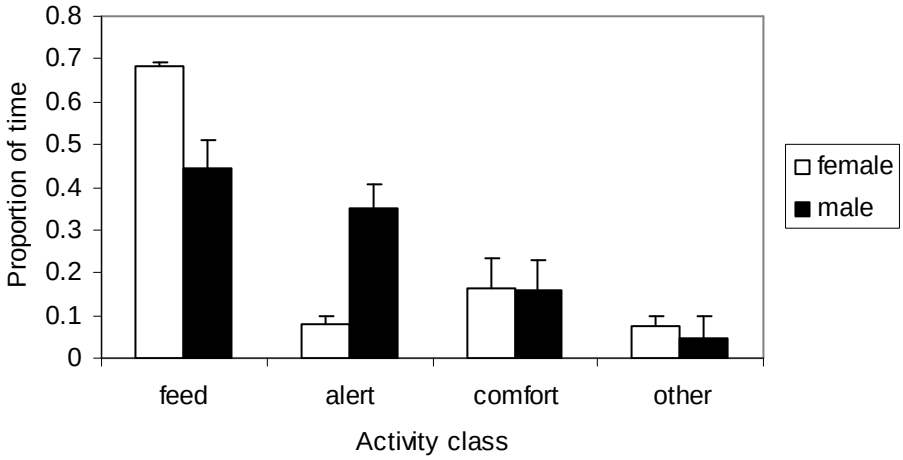

Figure 19. Activities of Greenland White-fronted Geese encountered alone during 6-9 May, 2010. SE shown.

Table 3. Activities of Greenland White-fronted Geese during 6-9 May and 17 May to 8 June, 2010.

	Early period (6 May to 9 May)		Late period (17 May to 8 June)	
	Proportion of time (SE)		Proportion of time (SE)	
	Male	Female	Male	Female
Feed	0.446 (0.051)	0.683 (0.055)	0.301 (0.063)	0.445 (0.075)
Alert	0.349 (0.040)	0.079 (0.027)	0.285 (0.060)	0.111 (0.026)
Comfort	0.159 (0.019)	0.166 (0.032)	0.259 (0.007)	0.357 (0.075)
Other	0.049 (0.017)	0.077 (0.019)	0.148 (0.005)	0.090 (0.023)

Observations carried out during the day (10h00 until 19h00) suggest that female Greenland White-fronted Geese consistently fed for more of the time than males (Figure 20). Conversely, males consistently spent more time being alert (Figure 21).

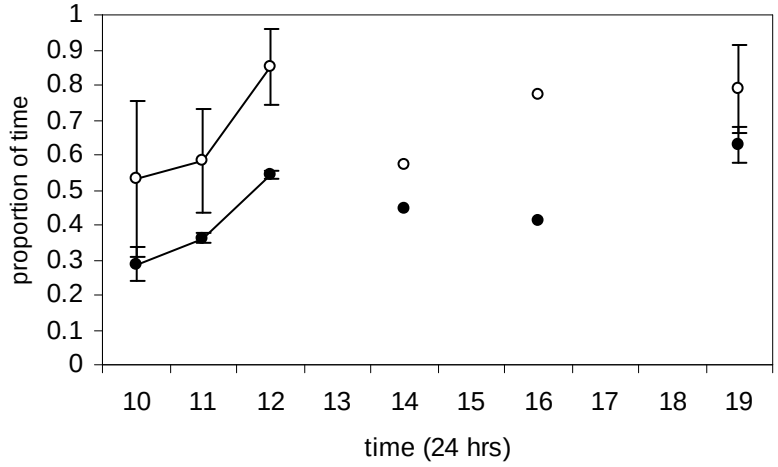

Figure 20. Mean hourly proportion of time Greenland White-fronted Geese spent feeding (± SEs) during activity budget assessments 6-9 May, 2010 (● male, ○ female).

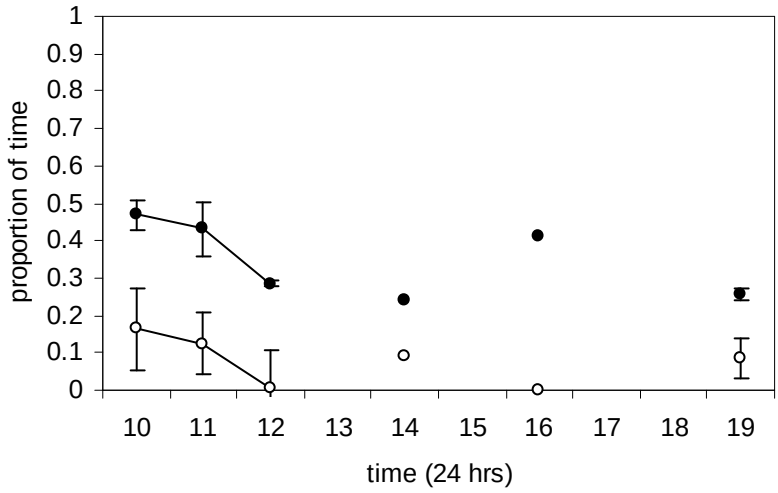

Figure 21. Mean hourly proportion of time Greenland White-fronted Geese spent alert (± SEs) during activity budget assessments 6-9 May, 2010 (● male, ○ female).

There were too few records of activity groups 'comfort' and 'other' to merit producing graphs for the 24 hour period.

A total of 22.5 hours of activity budgets of Greenland White-fronted Geese recorded on their own was undertaken during 17 May to 8 June. Activity budgets of white-fronts observed with Canada Geese were recorded separately and the results are presented in section 4.6.2.

Male Greenland White-fronted Geese spent the majority of time feeding (0.301), alert (0.285) and resting/engaged in comfort movements (0.259), whilst females spent the majority of time feeding (0.445) and resting/engaged in comfort movements (0.357; Figure 22, Table 3).

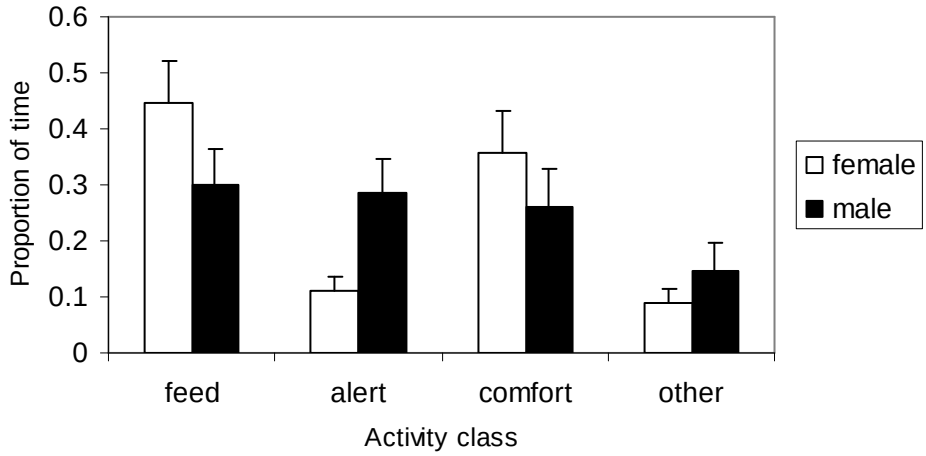

Figure 22. Mean hourly proportions of time spent in major activities (± SEs) of Greenland White-fronted Geese encountered alone during 17 May to 8 June, 2010.

Observations carried out during the 24 hour period (00h01 until 24h00) suggest that female white-fronts consistently fed for more time than males (Figure 23) notably so during the periods 05h00 to 07h00, 16h00 and 21h00 to 23h00. Conversely, males consistently spent more time alert (Figure 24).

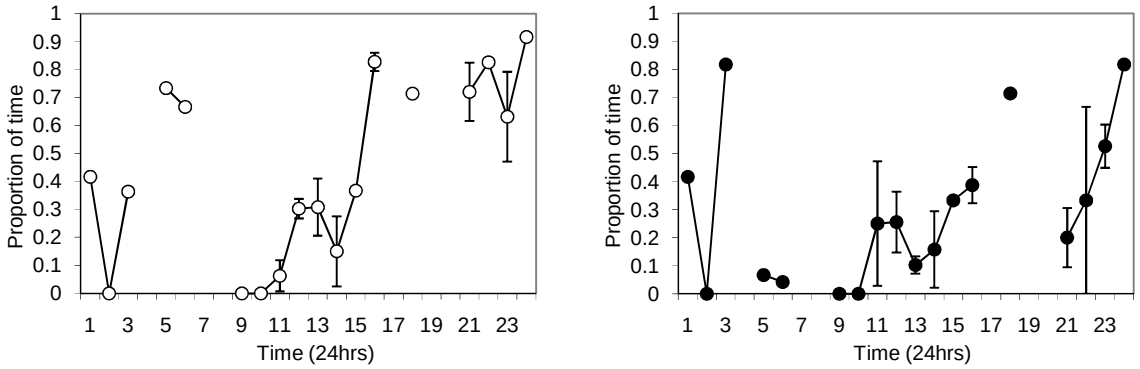

Figure 23. Mean hourly proportion of time Greenland White-fronted Geese spent feeding (± SEs) during activity budget assessments 17 May to 8 June 2010 (○ female, ● male).

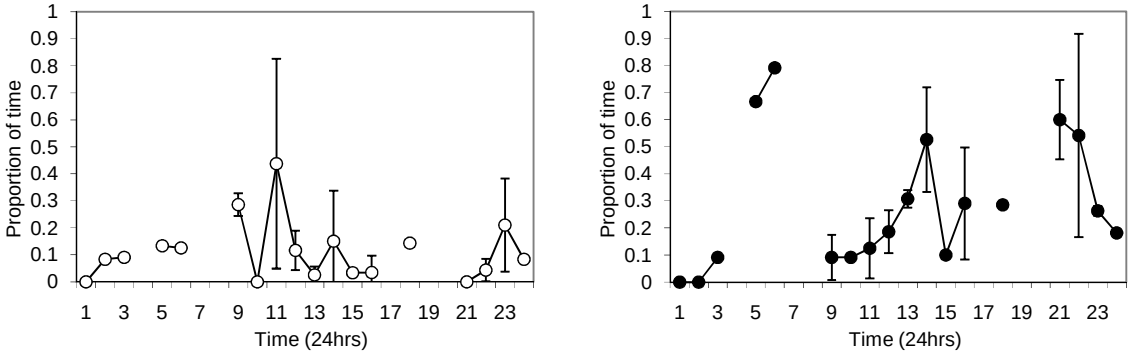

Figure 24. Mean hourly proportion of time Greenland White-fronted Geese spent alert (± SEs) during activity budget assessments 17 May to 8 June 2010 (○ female, ● male).

Both male and female white-fronts engaged in more comfort movements in late May to early June than during the early observation periods, females especially so during the middle of the day (Figure 25).

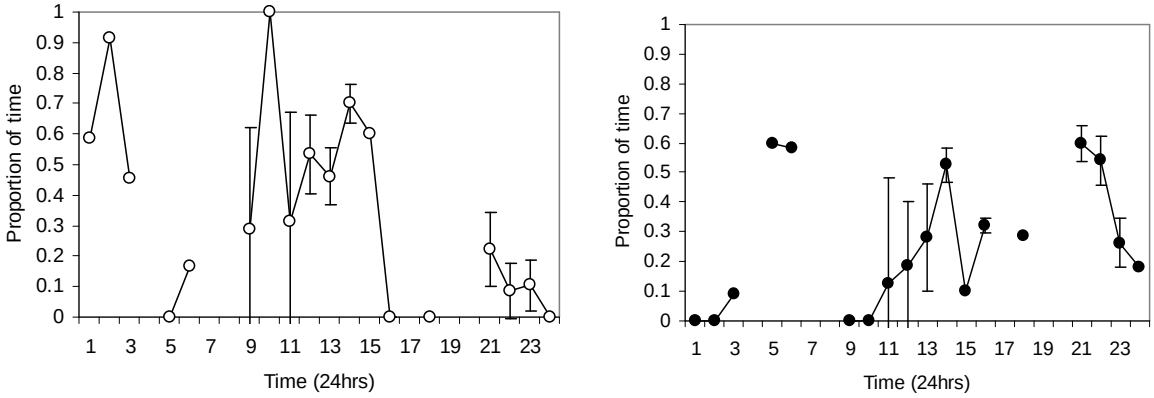

Figure 25. Mean hourly proportion of time Greenland White-fronted Geese spent resting or engaged (± SEs) in comfort movements during activity budget assessments 17 May to 8 June 2010 (○ female, ● male).

4.4.2. Activity budgets of Greenland White-fronted Geese encountered with Canada Geese (sympatric).

A total of 7 hours and 10 minutes of activity budgets of Greenland White-fronted Geese recorded in association with Canada Geese was undertaken from 23-25 May. Observations were carried out between 11h00 and 17h59. Canada Geese spent the majority of time resting/undertaking comfort movements (0.422) and feeding (0.346), and Greenland White-fronted Geese spent the majority of time undertaking the same activities (0.525 and 0.250 respectively; Table 4).

Table 4. Activities of Greenland White-fronted and Canada Geese during 23-25 May, 2010.

	Mean proportion of time (SE)	
	Canada Geese	Greenland White-fronted Goose
Feed	0.346 (0.102)	0.250 (0.091)
Alert	0.091 (0.017)	0.007 (0.004)
Comfort	0.422 (0.136)	0.525 (0.137)
Other	0.138 (0.038)	0.217 (0.095)

Although it is difficult to make comparisons between different sets of activity budgets, both male and female Greenland White-fronted Geese feeding alone (section 4.6.1) spent a greater proportion of time alert (0.285 and 0.111, respectively) than when in the company of Canada Geese (0.004).

During the observation period 11h00 to 17h59, both Canada Geese and Greenland White-fronted Geese fed more during the early afternoon than later, when they switched to resting/undertaking comfort movements (Figures 26-27).

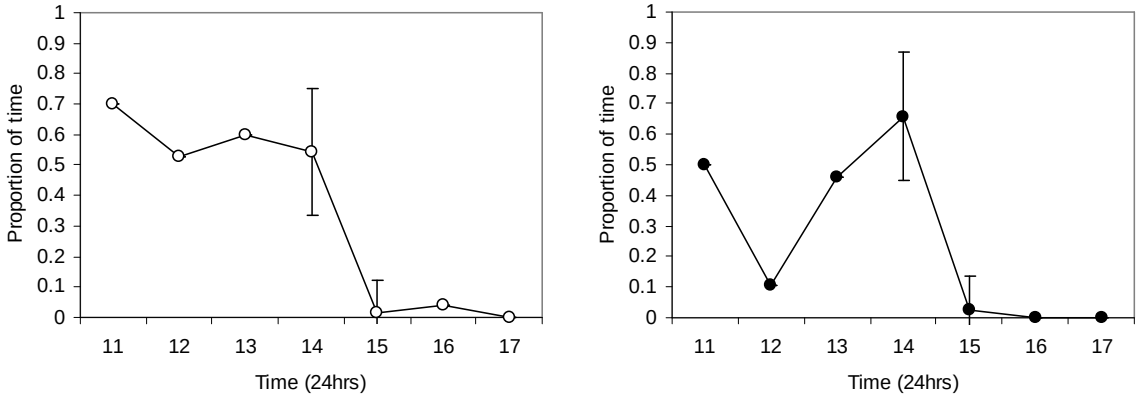

Figure 26. Mean hourly proportion of time Canada Geese (○) and Greenland White-fronted Geese (●) spent feeding (± SEs) during activity budget assessments 23 to 25 June 2010.

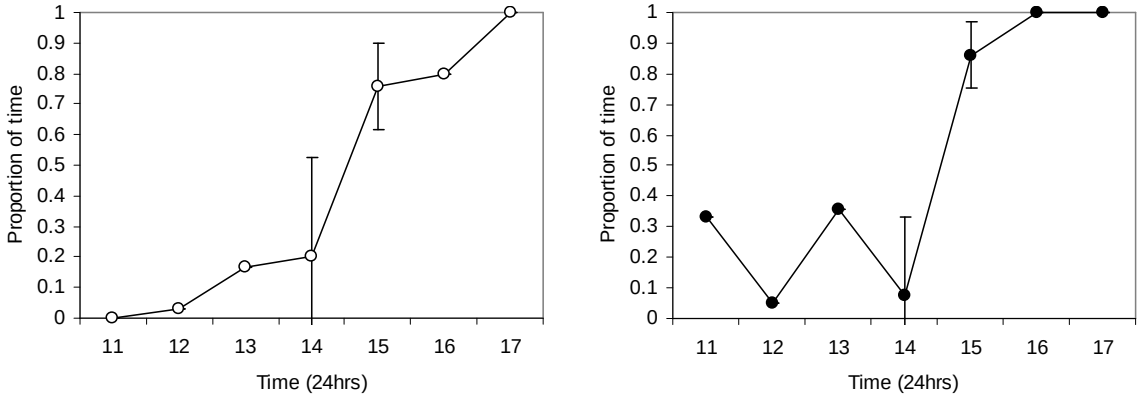

Figure 27. Mean hourly proportion of time Canada Geese (○) and Greenland White-fronted Geese (●) spent resting or engaged (± SEs) in comfort movements during activity budget assessments 23 to 25 June 2010.

Photo 4. Second summer Greenland White-fronted Goose (left) feeding in close association with a pair of Canada Geese (male shown to right; C. Mitchell).

4.4.3. Anecdotal observations of interactions between Greenland White-fronted Geese and Canada Geese

Greenland White-fronted Geese and Canada Geese were observed feeding together for activity budget analysis for just over 7 hours. In addition, geese were watched for an additional total of approx 18 hours outwith the activity budget periods. In over 25 hours of concentrated observation, eight observations of aggressive interaction were noted (Table 5. See Appendix 4 for detailed breakdown of all recorded interactions).

Table 5. Summary of aggressive interactions between Greenland White-fronted Geese (GWFG) and Canada Geese (CG) in Isunngua in May/June 2010.

Observer	Date	Time	Description	Assessment
LG	21/05/10	14h00	Pair of CG flew in, one had a collar (unread), landed 10 m downslope of GWFG, this pair moved upslope and as approached GWFG, collared bird head stretched towards GWFG which moved away c.5 m and CGs passed upslope to feed.	Mild aggression from Canada Goose
LG	23/05/10	11h30	Detailed observations from 11h30 on this initially sympatric group. 11h33 two CG leave. 12h15 observation position moved uphill from where another unmarked GWF could be seen and more uncollared CGs, now 13 in total. At 12h54 single CG flew off heading east. At point of greatest sympatry, GWFG feeding among CG for 5 mins with CG passing by within 1 m without conflict. 5 mins later CG seen to make head lunge at a GWFG 1 m in front of it which quickened step out of the way. Dark nail and lack of belly bars evident on one GWFG, other bird is full adult. By 14h00 birds on centre of marsh with LRG c.200 from them and 30 m above them. In 3 hours birds moved over an area of approx 150*50 m. Time of greatest “allopatricness” was when GWFGs on one side of marsh and CGs on other with the groups c.70 m apart.	Mild aggression from Canada Goose
HT	30 May	21h56	Canada Goose went close to GWFG and honked; GWFG came up out of a dip, resumed feeding out in the open; Canada Goose continues to walk towards the GWFG mostly with head up high but occasionally dipped down; now about 3 m apart.	Mild aggression from Canada Goose
HT	30 May	22h16	Canada Goose appeared to show some irritation towards the GWFG – it honked and thrust its head towards the GWFG which rapidly moved away a few paces before resuming feeding. Canada Goose walks towards the GWFG until they are again about 2 m apart.	Aggression from Canada Goose
MW	29 May	04h20	Canada Geese honking nearby (two birds). All five GWFG immediately hop in water and alert, swim away from the calling. One GWFG from the east pair nips at middle, loner GWFG.	Possible displacement by Canada Geese
MW	1-2 June	24h00	One Canada Goose starts chasing one of the pairs of GWFG. GWFG waddle out of the way of Canada	Aggression from

			Geese, but Canada Geese continues to go after them, honking. After 2 min the GWFG take off and land on a wetland further south of base camp (BC; east shore of Sanningasoq).	Canada Goose
MW	3 June	11h35	Two Canada Geese, both collared, swim onto shore where the GWFG are feeding. Canada Geese honking and pushing the GWFG 15 m further along shore. Canada Geese took over feeding patch. Another Canada Goose swam towards the two collared birds, and was nipped at by a collared bird. Collared Canada Geese move away, GWFG back to feeding.	Aggression from Canada Goose
MW	3 June	11h55	Both GWFG near each other and feeding the entire time. Lone Canada Goose came close and one GWFG lowered its head and showed aggression towards the Canada Goose. Canada Goose drifted away, and all three back to feeding.	Aggression to Canada Goose

In seven cases, Canada Geese initiated aggression towards the white-fronts which reacted by moving away (displacement). In none of these cases did the white-fronts react aggressively back towards the Canada Geese. However, on one occasion, a white-front initiated aggression towards a Canada Goose.

4.5 Disturbance

Throughout the duration of fieldwork, the team did not see a single human in the study area, so there was no opportunity to measure the frequency of disturbance, nor the effects of unsolicited human activities on the geese.

During the earliest phases of the fieldwork, fieldworkers were very keen to avoid disturbance at all costs, especially to Greenland White-fronted Geese which may have been nesting. For this reason, no systematic attempt was made to scare or cause any disturbance to either species early on. Later on, it became possible to monitor responses to disturbance, and in the course of regular fieldwork, data were compiled on goose reactions to pedestrian activity. Small sample sizes and high variance preclude detailed interpretations, but generally although both species appeared to detect disturbance by adopting head-up responses at similar distances (mean just over 169 m for white-fronts and 160 m for Canada Geese), white-fronts tended to show movement responses (walking and ultimately flying) at slightly greater distances (Figure 28).

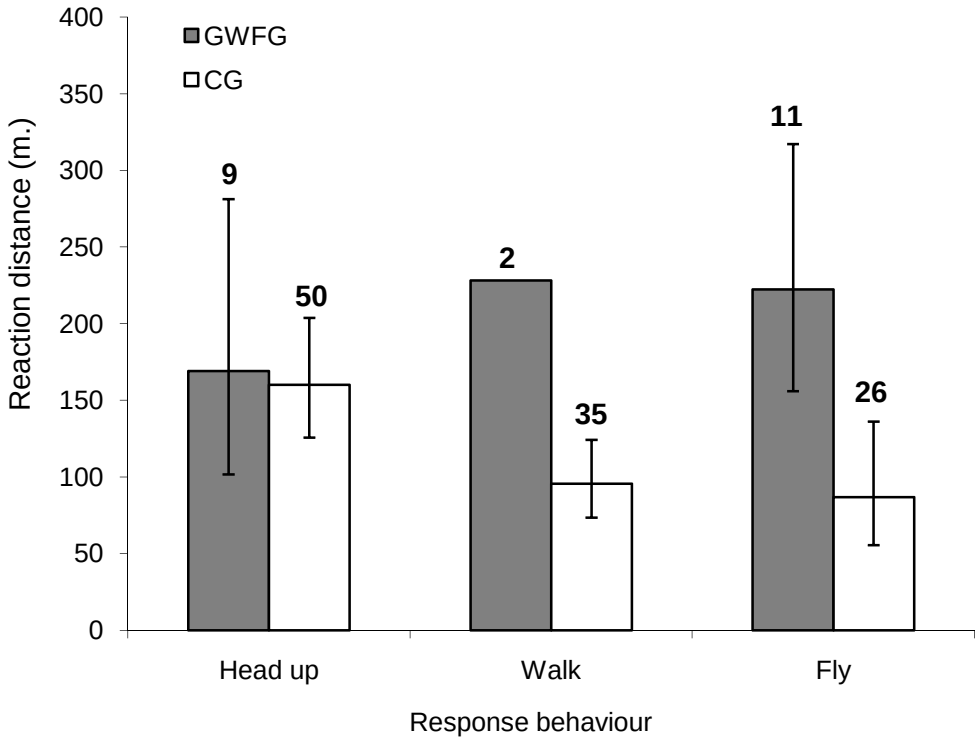

Figure 28. Mean reaction distances (± SEs) according to response behaviours of Greenland White-fronted and Canada Geese to disturbance. Sample sizes given above the bars. .

Anecodotal observations also suggest that white-fronts were more 'jumpy' and prone to flight more often than Canada Geese.

4.6 Nest site characteristics of Canada Geese

A total of 34 Canada Goose nests was found in the study area between 16 May and 11 June, including one from a previous year. Twenty eight nests contained eggs. The mean initiation date was 27 May (range 23 May – 1 June, n = 9) and mean clutch size was 4.57 (range 3-6, n = 21) for nests with known final clutch sizes. Too few nests of known age were found to enable an analysis of the relationship between clutch initiation date, clutch size and hatching success.

Nests were located from 233 to 490 m above sea level (median 360 m, n = 32). All nests were situated on lake shores or islands, averaging 1.84 m from water (median 1 m, range 0.3-10 m, n = 32) and 0.81 m above water level (median 0.5 m, range 0.1-2 m, n = 32). The size of lakes that were nearest to the nests varied greatly averaging 8.5 ha (median 3.3 ha, range 0.09-34.6 ha, n = 33). Most nests (57%, n=29) were constructed from grass/moss vegetation, the remainder were in *Betula* scrub or grass. Nests averaged 420 m from each other (median 250 m, range 100-2,030 m).

A summary of the findings is presented in Appendix 5.

Photo 5. Canada Goose (neck collar GA9) incubating a clutch of four eggs on the shore of Lake C (C.Mitchell)

5 Discussion

5.1 Arrival times and duration of feeding of pre nesting Greenland White-fronted Geese and Canada Geese

Although the earliest Greenland White-fronted Geese were seen on 1 May, the main arrival occurred around 5-6 May. This was very similar to the arrival periods witnessed in Eqalummiut Nunaat in 1979 (main arrival from 7 May onwards) and 1984 (8 May, although main arrival from 20 May). Unfortunately, no Greenland White-fronted Goose nests were found in Isunngua in 2010, but assuming a similar delay between main arrival and mean first egg dates based on 1979 observations (when conditions were relatively mild and snow free as in 2010), it seems reasonable to infer that this would have been around 22 May, i.e., 15 days after the main arrival. Three white-fronts fitted with satellite transmitters at Loch Ken in February 2008 arrived in west Greenland on 3-4 May 2008 (WWT data).

Canada Geese arrived conspicuously later to west Greenland than Greenland White-fronted Geese, with a first major arrival on 12 May, supplemented by a second major arrival on 19-20 May. Over thirty Canada Goose nests were found, and of the nine where the first egg date was known precisely, the mean date of clutch initiation was 27 May (median 29 May), i.e., 17 days after the first major arrival.

The first Canada Geese therefore arrived three days after the bulk of Greenland White-fronted Geese and large numbers of Canada Geese arrived almost three weeks after the very first white-fronts. This suggests that, in 2010, the fittest, earliest white-front pairs to arrive in west Greenland could potentially have had approximately 11 days in which to recoup depleted nutrient and energy stores without the presence of Canada Geese.

Although it is clear that later-arriving white-fronts would encounter substantial numbers of Canada Geese after 12 May, it would seem that the earliest arriving pairs attempting to breed are not exposed to the same level of potential competition from Canada Geese as those arriving later. Given that approximately half of the white-fronts arrived by 5 May and half of the Canada Geese by 18 May, there was an approximate 13 day gap in the arrival of the two species, which gives the white-fronts more of an opportunity to build up stores for investment in reproduction in the absence of potential competition than if both species arrived in west Greenland at the same time.

However, conditions can vary dramatically between years, and whilst 2010 was an early thawing year, conditions in early May can be very different in years with later initiation of spring (e.g. Fox & Stroud 1988). In such years, not only is physical access to feeding areas restricted by snow, but favoured underground plant parts are inaccessible within frozen substrates. Under such conditions in 1984, the first arriving birds were seen in Eqalummiut on 6 May did not stay in the area, and significant arrivals and pre-breeding feeding occurred only after 20 May (Fox & Ridgill 1985). Thus, in such years of late thaws, there may be little benefit (in terms of early access to food resources) from early arrival in Greenland given the limited early access to food. And under current conditions, any putative advantage for white-fronts from access to feeding areas prior to the later arrival of Canada Geese could thus be much more limited or non-existent.

Given the recent frequency of late winter heavy precipitation in April and May (Figure 3), such a scenario might result in greater (and more frequent) forced interaction between the two goose species than was observed in 2010.

In spring 2010, weather conditions in Isunngua and many other parts of west Greenland were warmer and drier than have been experienced in recent years. The very low precipitation in March and April before the geese arrived, and the very mild temperatures in

early May when they arrived meant that they experienced snow free conditions and thawed substrates in the lowlands. The geese apparently did not bother to feed along the glacial melt rivers, but shifted immediately to feeding in wetlands and pools which were already thawed and offered abundant food from arrival. All these factors suggest that early arriving geese enjoyed a premium over recent springs, and females likely attained optimal body condition earlier than in many recent years where they met greater snow cover and restricted feeding opportunities. Observations in the autumn and early winter suggest that 2010 was a very good breeding season for Greenland White-fronted Geese with 22.9% young in sample flocks on Islay, the highest since the record season of 1985 and a considerable increase over the below average production figures of many recent seasons. It seems very likely that benign spring conditions coupled with a warm summer in following weeks may have contributed to the high breeding success in that year.

Of course, it is important to be prudent about drawing too many conclusions from a single season, and from a tiny proportion of the total extent of the breeding grounds[2], but these observations fit with those of local people in Kangerlussuaq, who confirm that white-fronts generally arrive in very early May, one to two weeks before Canada Geese. Assuming these patterns are consistent, this suggests that the potential for competition after arrival on the breeding grounds is less than if the Canada Geese arrived at the same time.

From the weather maps, it would appear that although white-fronts were able to start their migration from Iceland at the beginning of May, it is likely that, in spring 2010, Canada Geese were prevented from migrating by up to eight days by an unfavourable weather system in the Labrador Sea. Thus, more observations of arrival times of both white-fronts and Canada Geese in years with different weather patterns would benefit our understanding of any differences.

5.2 Distribution of Greenland White-fronted Geese and Canada Geese

No Canada Geese were encountered during the early phase of the study, so no opportunities for comparing the distribution of that species with Greenland White-fronted Geese at that time arose.

From mid May until mid June, both Greenland White-fronted Geese and Canada Geese favoured land below 500 m with Canada Geese, at least, moving with their families to higher altitude lakes above 500m by July (Appendix 6). Both species favoured wetland areas or lake edges, often in close proximity to open water. However, the distribution of the two species suggested a subtle degree of spatial separation. Single white-fronts, or groups of three or more appeared to feed in the presence of Canada Geese more than pairs. This may have been due to pairs of white-fronts avoiding potential competition from Canada Geese. Sightings of Greenland White-fronted Geese also tended to be greater than 125 m from established Canada Goose nest territories again suggesting a degree of avoidance of territorial males.

5.3 Behaviour of Greenland White-fronted Geese and Canada Geese

Activity budgets confirm that during the period after arrival paired female Greenland White-fronted Geese spend the majority of time feeding, whilst males spend most time either feeding or alert acting as sentinels. This is a similar to previous observations by Fox & Madsen (1981) and Fox & Ridgill (1985). By late May to early June, it is probably too late for observed pairs to initiate successful nests and activity budgets show the amount of time females spent feeding declined.

[2] The central area of Isunngua was estimated to hold c.0.35% of the global Greenland Whitefront population in July 2010 (Stroud 2011).

When feeding with Canada Geese, at the end of May, Greenland White-fronted Geese spent less time alert than when feeding allopatrically. Casual observations (Appendix 4) suggest that, in certain circumstances, white-fronts may benefit from the presence of male Canada Geese acting as sentinels to their own feeding females.

Observations made over 25 hours of Greenland White-fronted and Canada Geese feeding together indicate that aggressive encounters between the two species were unusual. Eight encounters were recorded and in one of these a white-front initiated aggression towards a Canada Goose. In the other seven cases, the white-fronts simply moved a safe distance away from the Canada Geese and carried on feeding. Based on this very small sample of observations, if Canada Geese are competing with white-fronts at this key period in the annual cycle it appears to be relatively modest and subtle.

Nest site characteristics (Appendix 5) suggest that Canada Goose nest sites were without exception within 10 m of open water, and very close to water level and sometimes on very small islands within waterbodies. Greenland White-fronted Geese do not habitually nest close to water (mean 108 m and 70 m from water, n=8 and n=6, in 1979 and 1984 respectively in studies from Eqalummiut Nunaat, Fox & Stroud 1988), often on gently sloping hills or tops of elevations to provide all round visibility (Fencker 1950, Salomonsen 1950), so in this respect, there is little likelihood for direct competition for nest sites between the two species.

Differences in arrival dates of the two species, lack of observations of aggressive interactions and observations of possible advantages to feeding with Canada Geese in terms of vigilance benefits (and possible reduced response to disturbance events), suggest that any negative effects of Canada Geese on white-fronts are modest. However, the increasing number of breeding Canada Geese in Isunngua may have displaced Greenland White-fronted Geese from the area some time ago (within the last five to ten years) and may have occurred through a subtle swamping effect due to increasing numbers of the former rather than direct competition for resources in spring (either food or nest sites)[3]. In addition, records of so few aggressive inter-species encounters in spring 2010 may merely have reflected the few white-fronts encountered. Aggressive competition from Canada Geese may have been more intense in previous years, forcing white-fronts to abandon the area.

Intra-specific aggression amongst Canada Geese was observed on a number of occasions, especially when establishing breeding territories. Such aggression directed towards white-fronts may have happened in the past when more white-fronts were present in the area.

Although we have little evidence of interference competition, there is potential for exploitation competition. Although suitable breeding habitat for both species appears to be abundant in west Greenland, both white-fronts and Canada Geese noticeably concentrated on a few small-scale marshy areas or patches. In many of the pool systems Canada Geese had ripped up and eaten the same *Eriophorum angustifolium* shoots that the white-fronts were grubbing for. Thus, there might be a limited resource *per se*, or resource that has declined over time as Canada Geese exploit it year after year.

[3] In an analysis of numbers recorded in the July moulting period, Stroud (2011) showed that the number of Greenland White-fronted Geese in Isunngua, as a proportion of the global population in the preceding March, had declined from 0.51-0.62% in 1988-1995, to 0.28-0.34% in 2008-2010, suggesting that such a long-term decline may well have occurred.

5.4 Disturbance

No instances of human disturbance, other that the movements of participants involved with this fieldwork, were observed during the entire study period. In this part of west Greenland, as is presumably the case in other remote parts of the country, current human disturbance is negligible.

Both Greenland White-fronted and Canada Geese appear to detect disturbance by adopting head-up responses at similar distances (mean of 169 m for white-fronts and 160 m for Canada Geese), with white-fronts tending to show movement responses (walking and ultimately flying) at slightly greater distances. This concurs with experiences of both species during the non-breeding season with white-fronts being more prone to disturbance than Canada Geese.

5.5 Summary conclusions from the results of the fieldwork

There are many possible explanations for the poor breeding success of Greenland White-fronted Geese during 1996-2008, but there remain two major front-runners amongst the contending hypotheses, namely weather and competition with the increasing numbers of Canada Geese in west Greenland. It is impossible to establish anything more than correlations between breeding success and reproductive output, but these relationships suggest that heavy snowfall in April and May in west Greenland may have contributed to the poor breeding success of the population in those recent years. Likewise, it is impossible, without removal of Canada Geese to demonstrate that some form of inter-specific competition, caused by the arrival of this species in ever increasing numbers in west Greenland has resulted in reduced reproductive output of the White-fronted Geese that nest there.

The results of the studies presented here suggest that at least in the spring of 2010, Greenland White-fronted Geese arrived to snow free and relatively mild conditions, which meant abundant accessible food was available from their arrival. The first arrivals (which we infer were likely the most fit pairs in best body condition preparing to breed) had one to two weeks of pre-nesting feeding before the arrival of Canada Geese to potentially affect acquisition of locally derived nutrient and energy from local foraging to invest in clutches and incubation. This does not imply that there is no competition, nor that competition may not be widespread in seasons when snow melt is delayed, and Greenland White-fronted Geese may struggle to accumulate stores for investment in reproduction before the arrival of the Canada Geese (assuming the timing of migration of the two species differs little between years). The two species are now known to nest in very different habitats, so there is little likelihood of inter-specific competition for nest sites. Unfortunately, the Isunngua study area proved to hold very few summering Greenland White-fronted Geese, so although there were abundant indications that both species fed together and showed very low levels of inter-specific aggression, it was difficult to conclude very much about the interactions between the two species, and we still have no idea of how the two species might interact at the brood rearing stage.

Nevertheless, it was striking that, after 14 years of below average breeding success, the proportions of young amongst the flocks sampled on Islay in winter 2010/11 were amongst the four highest since records began (in 1962), and the highest since the record year of 1985. This relates well to the snow free and mild spring in west Greenland and the warm summer temperatures generally in 2010 which would be expected to combine to support unusually good conditions for breeding, supporting the weather hypothesis. Equally, there is no doubt that the numbers of Canada Geese in Isunngua were as high as very recent years and much higher than in the late 1980s (Stroud 2011). There was no reason to suspect that this was not the case throughout the entire west Greenland range of the White-fronted

Goose (where the two species occur together), which strongly suggests that competition was not the sole cause of low reproductive success in previous years, unless White-fronted Geese have been able to adapt in some way latterly to their presence (which does not seem to be the case in Isunngua where the proportion of the total White-fronted Goose population that occurs there has fallen since the Canada Geese arrived, Stroud 2011). We also suspect, but cannot prove, that the disproportionate harvest of family groups during the autumn hunt in Iceland selectively removed juveniles, but also the fecund parent birds, a factor that could have become critical as the population started to decline after 1999. Hence, we cannot dismiss the hypothesis that the cessation of hunting in Iceland in 2006 also contributed to the recent improvements in breeding success, as more parents survived to breed and more goslings survived to recruit into breeding age classes in subsequent years. Furthermore, we still cannot fully reject other hypotheses such as predation or disease which could also have played a part in suppressing reproductive output, but for which we have no direct evidence.

One thing is plain, the generally low proportion of potentially breeding mature adult Greenland White-fronted Geese that successfully return to their wintering quarters with young remains unusually low compared to almost all populations of northern nesting geese. Given that the legal restriction of hunting mortality has removed all the possible sources of human induced mortality throughout the annual cycle of this population, the Greenland White-fronted Goose remains vulnerable and it population size largely regulated by its relatively low reproductive success. This makes it unusual in the Western Palearctic and at present, contributes to its status as one of the few goose populations there not subject to relatively rapid increase. We need to know whether this is the result of female geese attempting to breed and failing (because of poor body condition, predation at egg or brood stage) or if it is because for some reason female geese fail to attain necessary condition to attempt to nest. We need to differentiate between these causes of low reproductive output if we are to be able to offer management recommendations about how to overcome this problem, since even if Greenland White-fronted Geese can enjoy bumper breeding success in mild seasons (even in the face of competition from Canada Geese) the population remains vulnerable to its low reproductive potential to replace natural annual losses.

6 Recommendations

The study in spring 2010 provided useful logistical and observation experiences to guide future fieldwork opportunities in west Greenland.

For any follow up fieldwork exploring the interaction between Greenland White-fronted and Canada Geese, the following recommendations are made:

- Based on the small number of encounters with Greenland White-fronted Geese future fieldwork should be carried out in an area that holds substantially more white-fronts. Despite the proximity to Kangerlussuaq airport and the time and cost benefits that proximity brings, identifying an area where more white-fronts are breeding is essential for future studies.

- The timing of arrivals of Greenland White-fronted and Canada Geese in spring 2010 may have been affected by weather patterns (notably wind speed and direction) further south. Further visits to west Greenland covering the arrival stage are needed to examine this in more detail, and with Canada Geese there may be opportunities to monitor arrival times via remote methods such as GPS satellite tags or data loggers.

- The ground that could be covered from the base camp used in the study was limited by the large lakes to the west and south that were essentially non-breeding habitat for geese. For a species that nests at low density a larger study area needs to be covered either from a central place or via a roving base camp.

- The most important conclusion from this work is that although Canada Geese may affect reproductive success in Greenland White-fronted Geese, a mild snow-free spring and warm summer in 2010 produced exceptional numbers of goslings despite Canada Goose presence. This confirms that now hunting has been stopped throughout the flyway, the population is largely regulated by reproductive output. We recommend that considerable effort by put into discovering why so few sexually mature geese return successfully to the winter quarters with young. We propose that this be made a major thrust of the forthcoming PhD study to be undertaken by Exeter University and WWT using remote telemetry to track females in a manner that does not affect their reproductive success. Trials are already underway to test such technology. Given the experiences of 2010, it is clear that it is difficult to gather sufficient sample sizes of nesting attempts of Greenland White-fronted Goose pairs by observation in the field and for this reason, the deployment of many remote devices on many individuals to track their precise position and behaviour will be a more effective approach to answering this question.

7 Acknowledgements

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8 References

Altmann, J. (1974). Observational study of behaviour: sampling methods. *Behaviour* 49: 227-267.

Anon**.** Conclusions of the second international workshop on Greenland White-fronted Geese. Islay, 24-26 February 2009. 6 pp.

Boertmann, D. (2007). *Rødliste 2007 over planter og dyr i Grønland.* [*2007 Red List of plants and animals in Greenland*]. Direktoratet for Miljø og Natur, Grønlands Hjemmestyre.

Boyd, H. & Fox, A.D. (2008). Effects of climate change on the breeding success of White-fronted Geese *Anser albifrons flavirostris* in west Greenland. *Wildfowl* 58: 55-70.

Eaton M.A., Brown A.F., Noble D.G., Musgrove A.J., Hearn R., Aebischer N.J., Gibbons D.W., Evans A. & Gregory R.D. (2009). Birds of Conservation Concern 3: the population status of birds in the United Kingdom, Channel Islands and the Isle of Man. *British Birds* 102: 296-341.

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

Fox, A.D. & Madsen, J. (1981). The pre-nesting behaviour of the Greenland White-fronted Goose. *Wildfowl* 32: 48-54.

Fox, A.D. & Ridgill, S.C. (1985). Spring activity patterns of migrating Greenland White-fronted Geese in West Greenland. *Wildfowl* 36: 21-28.

Fox, A.D. & Glahder, C.M. (2010). Post-moult distribution and abundance of white-fronted and Canada geese in West Greenland in 2007. *Polar Research* 29: 413-420.

Fox, A.D., Glahder, C., Mitchell, C., Stroud, D.A., Boyd, H. & Frikke J. (1996). North American Canada Geese (*Branta canadensis*) in West Greenland. *Auk* 113: 231-233.

Fox, A.D., Glahder, C.M. & Walsh, A.J. (2003) Spring migration routes and timing of Greenland white-fronted geese - results from satellite telemetry. *Oikos* 103: 415-425.

Fox, A.D., Stroud, D.A., Walsh, A.J., Wilson, H.J., Norriss, D. & Francis, I.S. (2006). The rise and fall of the Greenland White-fronted Goose: a case study in international conservation. *British Birds* 99: 242-261.

Fox, A.D. Stroud, D.A., Walsh, A.J., Wilson, H.J., Norriss, D.N. & Francis, I.S. (2009) A review of changes in abundance of the Greenland White-fronted Goose *Anser albifrons flavirostris* since 1982. *Die Vogelwelt.* 129: 317-325.

Fox, A.D., Ebbinge, B.S., Mitchell, C., Heinicke, T., Aarvak, T., Colhoun, K., Clausen, P., Dereliev, S., Faragó, S., Koffijberg, K., Kruckenberg, H., Loonen, M., Madsen, J., Mooij, J., Musil, P., Nilsson, L., Pihl, S. & van der Jeugd, H. (2010). Current estimates of goose population sizes in the western Palearctic, a gap analysis and an assessment of trends. *Ornis Svecica* 20: 115-127.

Gladher, C.M., Fox, A.D. & Walsh, A.J. (1999). Satellite tracking of Greenland White-fronted Geese. *Dansk Ornitologisk Forenings Tidsskrift* 93: 271-276.

Kristiansen J.N. & Jarrett N.S. (2002). Inter-specific competition between Greenland White-fronted Geese *Anser albifrons flavirostris* and Canada Geese *Branta canadensis interior* moulting in West Greenland: Mechanisms and consequences. *Ardea* 90: 1-13.

Salomonsen, F. (1950). *Grønlands Fugle. The Birds of Greenland*. Munksgård, Copenhagen.

Scribner, K.T., Malecki, R.A., Batt, B.D.J., Inman, R.L., Libants, S. & Prince, H. (2003). Identification of Source Population for Greenland Canada Geese: Genetic Assessment of a Recent Colonization. *Condor* 105: 771-782.

Stroud, R.A. (2011). A study of interactions between moulting Canada Geese, *Branta canadensis interior* and Greenland White-fronted Geese, *Anser albifrons flavirostris* at different temporal and spatial scales in Isunngua, West Greenland. BSc. Thesis (submitted). University of Wales, Bangor. 64 pp.

Stroud, D.A., Fox, A.D., Urquhart, C. & Francis, I.S. (2011). International Single Species Action Plan for the Conservation of the Greenland White-fronted Goose *Anser albifrons flavirostris* 2010 – 2020. Third Draft. Accessible at: http://gwfg-conservation.wikispaces.com/Draft%20international%20action%20plan

Appendix 1

Inventory of all non-goose sightings

This section describes the animals (other than geese) noted during the spring fieldwork period (26 April to 11 June) in the Issungua/Kangerlussuaq area.

Birds

Greenland White-fronted Goose *Anser albifrons flavirostris*
See other report sections.

Canada Goose *Branta canadensis interior*
See other report sections.

Mallard *Anas platyrhynchos conboschas*
Birds were present on arrival on 26 April. Most birds were initially feeding in the river outflow at Kangerlussuaq, and males always, apparently, greatly outnumbered females. Some birds were present on small areas of thawing marsh around the airport and the golf course, but also on some marshes a few kilometres further inland. Peak group counts built up to a peak of 25 males and 4 females on 7 May and declined gradually thereafter as birds dispersed inland to breeding areas. The distribution of all records of Mallard from mid May to early June is shown in Figure 29.

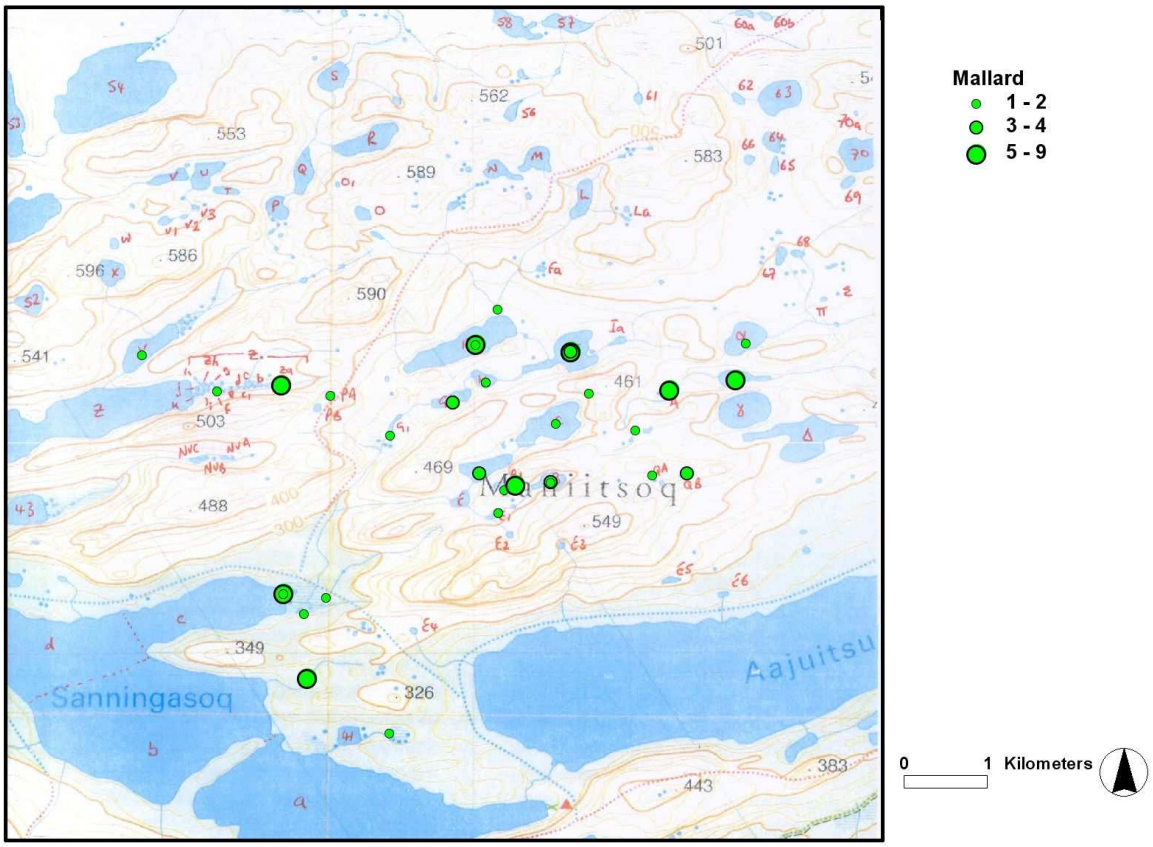

Figure 29. Distribution map of Mallard encountered in the main study area during fieldwork in Isunngua, mid May to early June, 2010.

Eurasian Wigeon *Anas penelope*
One pair seen on Lake Beta on 2 June was the only record.

Photo 6. Second summer drake Eurasian Wigeon at Lake Beta on 2 June, 2010 (C.Mitchell)

Long-tailed Duck *Clangula hyemalis*
The first record was of a pair resting on the ice at base camp, NE Sanningasoq on 22 May and then again on 25 May. Pairs were then seen on five other lakes on 26-28 May and five birds were together at base camp on 28 May. On 1 and 2 June, one or two pairs were noted on seven separate lakes, with three further pairs on two other lakes on 3 and 4 June. From 5 to 9 June, pairs were seen on five lakes. In all, from 22 May until 9 June, potentially breeding pairs were seen on 15 different lakes. The distribution of all records of Long-tailed Duck is shown in Figure 30.

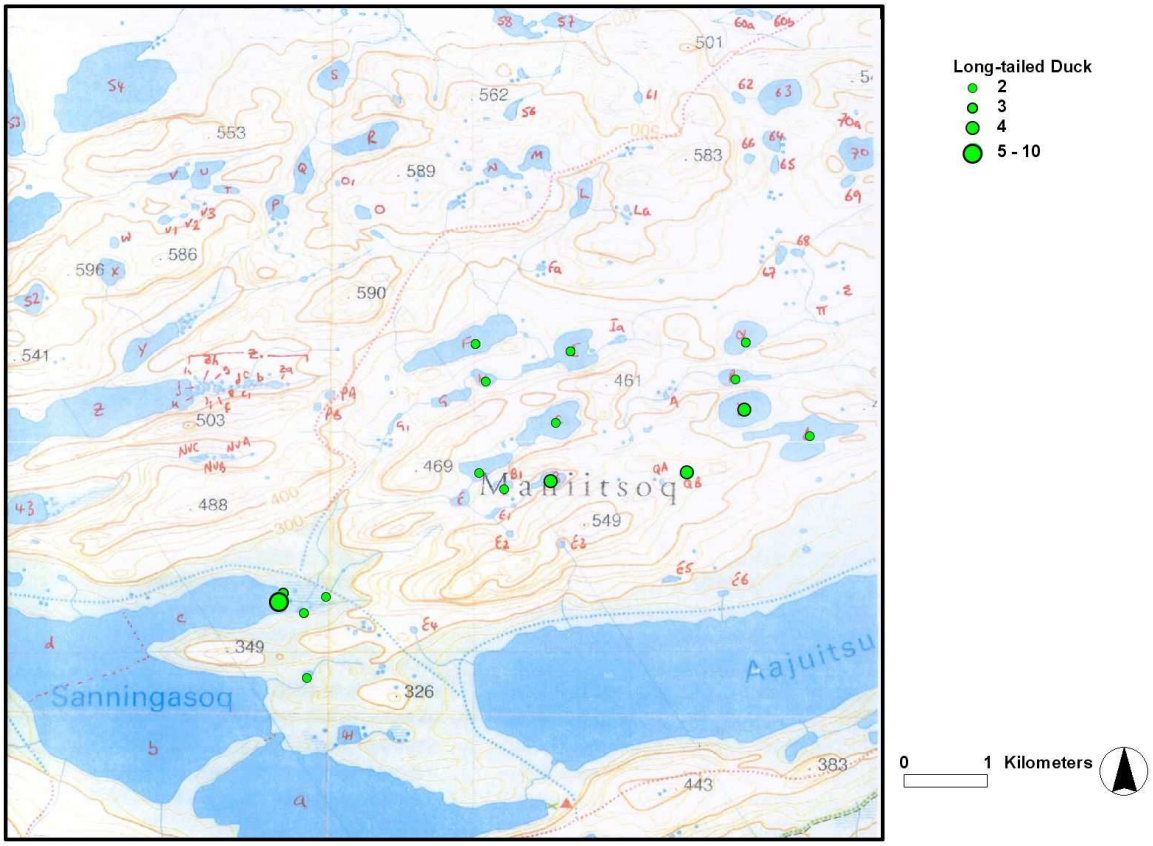

Figure 30. Distribution map of Long-tailed Duck encountered during fieldwork in Isunngua, mid May to early June, 2010.

Great Northern Diver *Gavia immer*
There was only one record – a calling bird was heard at base camp on 9 June.

Peregrine *Falco peregrinus*
Single birds were seen at base camp on 28 May and 3 June, with a further sighting of one bird at Lake F on 8 June. No signs were noted around a former breeding site on cliffs to the south above Kangerlussuaq airport.

Gyr Falcon *Falco rusticolus*
One flew from a possible nest crag by the road near the road gate near Long Lake on 2 May.

White-tailed Eagle *Haliaetus albicilla*
Most sightings were in the early part of the study period, in the vicinity of Kangerlussuaq and Sugarloaf. Here, up to two individuals were seen together between 26 April and 8 May, and we suspect that possibly two pairs may be present in the wider area, from the distribution of adults. Elsewhere, and later, there were records of single birds from four separate localities in the main study area between 16 May and 4 June.

Ptarmigan *Lagopus muta*
Single birds or pairs were recorded infrequently, scattered over the main study area and also occasionally in the main valley between Kangerlussuaq and the ice cap. Numbers did not appear to be particularly high.

Ringed Plover *Charadrius hiaticula*
The first record was on 6 May. All sightings were between 6 May and 8 May in the main valley between Kangerlussuaq and around Sugarloaf. Birds were in shingle areas around marshes or in quarries east of the golf course (up to four birds). Some of these birds may have been migrants moving through, but the areas in which they were seen are suitable for breeding.

Purple Sandpiper *Calidris maritima*
The only records came from 18 May 2010, when three pairs were present on the west shore of Sanningasoq, with spacing and behaviour indicative of breeding.

Red-necked Phalarope *Phalaropus lobatus*
Records came from 14 locations between 24 May and 8 June. Most records were of males, and the maximum number of birds seen together was six males and five females at Lake Beta. A pair was seen mating on 29 May. The distribution of all records of Red-necked Phalarope is shown in Figure 31.

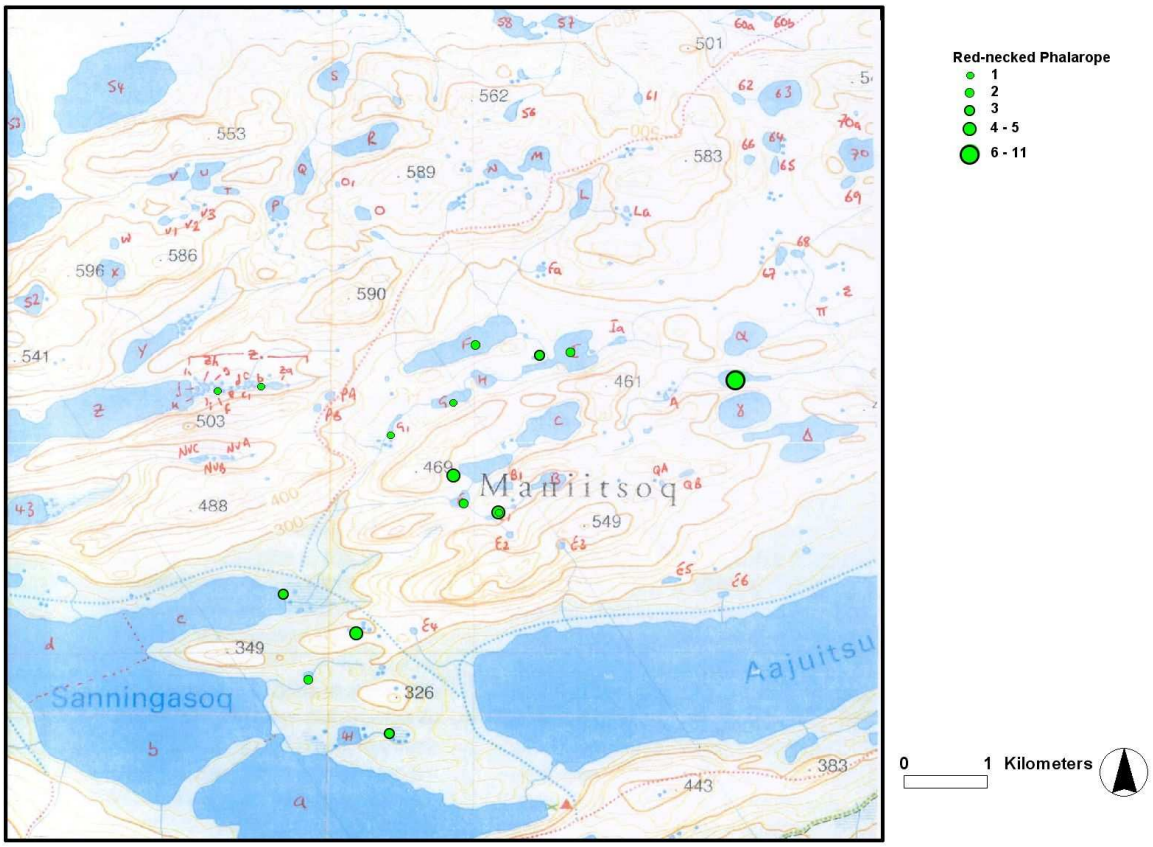

Figure 31. Distribution map of Red-necked Phalarope encountered during fieldwork in Isunngua, mid May to early June, 2010.

Photo 7. Pair of Red-necked Phalaropes on Lake Beta on 2 June, 2010 (C.Mitchell)

Wheatear *Oenanthe oenanthe*
The first record was of a bird on Sugarloaf on 1 May. Although there was a scattering of sightings over the area during the rest of the study, this species was not at all common. The first nest with eggs was found on 28 May.

Redpoll *Carduelis flammea*
This species was present on arrival on 26 April and was fairly widespread in the area around Kangerlussuaq. There were few records from the main study area. The first nest with eggs was found on 28 May.

Lapland Bunting *Calcarius lapponicus*
The first bird seen was on 5 May near Sugarloaf. Then seen only very rarely after that in the Kangerlussuaq area. In the main study area, birds were widely scattered though not abundant. Nest building was first observed on 28 May and the first nest (with 5 chicks) was found on 7 June.

Photo 8. Male Lapland Bunting photographed at base camp on 26 May, 2010 (H.Thomas)

Snow Bunting *Plectrophenax nivalis*
Snow Buntings were widespread on arrival on 26 April, scattered thinly across the Kangerlussuaq and Sugarloaf area. A female was seen carrying nest material on 2 May. There was only one record from the main study area.

Raven *Corvus corax*
Very large numbers were present around Kangerlussuaq on arrival and into early May. The settlement and rubbish dump here must act as a major winter resort for this species, and possibly non-breeders stay in the area throughout the summer. A maximum of 250 birds was seen on 6 May, mostly in the air at once over a wide area. Eighty five birds were in the marshes west of Sugarloaf on 8 May. Scattered nests were found in the valley east of Sugarloaf and towards Orkendalen. In the main study area, birds were rarely seen, with only two records.

Table 6. First records of spring migrant breeding birds not already present when we arrived (in order of date first seen) and dates of first nests found if applicable.

Species	First record noted	First nest with eggs found
Greenland White-fronted Goose	1 May	
Canada Goose	6 May/12 May	23 May
Wigeon	2 June	
Long-tailed Duck	22 May	
Great Northern Diver	9 June	
Peregrine	28 May	
Ringed Plover	6 May	
Purple Sandpiper	18 May	
Red-necked Phalarope	24 May	
Wheatear	1 May	28 May
Redpoll	n/a – present on arrival	28 May
Lapland Bunting	5 May	7 June (nest with chicks)

Mammals

Arctic Hare *Lepus arcticus*
There were scattered records during the study, but probably this species was not always noted.

Arctic Fox *Alopex lagopus*
There were 17 records during the study area of up to four individuals seen together. In the Sugarloaf area, it was thought likely that there were three separate dens within a 2-3 km radius of the mountain. In the main study area, singles or two animals were seen. Evidence of predation of a Canada Goose nest and a full-grown bird was found by Lake I and foxes were also seen trying to stalk Canada Geese. On one occasion, near Sanningasoq, a fight between a fox and a Canada Goose was won by the goose. The distribution of all records of Arctic Fox, together with dens, is shown in Figure 32. From the distribution of Arctic Fox sightings, and known dens, it appears that there probably at least four main territories within the main study area approximately evenly spaced at 3-5 km apart. Further sightings of individuals near Sugar Loaf to the south of the main study area are not shown for reasons of mapping clarity. Sightings of some mammals are given at the centre of lakes due mainly to imprecise grid references being available and/or animals being heard rather than seen in an area.

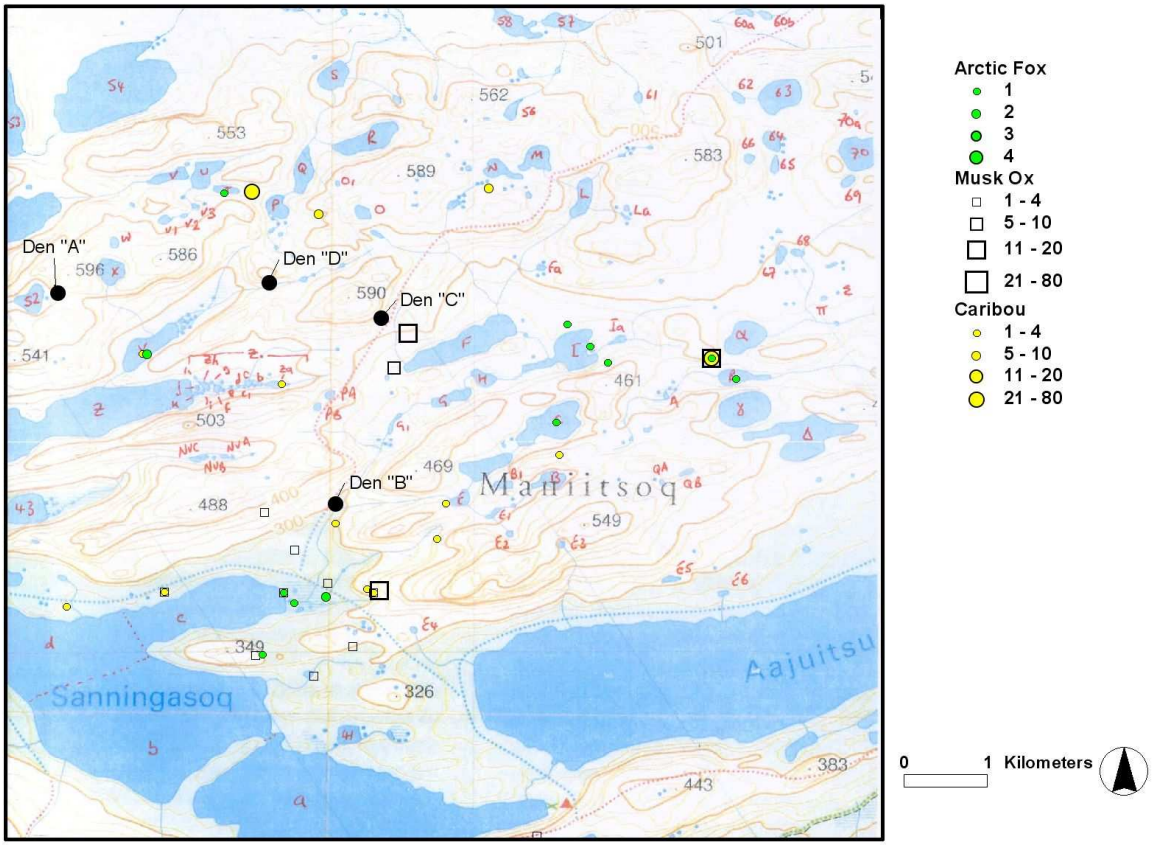

Figure 32. Distribution map of Arctic Fox, Must Ox and Caribou encountered during fieldwork in Isunngua, mid May to early June, 2010. Four fox dens are also indicated (A-D) with dens A and D known to be active in 2010.

Photo 9. Arctic Fox, Issungua photographed on 25 May, 2010 (H.Thomas)

Caribou *Rangifer tarandus*
Widespread in small numbers (up to six animals) in the Kangerlussuaq and Sugarloaf areas in late April and early May. Here, there were 20 sightings, mostly of 1-10 animals, but counts of 21 and 80 were made. The distribution of all records of Caribou is shown in Figure 32.

Musk Ox *Ovibos moschatus*
Up to 11 individuals were seen in the valley from Kangerlussuaq east to the ice cap, mainly in the Sugarloaf area. Further south, up to 22 were seen in Orkendalen, east of Mount Garnet. In the main study area, there were 22 sightings, mostly one to seven animals, but with records of 15 and 20 individuals. See map for distribution of sightings in the main study area. The distribution of all records of Musk Ox is shown in Figure 32.

Photo 10. Bull Musk Ox seen on 23 May, 2010 near base camp (H.Thomas).

Appendix 2

Inventory of all goose colour mark sightings

Greenland White-fronted Geese

Mark	Type	Date	Latitude	Longitude	Mate	Goslings	Flock	Observer
DU	Leg ring	29/05/2010	67.08865	-50.5517	UPD	0	3	LG
DZ	Leg ring	23/05/2010	67.10992	-50.4751				LG
J2F	Collar	28/05/2010	67.0906	-50.545	UNR	0	2	LG
J2F	Collar	06/06/2010	67.09060	-50.54495	UNR		2	MW
J2F	Collar	08/06/2010	67.09060	-50.54495	UNR		4	MW
J3F	Collar	18/05/2010	67.08677	-50.5573	J5F	0	2	LG/MW
J3F	Collar	27/05/2010	67.08533	-50.5684	J5F	0	2	LG/MW
J3F	Collar	28/05/2010	67.08736	-50.5595	J5F	0	2	LG/MW
J3F	Collar	29/05/2010	67.09060	-50.54495		8		MW
J5F	Collar	18/05/2010	67.08677	-50.5573	J3F	0	2	LG/MW
J5F	Collar	27/05/2010	67.08533	-50.5684	J3F	0	2	LG/MW
J5F	Collar	28/05/2010	67.08736	-50.5595	J3F	0	2	LG/MW
J5F	Collar	29/05/2010	67.09060	-50.54495		8		MW

Canada Geese

Mark	Type	Date	Latitude	Longitude	Mate	Goslings	Flock	Observer
G12	Leg ring	25/05/2010	67.11498	-50.4671				LG
GA1	Collar	21/05/2010	67.11953	-50.4905	GNL	0	2	LG
GA2	Collar	23/05/2010	67.09012	-50.5487	UNR	0	2	LG
GA3	Collar	19/05/2010	67.11741	-50.4671	GNH	0	7-12	LG
GA3	Collar	20/05/2010	67.11708	-50.467	GNH	0	3	LG
GA3	Collar	25/05/2010	67.11661	-50.4679	GNH	0	14	LG
GA3	Collar	28/05/2010	67.1157	-50.4696	?UPD	0	1	LG
GA3	Collar	04/06/2010	67.11500	-50.47000	UPD		1	CM
GA3	Collar	08/06/2010	67.11500	-50.47000	UPD		1	CM
GA4	Collar	25/05/2010	67.1093	-50.5177	UNR	0	9	LG
GA4	Collar	04/06/2010	67.11167	-50.49833	UNR		2	CM
GA4	Collar	05/06/2010	67.10000	-50.50167	UNR		2	CM
GA4	Collar	09/07/2010	67.11500	-50.47000	UNR	0	15	DAS
GA5	Collar	20/05/2010	67.11457	-50.4794	GB9	0	2	LG
GA5	Collar	21/05/2010	67.12018	-50.4875	UNR	0	6 (+)	LG
GA5	Collar	21/05/2010	67.10137	-50.4818	GB9	0	3	LG
GA5	Collar	21/05/2010	67.09922	-50.5021	UPD	0	5	LG
GA5	Collar	28/07/2010	67.13496	-50.4937		0	103	DAS
GA9	Collar	20/05/2010	67.11346	-50.4937	GB4	0	4	LG
GA9	Collar	21/05/2010	67.11368	-50.4946	GB4	0	2	LG
GA9	Collar	23/05/2010	67.11297	-50.4953	GB4	0	4	LG
GA9	Collar	24/05/2010	67.11298	-50.4964	GB4	0	2	LG
GA9	Collar	02/06/2010	67.10833	-50.48333	GB4		2	CM
GA9	Collar	07/06/2010	67.10833	-50.48333			1	CM
GA9	Collar	24/07/2010	67.13596	-50.4822	GB4	0	13	DAS
GA9	Collar	28/07/2010	67.13496	-50.4937	GB4	0	103	DAS
GB1	Collar	21/05/2010	67.11125	-50.4449	GNH	0	4	LG
GB1	Collar	26/05/2010	67.11668	-50.457	GD9	0	8	LG
GB1	Collar	28/05/2010	67.11451	-50.4657	GD9	0	2	LG
GB4	Collar	20/05/2010	67.11346	-50.4937	GA9	0	4	LG
GB4	Collar	21/05/2010	67.11368	-50.4946	GA9	0	2	LG
GB4	Collar	23/05/2010	67.11297	-50.4953	GA9	0	4	LG
GB4	Collar	24/05/2010	67.11298	-50.4964	GA9	0	2	LG
GB4	Collar	02/06/2010	67.10833	-50.48333	GA9		2	CM
GB4	Collar	24/07/2010	67.13596	-50.4822	GA9	0	13	DAS
GB4	Collar	28/07/2010	67.13496	-50.4937	GA9	0	103	DAS
GB6	Collar	24/05/2010	67.11128	-50.5028	UNR	0	2	LG

GB6	Collar	24/07/2010	67.13496	-50.4937	GNL	0	4	DAS
GB6	Collar	28/07/2010	67.13496	-50.4937		0	103	DAS
GB7	Collar	19/05/2010	67.10708	-50.4706	UNR	0	2	LG
GB7	Collar	21/05/2010	67.10486	-50.4672	UNR	0	2	LG
GB7	Collar	02/06/2010	67.10833	-50.48333	UNR		2	CM
GB9	Collar	20/05/2010	67.11457	-50.4794	GA5	0	2	LG
GB9	Collar	21/05/2010	67.10137	-50.4818	GA5	0	3	LG
GC0	Collar	21/05/2010	67.09922	-50.5021	GC7	0	5	LG
GC1	Collar	17/05/2010	67.09999	-50.50138	GD9		2	HT
GC1	Collar	21/05/2010	67.09922	-50.5021	GSY	0	5	LG
GC1	Collar	22/05/2010	67.09999	-50.50138			2	HT
GC1	Collar	23/05/2010	67.10009	-50.5014	[GSY]	0	2	LG
GC1	Collar	24/05/2010	67.09999	-50.5014	[GSY]	0	2	LG
GC1	Collar	01/06/2010	67.10000	-50.50167	GSY		2	CM
GC1	Collar	06/06/2010	67.10000	-50.50167	GSY		2	CM
GC1	Collar	28/07/2010	67.13496	-50.4937	UNR	3	103	DAS
GC2	Collar	17/05/2010	67.10383	-50.46775	GIL		2	HT
GC2	Collar	01/06/2010	67.10000	-50.47167			1	CM
GC2	Collar	06/06/2010	67.10000	-50.47167				CM
GC2	Collar	28/07/2010	67.13496	-50.4937	GIL	7	103	DAS
GC3	Collar	19/05/2010	67.11051	-50.5042	???	0	14 (+)	LG
GC3	Collar	20/05/2010	67.11563	-50.5153	GD2	0	2	LG
GC3	Collar	04/06/2010	67.11500	-50.51167	GD2		2	CM
GC3	Collar	09/07/2010	67.12462	-50.4817	GD2	3		DAS
GC3	Collar	24/07/2010	67.13496	-50.4937	GD2	3	20	DAS
GC3	Collar	28/07/2010	67.13496	-50.4937	GD2	3	103	DAS
GC4	Collar	24/05/2010	67.10461	-50.49	GD7	0	2	LG
GC4	Collar	02/06/2010	67.10333	-50.49167	GD7		2	CM
GC5	Collar	19/05/2010	67.1052	-50.4853	GNI	0	2	LG
GC5	Collar	24/05/2010	67.10575	-50.4829	GNI	0	2	LG
GC5	Collar	02/06/2010	67.10833	-50.48333	GNI		2	CM
GC5	Collar	07/06/2010	67.10833	-50.48333	GNI		2	CM
GC7	Collar	21/05/2010	67.09922	-50.5021	GC0	0	5	LG
GC7	Collar	02/06/2010	67.10333	-50.49167	GC0		2	CM
GC7	Collar	07/06/2010	67.10333	-50.49167	GC0		1	CM
GC0	Collar	02/06/2010	67.10333	-50.49167	GC7		2	CM
GC0	Collar	07/06/2010	67.10333	-50.49167	GC7		1	CM
GD1	Collar	01/06/2010	67.09500	-50.48833	GNY		2	CM
GD1	Collar	06/06/2010	67.09500	-50.48833	GNY			CM
GD2	Collar	20/05/2010	67.11563	-50.5153	GC3	0	2	LG
GD2	Collar	04/06/2010	67.11500	-50.51167	GC3		2	CM
GD2	Collar	09/07/2010	67.12462	-50.4817	GC3	3		DAS
GD2	Collar	24/07/2010	67.13496	-50.4937	GC3	3	20	DAS
GD2	Collar	28/07/2010	67.13496	-50.4937	GC3	3	103	DAS
GD7	Collar	19/05/2010	67.10126	-50.4812	UNR	0	2	LG
GD7	Collar	24/05/2010	67.10461	-50.49	GC4	0	2	LG
GD7	Collar	02/06/2010	67.10333	-50.49167	GC4		2	CM
GD8	Collar	19/05/2010	67.11549	-50.4704	GF7	0	7-12	LG
GD8	Collar	22/05/2010	67.09999	-50.50138	GF7		2	HT
GD8	Collar	23/05/2010	67.10436	-50.4895	GF7	0	2	LG
GD8	Collar	24/05/2010	67.10693	-50.472	GF7	0	2	LG
GD8	Collar	02/06/2010	67.10833	-50.48333	GF7		2	CM
GD9	Collar	17/05/2010	67.09999	-50.50138	GC1		2	HT
GD9	Collar	26/05/2010	67.11668	-50.457	GB1	0	8	LG
GD9	Collar	28/05/2010	67.11451	-50.4657	GB1	0	2	LG
GD9	Collar	09/07/2010	67.11521	-50.4733	UNR	0	15 (+)	DAS
GF7	Collar	19/05/2010	67.11549	-50.4704	GD8	0	7-12	LG
GF7	Collar	22/05/2010	67.09999	-50.50138	GD8		2	HT
GF7	Collar	23/05/2010	67.10436	-50.4895	GD8	0	2	LG
GF7	Collar	24/05/2010	67.10693	-50.472	GD8	0	2	LG
GF7	Collar	02/06/2010	67.10833	-50.48333	GD8		2	CM
GF8	Collar	02/06/2010	67.10333	-50.49167	GNJ		2	CM

GF8	Collar	28/07/2010	67.13496	-50.4937	GNI	1	103	DAS
GH0	Collar	21/05/2010	67.13803	-50.52561	GH2		6	HT
GH0	Collar	28/05/2010	67.13803	-50.52561	GH2		4	HT
GH0	Collar	25/07/2010	67.13063	-50.5532	UPD	3	27	DAS
GH0	Collar	27/07/2010	67.12375	-50.5986	GH2	2	65	DAS
GH1	Collar	21/05/2010	67.13063	-50.55325	GH7		4	HT
GH1	Collar	25/07/2010	67.13063	-50.5532	GH2	3	27	DAS
GH2	Collar	21/05/2010	67.13803	-50.52561	GH0		6	HT
GH2	Collar	28/05/2010	67.13803	-50.52561	GH0		4	HT
GH2	Collar	15/07/2010	67.13063	-50.5532	GHD?	3	34	DAS
GH2	Collar	25/07/2010	67.13063	-50.5532	GH1	3	27	DAS
GH2	Collar	27/07/2010	67.12375	-50.5986	GH0	2	65	DAS
GH6	Collar	28/05/2010	67.13477	-50.48852			3	MW
GH6	Collar	28/07/2010	67.13496	-50.4937	GNJ	2	103	DAS
GH7	Collar	21/05/2010	67.13063	-50.55325	GH1		4	HT
GH7	Collar	25/07/2010	67.13063	-50.5532			27	DAS
GH7	Collar	27/07/2010	67.12375	-50.5986		2	65	DAS
GHG	Collar	28/05/2010	67.13477	-50.48852			1	MW
GIB	Collar	28/05/2010	67.11596	-50.4604				LG
GIF	Collar	23/05/2010	67.10379	-50.5035	???	0	2	LG
GIF	Collar	26/05/2010	67.10468	-50.4905	UNR	0	2	LG
GIF	Collar	07/06/2010	67.10333	-50.49167	UNR		2	CM
GIF	Collar	09/07/2010	67.11521	-50.4733	UNR	0	15 (+)	DAS
GIL	Collar	17/05/2010	67.10383	-50.46775	GC2		2	HT
GIL	Collar	28/07/2010	67.13496	-50.4937	GC2	7	103	DAS
GIN	Collar	01/06/2010	67.11521	-50.59050	GLZ		2	HT
GIU	Collar	19/05/2010	67.11051	-50.5042	GNL	0	14 (+)	LG
GIY	Collar	05/06/2010	67.13063	-50.55325			12	MW
GJ0	Collar	23/05/2010	67.13483	-50.54604	UNR		2	HT
GJ0	Collar	28/05/2010	67.13063	-50.55325	UNR		2	HT
GJ0	Collar	25/07/2010	67.13063	-50.5532	UNR	6	27	DAS
GJ0	Collar	27/07/2010	67.12375	-50.5986	UNR	6	65	DAS
GJ1	Collar	28/05/2010	67.13477	-50.48852			3	MW
GJ8	Collar	21/05/2010	67.13607	-50.56250	GL8		2	HT
GJA	Collar	21/05/2010	67.13063	-50.55325	UNR		2	HT
GJA	Collar	15/07/2010	67.13063	-50.5532	UNR	2	34	DAS
GJB	Collar	05/06/2010	67.11167	-50.56000	GP3		2	CM
GJF	Collar	21/05/2010	67.13803	-50.52561	GJV		6	HT
GJF	Collar	23/05/2010	67.12996	-50.52990	GJV		2	HT
GJF	Collar	23/05/2010	67.13483	-50.54604	GJV		2	HT
GJF	Collar	28/07/2010	67.13496	-50.4937	GJV	3	103	DAS
GJS	Collar	28/05/2010	67.13223	-50.56784	GJT		2	HT
GJT	Collar	28/05/2010	67.13223	-50.56784	GJS		2	HT
GJT	Collar	25/07/2010	67.13223	-50.56784				DAS
GJV	Collar	21/05/2010	67.13803	-50.52561	GJF		6	HT
GJV	Collar	23/05/2010	67.12996	-50.52990	GJF		2	HT
GJV	Collar	23/05/2010	67.13483	-50.54604	GJF		2	HT
GJV	Collar	28/07/2010	67.13496	-50.49368	GJF	3	103	DAS
GJY	Collar	20/05/2010	67.13496	-50.49368	UNR		2	HT
GJY	Collar	28/07/2010	67.13496	-50.4937	UNR	0	103	DAS
GL1	Collar	01/06/2010	67.11193	-50.55246			6	HT
GL1	Collar	05/06/2010	67.11167	-50.56000	GL7		2	CM
GL1	Collar	12/07/2010	67.13223	-50.5678	GL7		6	DAS
GL1	Collar	15/07/2010	67.12375	-50.5986	GL7	3	15	DAS
GL3	Collar	26/05/2010	67.11325	-50.4335	GP1	0	2	LG
GL3	Collar	28/05/2010	67.11264	-50.433	GP1	0	2	LG
GL5	Collar	22/05/2010	67.08834	-50.6415		5		MW
GL6	Collar	03/06/2010	67.09000	-50.55167	UNR		5	CM
GL6	Collar	05/06/2010	67.09000	-50.55167	UNR		2	CM
GL6	Collar	07/06/2010	67.09000	-50.55167	UNR		2	CM
GL6	Collar	09/06/2010	67.09000	-50.55167	UNR		2	CM
GL7	Collar	25/05/2010	67.11193	-50.55246			6	HT

GL7	Collar	01/06/2010	67.11193	-50.55246			6	HT
GL7	Collar	05/06/2010	67.11167	-50.56000	GL2		2	CM
GL7	Collar	12/07/2010	67.13223	-50.5678	GL1		6	DAS
GL7	Collar	15/07/2010	67.12662	-50.5984	GL1	3	15	DAS
GL8	Collar	21/05/2010	67.13607	-50.56250	GJ8		2	HT
GL9	Collar	22/05/2010	67.08834	-50.6415		5		MW
GL9	Collar	23/05/2010	67.09012	-50.5487	UPD	0	1-3-4	LG
GLF	Collar	25/05/2010	67.11193	-50.55246			6	HT
GLF	Collar	01/06/2010	67.11193	-50.55246			6	HT
GLF	Collar	05/06/2010	67.11167	-50.56000	UNR		2	CM
GLF	Collar	09/06/2010	67.11167	-50.56000			1	CM
GLU	Collar	25/05/2010	67.11193	-50.55246			6	HT
GLU	Collar	01/06/2010	67.11193	-50.55246			6	HT
GLU	Collar	05/06/2010	67.11167	-50.56000	UNP		2	CM
GLZ	Collar	01/06/2010	67.11521	-50.59050	GIN		2	HT
GN4	Collar	17/05/2010	67.10137	-50.48178	UNR		2	HT
GNA	Collar	25/05/2010	67.11193	-50.55246	UNR		2	HT
GNA	Collar	01/06/2010	67.11193	-50.55246			1	HT
GNA	Collar	05/06/2010	67.11167	-50.56000	UNR		2	CM
GNH	Collar	19/05/2010	67.11741	-50.4671	GA3	0	7-12	LG
GNH	Collar	20/05/2010	67.11708	-50.467	GA3	0	3	LG
GNH	Collar	21/05/2010	67.11125	-50.4449	GB1	0	4	LG
GNH	Collar	25/05/2010	67.11661	-50.4679	GA3	0	14	LG
GNI	Collar	19/05/2010	67.1052	-50.4853	GC5	0	2	LG
GNI	Collar	24/05/2010	67.10575	-50.4829	GC5	0	2	LG
GNI	Collar	02/06/2010	67.10833	-50.48333	GC5		2	CM
GNI	Collar	07/06/2010	67.10833	-50.48333	GC5		2	CM
GNI	Collar	28/07/2010	67.13496	-50.4937	GF8	1	103	DAS
GNJ	Collar	23/05/2010	67.10175	-50.4962	UNR	0	2	LG
GNJ	Collar	26/05/2010	67.10394	-50.497	UPD	0	3	LG
GNJ	Collar	02/06/2010	67.10333	-50.49167	GF8		1	CM
GNJ	Collar	07/06/2010	67.10333	-50.49167			1	CM
GNJ	Collar	28/07/2010	67.13496	-50.4937	GH6	2	103	DAS
GNL	Collar	19/05/2010	67.11051	-50.5042	GIU	0	14 (+)	LG
GNL	Collar	21/05/2010	67.11953	-50.4905	GA1	0	2	LG
GNL	Collar	09/07/2010	67.12462	-50.4817	GA1	1		DAS
GNL	Collar	24/07/2010	67.13496	-50.4937	GB6	0	4	DAS
GNL	Collar	28/07/2010	67.13496	-50.4937		0	103	DAS
GNS	Collar	22/05/2010	67.08593	-50.5524	GNU	0	2	LG
GNS	Collar	28/05/2010	67.08653	-50.5571	GNU	0	6	LG
GNS	Collar	29/05/2010	67.08991	-50.54870	GNU		2	HT
GNS	Collar	03/06/2010	67.09000	-50.55167	GNU		2	CM
GNU	Collar	19/05/2010	67.08991	-50.5487	?UNR	0	4	LG
GNU	Collar	22/05/2010	67.08593	-50.5524	GNS	0	2	LG
GNU	Collar	28/05/2010	67.08653	-50.5571	GNS	0	6	LG
GNU	Collar	29/05/2010	67.08991	-50.54870	GNS		2	HT
GNU	Collar	03/06/2010	67.09000	-50.55167	GNS		2	CM
GNY	Collar	01/06/2010	67.09500	-50.48833	GD1		2	CM
GNY	Collar	06/06/2010	67.09500	-50.48833	GD1			CM
GP1	Collar	26/05/2010	67.11325	-50.4335	GL3	0	2	LG
GP1	Collar	28/05/2010	67.11264	-50.433	GL3	0	2	LG
GP3	Collar	05/06/2010	67.11167	-50.56000	GJB		2	CM
GP6	Collar	25/05/2010	67.11193	-50.55246			6	HT
GSY	Collar	21/05/2010	67.09922	-50.5021	GC1	0	5	LG
GSY	Leg ring	01/06/2010	67.10000	-50.50167	GC1		2	CM
GSY	Leg ring	06/06/2010	67.10000	-50.50167	GC1		2	CM

Appendix 3

Survey effort

The routes taken during the surveys were recorded on paper maps or on a GPS. These were then digitised or downloaded into a GIS and the routes were then buffered to a radius of 500 m, it being assumed that all geese and other wildfowl and mammal species would be detected within that distance (although of course geese on the ground or flying could often be seen over a kilometre or more). These buffered routes were then gridded and the survey effort per day for each 50 m cell added together over the period (Figure 33).

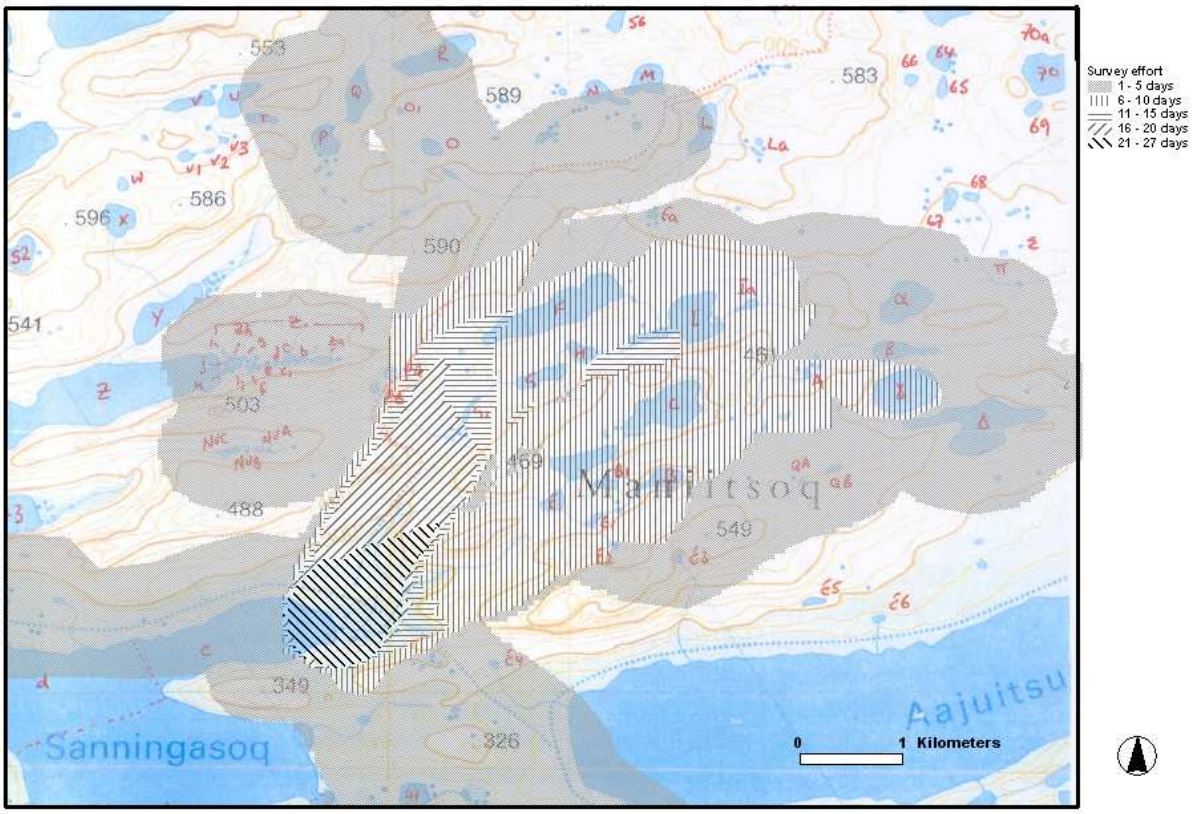

Figure 33. Survey effort expended in days between 16 May to 11 June within the main study area. The routes walked were buffered to 500 m either side to establish the area effectively surveyed for wildfowl and mammals. Some lakes and valleys near to base camp received up to 27 days of observation during this period.

Appendix 4

Observations of direct interactions between Greenland White-fronted Geese and Canada Geese

25 May (16h20): One GWFG came into view roosting on the SE shore of lake Y. Then a second GWFG was located roosting about 20 feet further NE along the shoreline. There were three Canada Geese feeding close by (collar GNA/mate and a single).

Time	Observation (H. Thomas)	Comment
16h58	Four more Canada Geese come into view on the N side (making a total of seven in sight) with some aggravation going on; GWFG out of sight.	Canada Geese squabbling amongst themselves
17h13	One GWFG still feeding below me. Two collared Canada Geese reach another pair and fighting breaks out – lots of noise, splashing and chasing.	Canada Geese squabbling amongst themselves
17h25	Collared pair of Canada Geese make more noise and push the un-collared single Canada Geese clockwise along the shore.	Canada Geese squabbling amongst themselves
17h27	One GWFG below me feeding at the edge of the pool. Collared pair of Canada Geese still on shore having now pushed the single Canada Geese clockwise along the shoreline to the southern side of the river-mouth.	Canada Geese squabbling amongst themselves
	The GWFG swims at the head of the line of birds. The GWFG ends up nearest the fox which currently has its back to the lake. With the three Canada Geese remaining in the water, the GWFG swims until it can wade in the shallows towards the shore line…clearly going towards the fox while the three Canada Geese hang back in the water.	GWFG tries to decoy fox
	Fox works around the shoreline clockwise, the GWFG swims a parallel course in the water but can't or does not fully keep up.	GWFG tries to decoy fox

29 May (08h42): Two Canada Geese on shore at base of promontory near BC and one GWFG between them:

Time	Observation (H. Thomas)	Comment
08h52	GWFG now about 0.5 m from nearest Canada Geese and is now the easternmost of the three birds, all three dipping their heads under water	No interaction
08h58	GWFG head dipping / Canada Geese head dipping / Canada Geese head dipping	No interaction

09h00	Two collared Canada Geese arrive – disagreement breaks out immediately amongst the Canada Geese, the GWFG stays out of it. The two original Canada Geese and the GWFG end up swimming about.	Canada Geese squabbling amongst themselves

30 May (20h57) single GWFG lands in marshes behind BC:

Time	Observation (H. Thomas)	Comment
21h26	GWFG ignores various Canada Geese movements and continues to feed	No interaction
21h56	A single Canada Goose went close to GWFG and honked; GWFG came up out of a dip, resumed feeding out in the open; Canada Goose continues to walk towards the GWFG mostly with head up high but occasionally dipped down; now about 3 m apart	Mild aggressive encounter
21h57	both feeding and crossed paths. Canada Goose now to my left, GWFG to my right; GWFG feeding out on the open marsh walking away from the Canada Goose;	No interaction
22h16	Canada Goose appeared to show some irritation towards the GWFG – it honked and thrust its head towards the GWFG which rapidly moved away a few paces before resuming feeding. Canada Goose walks towards the GWFG until they are again about 2 m apart	Aggressive encounter
22h21	GWFG stretches its wings, then Canada Goose does same; standing very close together again with heads up. Canada Goose walks past the GWFG; GWFG flaps its wings then with head down feeding, wanders off in the direction of the Canada Goose	No interaction
22h27	both now feed although Canada Goose has head up a lot, GWFG feeds continuously with little regard for looking.	GWFG benefitting from vigilance of Canada Goose? Situation lasted for approx one hour

23 May, on marshes between lakes G and G1

Time	Observation (M. Weegman)	Comment
11h38	Entire flock, Canada Geese and GWFG feeding, walking about the marsh.	No apparent interaction

29/5/2010, across bay from base camp

Time	Observation (M. Weegman)	Comment
04h05	Pair to the far west both laying now and sleeping. Middle bird sleeping. East two GWFG sleeping. One Canada Geese sleeping right next to loner GWFG. One more Canada Geese feeding 2 m. away	No interaction
04h15	Some squabbling and the east two GWFG push the middle GWFG and the two west GWFG over 25 m. Seems that west pair of GWFG worried about spacing to next group the entire time	Interaction between GWFG
04h20	Canada Geese honking nearby (two birds). All five GWFG immediately hop in water and alert, swim away from the calling. One GWFG from the east pair nips at middle, loner GWFG	Possible displacement

1/2 June, marshes east of BC

Time	Observation (M. Weegman)	Comment
24h00	One Canada Goose starts chasing one of the pairs of GWFG. GWFG waddle out of the way of Canada Geese, but Canada Geese continues to go after them, honking. After 2 min the GWFG take off and land on a wetland further south of BC.	Interaction

3 June, across bay from BC on Sanningasoq

Time	Observation (M. Weegman)	Comment
11h35	Two Canada Geese, both collared, swim onto shore where the GWFG are feeding. Canada Geese honking and pushing the GWFG 15 m. further along shore. Canada Geese took over feeding patch. Another Canada Goose swam towards the two collared birds, and was nipped at by a collared bird! Collared Canada Geese move away, GWFG back to feeding.	Interaction
11h55	Both birds near each other and feeding the entire time. Lone Canada Geese came close and one GWFG lowered it's head and showed aggression towards the Canada Geese. Canada Geese drifted away, and all three back to feeding.	Aggression by GWFG towards Canada Geese

5 June, south side of marshes to east of BC

Time	Observation (M. Weegman)	Comment
09h05	A lone Canada Geese has joined the mix. This bird has perfectly spaced itself between the two pairs of GWFG. Easterly pair - both birds walking and feeding. Canada Geese at sentry. Westerly pair - one bird alert, the other sleeping	GWFG benefiting from vigilance of Canada Geese
09h15	Another Canada Geese arrived and attacked the two Canada Geese. As soon as the bird flew in, it started nipping at the other Canada Geese, pushing them away from the GWFG. Easterly pair of GWFG - watching the Canada Geese. Westerly pair of GWFG - both alert, one seat, the other standing	Canada Geese interaction

8 June, marshes to east of BC

Time	Observation (M. Weegman)	Comment
21h30	Two Canada Geese land where the GWFG are. Awkward landing, displacing the three GWFG. Two GWFG move right, one moves left. Canada Geese flush after just one minute, leaving three GWFG.	No apparent interaction
22h20	Both GWFG sitting, looking around. For the last six minutes, GWFG fed constantly, never bringing heads up. Appear to be using Canada Geese sentry as their sentry too	GWFG benefiting from vigilance of Canada Geese
22h25	Both GWFG preening and still using Canada Geese as sentry.	Feeding situation with GWFG apparently benefiting from vigilance of Canada Geese continues until 01h35

5 June, marshes at east end of lake Z

Time	Observation (C. Mitchell)	Comment
14h15 to 17h00	Sub-adult GWFG feeding in association with a pair of Canada Geese. Continuous observation for c.165 minutes. No aggressive encounters observed. Male Canada Geese vigilant for much of time as his female actively fed. On two occasions, male Canada Geese showed aggression towards conspecifics.	GWFG may have benefited from vigilance of Canada Geese

21 May, eastern end of Lake F

Time	Observation (L. Griffin)	Comment
14h00	Pair of CG flew in, one had a collar (unread), landed 10 m downslope of GWFG, this pair moved upslope and as approached GWFG, collared bird head stretched towards GWFG which moved away c.5 m and CGs passed upslope to feed.	Mild aggression from Canada Goose

23 May, marshland 100m west of Lake G

Time	Observation (L. Griffin)	Comment
11h30	Detailed observations from 11h30 on this initially sympatric group. 11h33 two CG leave. 12h15 observation position moved uphill from where another unmarked GWF could be seen and more uncollared CGs, now 13 in total. At 12h54 single CG flew off heading east. At point of greatest sympatry, GWFG feeding among CG for 5 mins with CG passing by within 1 m without conflict. 5 mins later CG seen to make head lunge at a GWFG 1 m in front of it which quickened step out of the way. Dark nail and lack of belly bars evident on one GWFG, other bird is full adult. By 14h00 birds on centre of marsh with LRG c.200 from them and 30 m above them. In 3 hours birds moved over an area of approx 150*50 m. Time of greatest “allopatricness” was when GWFGs on one side of marsh and CGs on other with the groups c.70 m apart.	Mild aggression from Canada Goose

Appendix 5

To be submitted as a short note to Wildfowl

Nesting and breeding biology of Canada Geese in Isunngua, west Greenland

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Abstract

Canada Geese *Branta canadensis* of the subspecies *interior* have apparently colonised west Greenland in the last 20 years. In 2010, geese from this population nesting in Isunngua, west Greenland (67°N) had identical mean first egg dates (27 May) but greater mean clutch size (4.57 vs. 3.80; n = 21) compared to ancestral stock breeding in Ungava Bay, northern Québec 1,300 km further south. This may be explained by mean May temperatures in Isunngua having been on average 2°C higher than in Ungava for the 20 year period up to 2010, which may enable females to enhance reproductive investment in Isunngua under similar conditions in both areas. Nesting success appeared as high as reported from other parts of the range of this subspecies. Unlike the endemic Greenland White-fronted Geese *Anser albifrons flavirostris*, Canada Goose nest sites were closely associated with water (median distance 1 m, mean 1.84 m from shorelines, n = 32). The milder spring conditions than on traditional nesting grounds, availability of abundant food and lack of competition for nest sites may have combined to help explain the rapid increases of this goose population in west Greenland in recent years.

Key words: *Branta canadensis interior*, timing of nesting, clutch size, nest sites, nest success, Ungava

Introduction

A *Branta* genus goose species, presumably a smaller subspecies of Canada Goose *Branta canadensis*, may have co-existed with Greenland White-fronted Geese *Anser albifrons flavirostris* on their west Greenland breeding areas in historical times. Gotfredsen (2002) documented bone remains of a small *Branta* goose in the interior of the Nuuk/Godthåb District since at least c. 1000-1400 A.D. and the interior of the Sisimiut/Holsteinsborg District since at least c. 1200-1300 A.D. which she considered most likely from Canada Geese. However, despite the fact the Canada Goose was proven breeding in the vicinity of Sarqaqdalen from the mid 1940s (Salomonsen 1950), even by the 1960s the species remained a relatively scarce breeder throughout Greenland according to Salomonsen (1967). No birds were seen during extensive goose surveys in Eqalummiut Nunaat in central west Greenland (67°30'N) during summer 1979 (Fox & Stroud 1981), although a single early migrant passed through in May and two were seen in that area in June 1984 (unpubl. data). Salomonsen (1967) considered two small races of Canada Geese occurred in the 1960s, *parvipes* and *hutchinsii*, the latter breeding regularly in the Ilulissat area (69ºN) with moulting non-breeders further north in the Uummannaq area (70ºN).

Since the late 1980s, summering and breeding Canada Geese have become increasingly common in west Greenland, but evidence from observations, capture and marking, satellite telemetry, genetic analysis and resightings from the staging and wintering grounds confirm that most of the Canada Geese present in summer around 67ºN are of the larger subspecies *interior* (which breed from Ontario to northern Québec) and that these geese winter along the Atlantic Coast in Connecticut, Delaware, Maryland, Massachusetts, New Jersey, New York and Pennsylvania (Fox *et al.* 1996, Kristiansen *et al.* 1999, Scribner *et al.* 2003, Stroud 2011). The subspecies involved further north in Greenland have not been studied in detail in recent years and their identity therefore remains unknown (Lyngs 2003).

Canada Geese have mostly been recorded in Isunngua, Eqalummiut Nunaat, Naternaq/Lersletten, Qeqertarsuaq/Disko, the Nugssuaq Peninsula and Sigguup Nunnuua/Svartenhuk (Fox & Glahder 2010). In addition, a few breeding pairs and several summer visitors have been

reported from Nuuk and Maniitsoq. Spring and autumn migrant Canada Geese are recorded annually in Paamiut in southernmost Greenland (Boertmann 1994), although recent aerial surveys have failed to find these (Malecki *et al*. 2000, Fox & Glahder 2010). Small numbers of breeding and moulting birds have been recorded as far north as Avanersuaq in the NW Greenland (Boertmann & Glahder 1999, Lyngs 2003). Most recent estimates suggest in excess of 41,500 Canada Geese in west Greenland as of 2007 (Fox & Glahder 2010).

The apparent rapid colonization of west Greenland by increasing numbers of the larger *interior* Canada Geese is of conservation interest because the newly colonized areas were formerly exploited solely by Greenland White-fronted Geese that winter in Ireland and Britain (Bennike 1990, Fox *et al.* 1996, Kristiansen *et al.* 1999). Because both species are migratory herbivores of similar body shape, there has been considerable interest in the potential for interspecific competition (Kristiansen & Jarrett 2002, Levermann & Raundrup undated). Results from one study in Isunngua during the moult suggested that Greenland White-fronted Geese maintained a poorer diet in sympatry than in allopatry (Kristiansen & Jarrett 2002), and that both species tended to select the same plant species in the diet when in isolation. However, there was no evidence for competition at a larger site on Disko (Boertmann & Egevang 2002, Levermann & Raundrup undated).

It has been suggested that competitive interactions with Canada Geese have contributed to the recent low productivity of Greenland White-fronted Geese since the mid 1990s (Fox et al. 2009), but clearly if this were to be the case, it is likely that such interactions would need to occur before egg-laying or during the brood rearing period. Studies have not taken place during either of these periods in recent years, so for this reason, fieldwork was carried out in west Greenland in the summer of 2010 to compile basic information about breeding Canada Geese of Isunngua. This paper documents the basic nesting and breeding biology of the species for comparison with apparently ancestral populations in northern Québec, and is the first to provide information on clutch size for this expanding population.

Study area & Methods

Isunngua, Sisimiut Kommune is an area of low arctic continental tundra northeast of the airport at Kangerlussuaq (67°05'N, 50°32'W), directly west of the Ice Cap, in west Greenland. The landscape comprises a gently sloping heavily glaciated plateau, between 200 and 600 m elevation, with many glacial lakes, marshes and streams down to sea level. Terrestrial vegetation is dominated by willow (*Salix glauca*) and dwarf birch (*Betula nana*) scrub, with open *Calamagrostis* spp. grasslands.

Between 16 May and 11 June 2010 we searched for Canada Goose nests by walking around all lakes and marshes within an area of about 60 km^2. The lake terrain was separated into four circuits (mean 15 km) with each circuit sampled at least twice at approximately five day intervals. At each nest site, we recorded nest characteristics, including distance from water (m), height above water (m), number of eggs and a visual assessment of the broad vegetation type (most plants not being in leaf) immediately surrounding the nest. The latitude and longitude of each nest was also recorded along with its altitude (m) onto a GPS. These positions were input into a geographical information system so that nearest neighbour distances between occupied nests could be calculated. Canada Geese have been marked with yellow neck-collars and leg bands in recent years and any marked individuals associated with breeding attempts were recorded at the time of nest finding so that breeding success could be checked later in the season.

Results

A total of 34 Canada Goose nests was found in the study area between 16 May and 11 June, including one from a previous year. Twenty eight nests contained eggs. The mean initiation date was 27 May (range 23 May – 1 June, n = 9) and mean clutch size was 4.57 (range 3-6, n = 21) for nests with known final clutch sizes. Too few nests of known age were found to enable an analysis of the relationship between clutch initiation date, clutch size and hatching success.

Nests were located from 233 to 490 m above sea level (median 360 m, n = 32). All nests were situated on lake shores or islands, averaging 1.84 m from water (median 1 m, range 0.3-10 m, n = 32) and 0.81 m above water level (median 0.5 m, range 0.1-2 m, n = 32). The size of lakes that were nearest to the nests varied greatly averaging 8.5 ha (median 3.3 ha, range 0.09-34.6 ha, n = 33). Most nests (57%, n = 29) were constructed from grass/moss vegetation, the remainder were in *Betula* scrub or grass. Nests averaged 420 m from each other (median 250 m, range 100-2,030 m).

Initial egg survival was high, with 21 nests maintaining their clutch sizes (total 96 eggs) over 206 exposure days. At least 26 nests were still active on 6 June and, in cases where they were revisited thereafter, up to 11 June when fieldwork finished.

Of the 28 nests monitored, at least 13 were tended by pairs in which at least one of the adults was marked with a neck collar, of which 10 pairs were both collared. Eight of these identifiable pairs were not seen in July, whereas five pairs were seen at higher altitude lakes during 15-28 July. In four cases, broods of 1-3 young were seen, with the other pair thought not to have young. If all eggs hatched for these five pairs seen with or without young then there was a failure rate of between 25-100% at the gosling stage, with a mean failure rate of 53% of the eggs overall. Because the broods had moved up to 4 km (straight line distance) from their hatch sites, it cannot be assumed that the breeding attempts of the eight marked pairs that were not seen in July had failed as they may have been rearing their broods on lakes that were not surveyed at that time. The mean brood size of all marked birds encountered in July was 2.92 (n = 13 families). If these broods hatched from nests with mean clutch sizes, this suggests a success rate of 63.9% for those nests. Other pairs seen without young may have failed in their breeding attempt or may not have attempted to nest.

Discussion

It is well demonstrated within North America that clutch size in Canada Geese declines with latitude (Dunn & MacInnes 1987). There is good evidence that the population of *interior* in the vicinity of

Isunngua has originated from the stock that breeds in eastern Hudson Bay as far as northernmost Québec (as far north as 62º30'N) and east into Ungava Bay (Scribner *et al.* 2003). Hence, it might be expected that colonizing Canada Geese breeding in this area of west Greenland (67ºN) would breed less successfully than on the original, more southerly, breeding grounds. Two Canada Geese marked in west Greenland staged in Ungava in spring before returning to the breeding grounds (Scribner *et al.* 2003), so these individuals must have lengthened their spring migration route by c. 1,300 km, with potential fitness costs arising from delaying the start of breeding and with considerable additions to the energetic costs and enhanced risks of prolonged spring migration.

It is therefore a little surprising to find that mean first egg dates in Greenland in 2010, were identical to ancestral Canada Goose populations breeding in Ungava, Québec (27 May 2010; Cotter 2010). In addition, mean clutch size in Greenland was greater than in Québec in 2010 (4.57 vs. 3.80, Cotter 2010). Hence, not only were geese of the same stock initiating breeding at the same time by continuing 1,300 km north, but females were apparently able to enhance reproductive investment under otherwise similar conditions in spring 2010. This apparent paradox may be explained by comparing the mean May temperatures for the two areas (Figure 1), where the May temperature is consistently 2ºC warmer in interior west Greenland than in northern Québec. Hence, by flying north, in most years, *interior* Canada Geese can arrive in warmer conditions than formerly encountered on the traditional nesting grounds of this population. Ironically, despite the apparent risk, this may mean that females can recoup stores of energy faster in west Greenland for the same date than can locally breeding females in Québec. This may contribute to the explanation for the lack of difference in first egg dates and the greater clutch sizes in Greenland. Clutch size in Isunngua was also greater than in *interior* geese nesting in North Indian Lake, Manitoba (mean 4.10, 57ºN, 230 m above sea level (a.s.l.), Raveling 1977) and Cape Churchill, Manitoba (4.10, 58ºN, 10 m a.s.l., Malecki 1976), but similar to those of *interior* sub-species breeding well south at Kinoje Lake, Ontario (4.57, 51ºN, 67 m a.s.l., Raveling & Lumbsden 1977) and less than those of Sutton River, Ontario (5.50, 55ºN, 45 m a.s.l., Hanson 1965).

This project did not rigorously attempt to follow nesting through to hatching, but visits to the same area during the moult period gave some opportunity to assess production of young by nesting collared individuals witnessed earlier in the season. Nest survival in the first two weeks of incubation appeared high, with no known egg or nest losses during the period of observations (which compares with 95% nest survival in Ungava, Cotter 2010). It would be interesting to gather larger sample sizes for clutch size and nest success to compare survival rates between *interior* geese in Canada and Greenland and to understand what effects any differences in predator abundance, nesting habitat and climate may have in the two countries. However, there is no indication that nest survival is any worse in Greenland than in Canada based on data from 2010.

Nest sites were exclusively associated with water; *interior* Canada Goose nests in Isunngua were without exception within 10 m of open water, and very close to water level. This was also the case for *hutchinsii* Canada Geese breeding amongst *frontalis* White-fronted Geese in Kent Peninsula (Bromley *et al*. 1995) where all Canada Goose nests were associated with open water. The consistency of the current study with that conducted in 1998 by Kristiansen & Jarrett (2001) where the attributes of 14 nests found after the breeding season is noteworthy. Kristiansen & Jarrett (2001) recorded a mean nest distance to water of 1.91 m, mean nest height above the water surface of 0.82 m, mean nest altitude of 461 m a.s.l. and mean lake size of 6.6 ha, compared with 1.9 m, 0.8 m, 352 m and 8.5 ha, respectively for the same measures in 2010. Greenland White-fronted Geese do not habitually nest close to water (mean 108 m and 70 m from water, n=8 and n=6, in 1979 and 1984 respectively in studies from Eqalummiut Nunaat, Fox & Stroud 1988), but more often on gently sloping hills or tops of elevations to provide all round visibility (Salomonsen 1950). In this respect, there is little likelihood for direct competition for nest sites between the two species in this part of the range. It should be noted however, that in recent years, Isunngua has only held 0.3% of the total population of Greenland White-fronted Geese, and that the landscapes used by the geese are different further north in west Greenland (e.g. Egevang & Boertmann 2001). For both of these reasons, caution should be exercised as to the extent to which findings from Isunngua can be taken as reflecting conditions further north in the range.

Breeding densities of *interior* Canada Geese in coastal parts of Ungava Bay fell sharply between 1993 and 1994, increased after 1998, and recently declined again since the peak in 2002 (Harvey & Rodrigue 2010). Densities of nesting pairs in the coastal zones along Hudson Bay further south in Québec have increased more dramatically (Harvey & Rodrigue 2010), but it is unclear if density dependent dispersal causing emigration is the reason for continuing increases in the numbers summering in west Greenland. However, the results presented here show that *interior* race Canada Geese colonizing west Greenland from Québec have encountered new nesting habitat that is potentially warmer than the traditional nesting areas at the same time of year, suggesting there are advantages to individuals in continuing to Greenland to breed in these new territories, before taking other factors (such as extent of food supply and abundance and diversity of predators) into account. This hypothesis is supported by the fact that in the same year, first egg dates were the same in Greenland as 1,300 km further south in Canada and clutch sizes were larger. Although we lack detailed studies of nest survival and gosling production, these do not seem substantially different from those in Canada.

Quite why Canada Geese were less abundant in the 1940s and 1950s than is currently the case is not clear, especially if the species, albeit a different race, has long been established in west Greenland (Gotfredsen 2002). It may be that the population size was smaller in former times, but may also be due to the fact that spring conditions in Québec have been far more severe in earlier times than they are now (cf. Figure 1). The results presented here also suggest that, in this limited west Greenland study area, Canada Geese suffer no competition for nesting sites from the endemic Greenland White-fronted Geese. These factors suggest that conditions are very amenable for Canada Geese breeding in west Greenland, which may explain their dramatic increase from relatively few birds in the late 1980s to over 41,000 in 2007 (Fox & Glahder 2010).

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References

Bennike, O. 1990. Observations of geese and other birds in West Greenland 1989 and 1990. *Dansk Ornithologisk Forenings Tidsskrift* 84: 145-150.

Boertmann, D. 1994. An annotated checklist of the birds of Greenland. *Meddelelser om Grønland, Bioscience* 38: 1-63.

Boertmann D. & Egevang C. 2002. Canada Geese *Branta canadensis* in West Greenland: In conflict with Greenland White-fronted Geese *Anser albifrons flavirostris*? *Ardea* 90: 335 - 336.

Boertmann, D. & Glahder, C. 1999. *Grønlandske gåsebestande – en oversigt.* Faglig rapport fra Danmarks Miljøundersøgelser No. 276. 59 pp.

Bromley, R.G., Heard, D.C. & Croft, B. 1995. Visibility bias in aerial surveys relating to nest success of arctic geese. *Journal of Wildlife Management* 59: 364-371.

Cotter, R. 2010. *Atlantic Population Canada Geese-Ungava Peninsula 2010 Preliminary Report: Recruitment.* Report to Atlantic Flyway Technical Committee. Canadian Wildlife Service-Québec Region, Sainte Foy.

Dunn, E.H. & MacInnes, C.D. 1987. Geographic variation in clutch size and body size of Canada Geese. *Journal of Field Ornithology* 58: 355-371.

Egevang, C. & Boertmann, D. 2001. The Greenland Ramsar Sites of Disko: a status report. National Environmental Research Institute Report No. 368. 78 pp. http://www2.dmu.dk/1_viden/2_Publikationer/3_fagrapporter/rapporter/FR368.pdf

Fox, A.D. & Stroud, D.A. (Eds.). 1981. *Report of the 1979 Greenland White-fronted Goose Study Expedition of Eqalungmiut Nunât, west Greenland.* Greenland White-fronted Goose Study, Aberystwyth. 319 pp.

Fox, A.D. & Stroud, D.A. 1988. The breeding biology of the Greenland White-fronted Goose *Anser albifrons flavirostris*. *Meddelelser om Grønland, Bioscience.* 27: 1-16.

Fox, A. D., Glahder, C.M., Mitchell, C.R., Stroud, D.A., Boyd, H. & Frikke, J. 1996. North American Canada Geese (*Branta canadensis*) in West Greenland. *Auk* 113: 231-233.

Fox, A. D., Stroud, D.A., Walsh, A.J., Wilson, H.J., Norriss, D.N. & Francis, I.S. 2009. A review of changes in abundance of the Greenland White-fronted Goose *Anser albifrons flavirostris* since 1982. *Die Vogelwelt.* 129: 317-325.

Fox, A.D. & Glahder, C.M. 2010. Post-moult distribution and abundance of white-fronted and Canada geese in West Greenland in 2007. *Polar Research* 29: 413-420.

Gotfredsen, A.B. 2002. Former occurrences of geese (Genera *Anser* and *Branta*) in ancient West Greenland: morphological and biometric approaches. In: Proceedings of the 4th Meeting of the International Council for Archaeozoology Bird Working Group, Kraków, Poland, 11-15 September 2001. *Acta zoological cracowiensis* 45 (special issues): 179-204.

Hanson, H. 1965. *The Giant Canada Goose*. Southern Illinois University Press, Carbondale.

Harvey, W.F. & Rodrigue, J. 2010. A breeding pair survey of Canada Geese in Northern Québec – 2010. Report of the Maryland Department of Natural Resources, Annapolis. Accessible at: http://www.dnr.state.md.us/wildlife/Hunt_Trap/pdfs/2010_APCanadaGoose_PairSurvey.pdf (last accessed 26 April 2011).

Kristiansen, J.N., Fox, A.D. & Jarrett, N.S. 1999. Resightings and recoveries of Canada Geese ringed in West Greenland. *Wildfowl* 50: 199-203.

Kristiansen, J. N. & Jarrett, N.S. 2001. Nest sites of the newly established Canada Goose population in West Greenland. *Dansk Ornithologisk Forenings Tidsskrift* 95: 173-176.

Kristiansen, J. N. & Jarrett, N.S. 2002. Inter-specific competition between Greenland White-fronted Geese *Anser albifrons flavirostris* and Canada Geese *Branta canadensis interior* moulting in West Greenland: mechanisms and consequences. *Ardea* 90: 1-13.

Levermann, N. & Raundrup, K. undated. *Do the Greenland white-fronted geese stand a chance against the invasive Canadians?* Unpublished report, Biologisk Institut, Copenhagen University.

Lyngs, P. 2003. Migration and winter ranges of birds in Greenland. *Dansk Ornitologisk Forenings Tidsskrift* 97: 1-167.

Malecki, R. A. 1976. *The breeding biology of the Eastern Prairie Population of Canada Geese*. Dissertation, University of Missouri, Columbia, USA.

Malecki, R.A., Fox, A.D. & Batt, B.D.J. 2000. An aerial survey of nesting Greater White-fronted and Canada Geese in west Greenland. *Wildfowl* 51: 49-58.

Raveling, D.G.1977. Canada Geese of the Churchill River Basin in North-central Manitoba. *Journal of Wildlife Management* 41: 35-47.

Raveling, D.G. & Lumbsden, H.G. 1977. Nesting ecology of the Canada Geese in the Hudson Bay Lowlands of Ontario: evolution and population regulation. *Fish and Wildlife Research Report* 98: 1-77.

Salomonsen, F. 1950. *Grønlands Fugle. The Birds of Greenland*. Munksgård, Copenhagen.

Salomonsen, F. 1967. *Fuglene på Grønland*. Rhodos, Copenhagen.

Scribner, K.T., Malecki, R.A., Batt, B.D.J., Inman, R.L., Libants, S. & Prince, H.H. 2003. Identification of the source population for Greenland Canada Geese: genetic assessment of a recent colonization. *Condor* 105: 771-782.

Stroud, R.A. 2011. A study of interactions between moulting Canada Geese, *Branta canadensis interior* and Greenland White-fronted Geese, *Anser albifrons flavirostris* at different temporal and spatial scales in Isunngua, West Greenland. Unpublished B.Sc. thesis, University of Wales, Bangor.

FIGURE

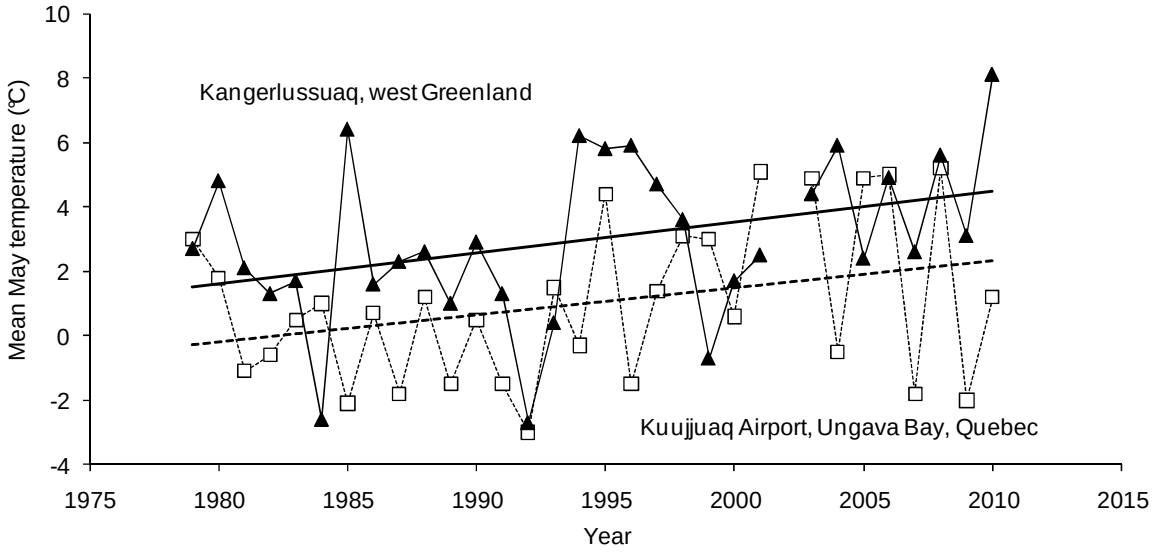

Figure 1. Mean May temperatures for Kangerlussuaq, west Greenland (solid triangles, 67º01'N 50º42'W, downloaded from: http://www.tutiempo.net/en/Climate/Sdr_Stroemfjord/42310.htm) and from Kuujjuaq Airport, Quebec (open squares, 58º06'N 68º41'W, downloaded from http://www.tutiempo.net/en/Climate/Kuujjuaq/719060.htm). Lines show fitted regression models to both sets of data, the solid line indicating Kangerlussuaq, the dashed line, Kuujjuaq.

Appendix 6

Post breeding movements of marked Canada Geese seen during May to July, 2010.

Movements of marked birds, either singly or as part of a pair, greater than 1 km, involved straight line distances of up to 4 km (Figure 34; for reasons of mapping clarity only the movement of GL9 of nearly 2 km from west to east within Sanningasoq over two days in May is not shown). Adults (with goslings if they successfully bred), moved from the more lowland nesting lakes to specific lakes above 500 m, with lakes N, M and X proving particularly attractive as moult locations for ringed geese.

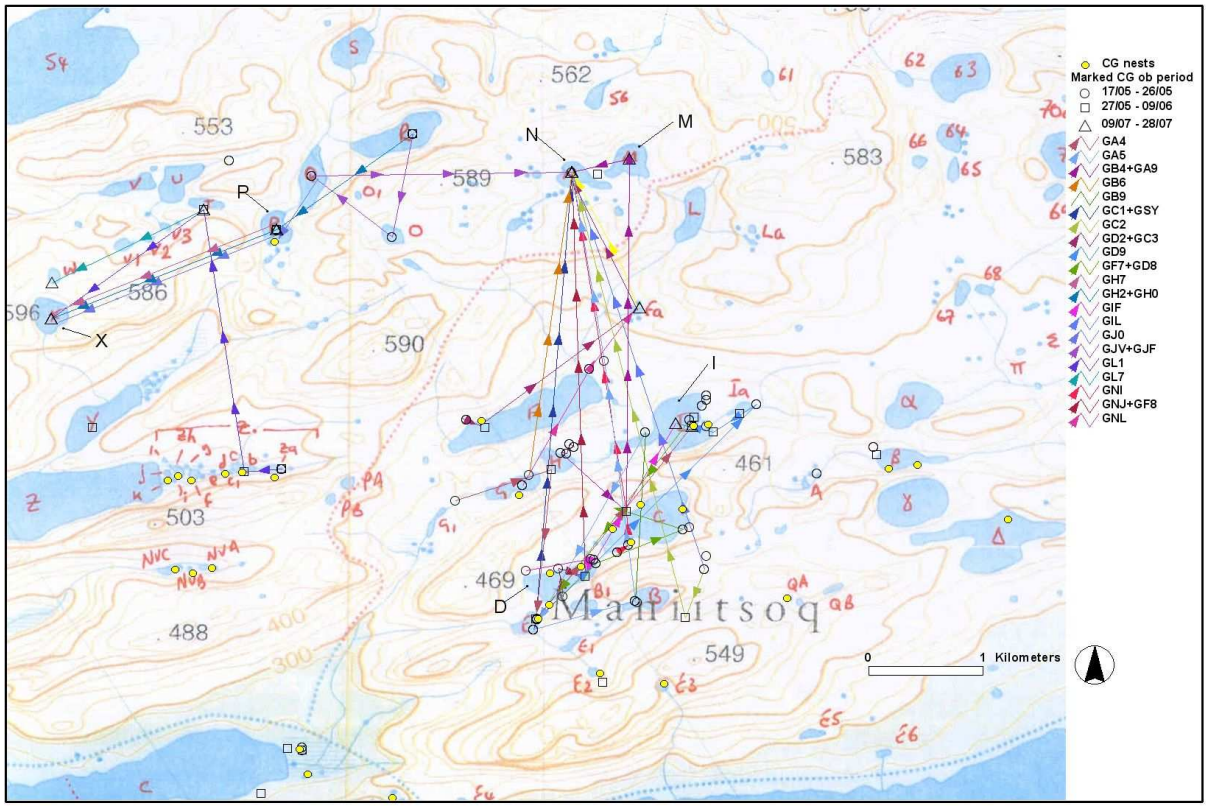

Figure 34. Post breeding movements of Canada Geese in Isunngua between nesting sites and moult sites.

The reduction in number between the mean number of eggs laid in each clutch (4.57) and the mean number of goslings seen per brood in July (2.92; values from Appendix 6) might be related to predation pressure experienced during these substantial movements, as the birds travelled across land. It appears that over the period of a month, judging by the sites at which marked Canada Geese were observed, the breeding areas in the lowlands had largely been vacated.