Post-moult distribution and abundance of white-fronted geese and Canada geese in West Greenland in 2007

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Abstract

Rapid increases in North American Canada geese (*Branta canadensis*) summering in West Greenland since the mid-1980s compare with declines in the endemic population of white-fronted geese (*Anser albifrons flavirostris*) nesting in the same region since 1999 (wintering in Europe). To provide information on the distribution and abundance of the two species in Greenland during the prelude to the autumn migration back to winter quarters, we here report on the first ever post-moult aerial surveys of West Greenland between 64° and 73°N (from regular transects and transit reconnaissance flights in August 2007), which located 1888 Greenland white-fronted geese and 6071 Canada geese. Strip transect surveys found 733 Greenland white-fronted geese and 1318 Canada geese in the 993 km^2 surveyed, which, given a white-fronted goose global population of 23 200 in winter 2007/08, suggests more than 41 500 Canada geese in West Greenland post-moult in 2007. Virtually no geese were found south of 66°N. The Eqalummiut nunaat–Nassuttuup nunaa and Naternaq Ramsar wetlands of international importance, and lowland Disko Island, Saqqaqdalen and Svartenhuk supported the highest densities of both species. Results confirmed that areas important for both species during spring, nesting and moulting periods retain high densities of post-moulting geese. Canada and white-fronted geese rarely occurred together within 2.5 km × 400 m transect sectors, as found during breeding surveys. Only in western Svartenhuk and western Disko were there Canada goose concentrations that could potentially support an intensive autumn hunt, whilst avoiding disturbance to white-fronted geese.

Agricultural monocultures of selectively bred cereals, root crops and highly nutritious grasses now dominate extensive areas of temperate Europe and North America, providing artificial winter food to Arctic-nesting geese (van Eerden et al. 2005). As a result, many goose populations have expanded in abundance and range since the 1970s (e.g., Madsen et al. 1999; Abraham et al. 2005; van Eerden et al. 2005), increasing overlap in time and space throughout the annual cycle, where allopatry was formerly common, and enhancing interspecific interactions (Madsen et al. 1999). At specific bottlenecks in the annual cycle, unevenness in the ability to exploit limited resources may affect the distribution and abundance of one co-occuring species over another, and potentially affect fitness components (Newton 1998; Keddy 2001). Behavioural dominance of one goose species over another sympatric species may affect feeding behaviour, distribution and/or access to favoured food items of the less dominant species, leading to local displacement.

Greater Canada geese (*Branta canadensis*) have colonized West Greenland from North America, as a breeding species and moult migrant. A rare, but regular, breeding summer visitor before 1980, the species is now abundant between 66° and 70°N in West Greenland (Salomonsen 1981; Boertmann 1994; Fox et al. 1996; Malecki et al. 2000). Colonizers apparently originate from the North Atlantic population (*B. canadensis interior*) breeding in northern Quebec (Scribner et al. 2003). Ringing and telemetry studies show that they migrate via Labrador to winter along the Atlantic seaboard of the USA (Kristiansen et al. 1999; Scribner et al. 2003). Canada geese are behaviourally dominant over the endemic Greenland white-fronted geese (*Anser albifrons flavirostris*) during the flightless moult period when access to food becomes potentially limiting (Kristiansen & Jarrett 2002). The colonization of Greenland by Canada geese (with a mean adult body mass during moult of ca. 3.2 kg) wintering in Atlantic coast North America could potentially affect the abundance of the smaller white-fronted geese (ca. 2.5 kg) wintering in western Europe. Although hard evidence for competition on a larger scale or in a way that may affect the reproductive output in the Greenland white-fronted goose is lacking, it remains important to monitor the development of the Canada goose population in West Greenland.

Following the population expansion achieved under legislation protecting geese from winter hunting in Ireland and the UK during the period 1982–1999, white-fronted geese summering in West Greenland have declined from ca. 35 600 in 1999 to 23 200 individuals in 2008 (Fox et al. 2006; Fox et al. 2008). Since 1999, low reproductive success has failed to replace annual mortality losses, although there is no consistent evidence that increasing interspecific competition or enhanced predation rates of nesting attempts have been behind the phenomenon. Several explanations have been put forward to account for reductions in reproductive output, with most centred on the condition of females. Elevated disease or parasite burdens seem unlikely (Fox et al. 2006), but recent low reproductive output apparently correlates with the heavier spring snowfall (which delays reproduction) experienced since 1995 (Boyd & Fox 2008).

The geographical distribution of both species was described prior to 1999 (Fencker 1950; Fox & Stroud 1988; Kristiansen et al. 1999). However, the relative densities throughout West Greenland were unknown prior to the systematic aerial surveys of breeding pairs undertaken in 1999, and repeated in 2005 (Malecki et al. 2000; Fox & Glahder unpubl. ms), which found the highest densities of both species between 66°55′N and 67°30′N, and found very few pairs further south and only locally in suitable habitat north of Nuussuaq (70°30′N; see Figs. 1, 2 for place names). Neither species have been surveyed post-moult, when both species must deposit fat stores in preparation for autumn migration to winter quarters. For this reason, a late summer survey was undertaken in August 2007 to map the distribution and abundance of both species, to compare with midsummer nesting surveys, and to identify important goose areas during the post-moult and premigration period, and provide a baseline for comparisons with future surveillance programmes. An autumn Canada goose hunt in West Greenland may offer a harvestable resource as well as a potential means to limit numbers, should it be shown that the increase in this colonizing species is having a deleterious effect on the endemic white-fronted goose. Hence, a secondary objective was to assess the degree of segregation of the two species with a view to the geographic potential for implementing a Canada goose hunt without adverse effects on the native species.

Methods

Transects were flown at 200–230 km h^{-1} at 25–36 m above the ground using a specially adapted twin-engined Partenavia Observer aircraft, with a Plexiglas dome for forward observations and bubble observation windows to either side. Short sections of the survey transects were unavoidably flown at up to 120 m above ground level over difficult terrain. Two observers seated (1) to the right of the pilot and (2) immediately behind him recorded all goose observations, as single birds, pairs or groups of individuals, and the perpendicular distance to the individual or cluster was measured using the angle of declination from the horizontal with a hand-held inclinometer. Details were spoken onto a dictaphone tape with the precise observation time, which was synchronized with the clock on a GPS that tracked the course of the aircraft for the survey duration, recording the position of the aircraft every 5 seconds. After transcription to a spreadsheet, timed events were converted to a latitude/longitude position using a bespoke PASCAL program. Declination angles for all observations were also converted geometrically to distance from the track line based on a flight altitude of 30 m, and entered on the database. We planned to correct our observations for the decreasing detectability of geese with distance using distance sampling software (Thomas et al. 2006), but found little evidence of distance detection bias in the first 200 m from the observation platform, and effects out to 300 m were weak (as found elsewhere; Certain & Bretagnolle 2008). Furthermore, because 1999 data were collected using a strip transect approach (counting all geese within the first 200 m of the aircraft and assuming complete detection within this area; Buckland et al. 2001), the data we present here are based on all records within the first 200 m out from the track line for comparative treatment with the earlier surveys. We also used these data to compare the presence/absence of one or both species on the entire transect length and in 2.5-km lengths along each transect to test whether both species were more or less likely to occur together with each other than would be expected by chance at a local (2.5-km transect lengths) and larger (entire transect) scale using simple χ^2 contingency tables (after Malecki et al. 2000).

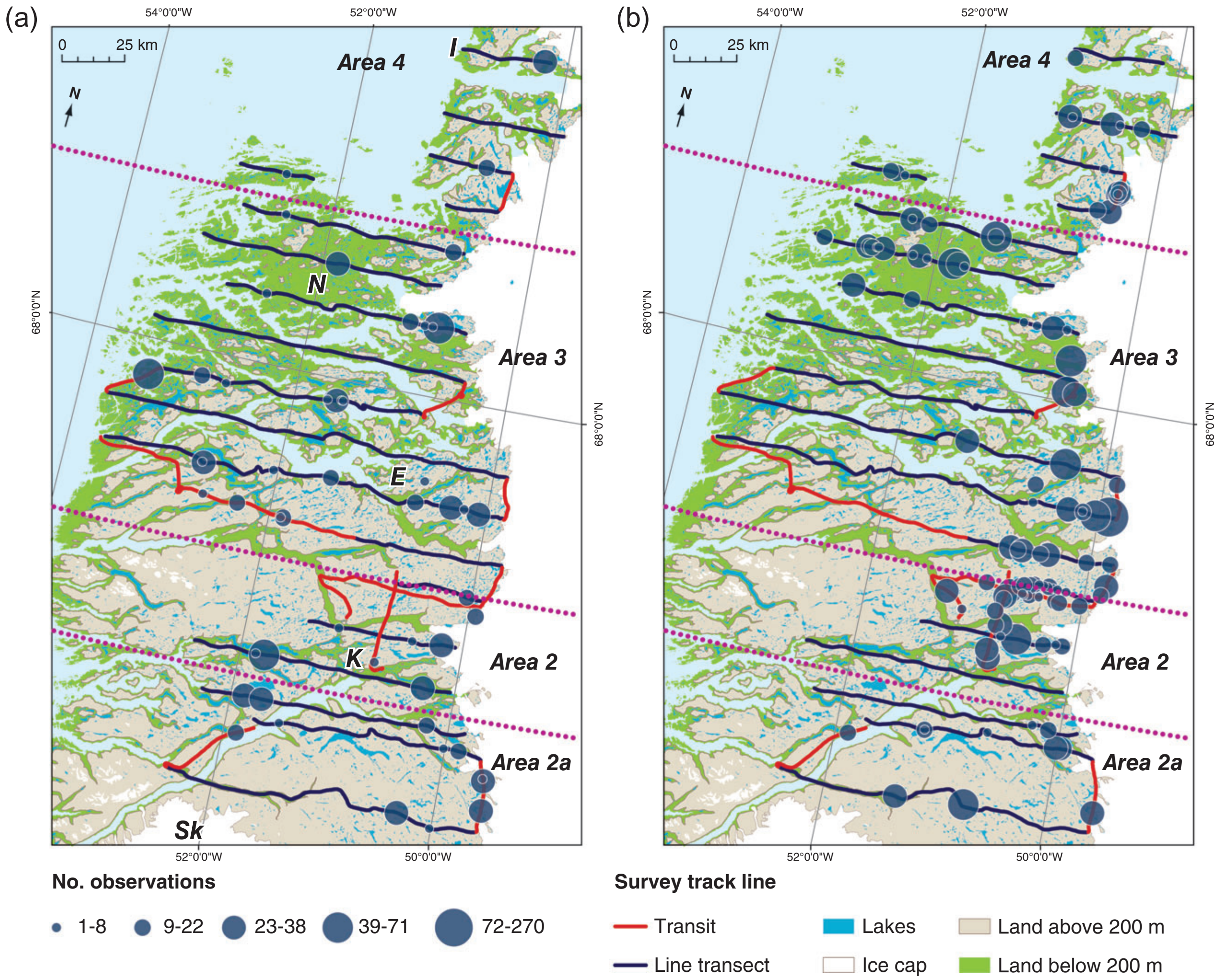

Fig. 1 Map showing the distribution of encounters of all (a) white-fronted geese (*Anser albifrons flavirostris*) and (b) Canada geese (*Branta canadensis*) during surveys undertaken in August 2007 between 66°15′ and 69°30′N in the West Greenland study area. The transects used in the study, falling in areas 2 and 3, and part of area 4 (defined by red dotted lines), are as described by Malecki et al. (2000). Transect lines are marked in black; low-level transit flights where geese were encountered between transects are indicated in red. Abbreviations indicate places named in the text, as follows: E, Eqalummiut nunaat–Nassuttuup nunaa; I, Ilulissat; K, Kangerlussuaq; N, Naternaq; Sk, northern fringe of the Sukkertoppen ice cap.

Surveys were flown on 14, 15, 17, 18, 20 and 22 August 2007, covering areas 2, 3 and 4 (for survey areas covered in 1999, see Malecki et al. 2000), under similar weather conditions, as well as part of area 1, covered in connection with an environmental assessment programme associated with the potential construction of an aluminium smelter in the area to the south (Johansen et al. 2008).

Results

Overall numbers and distribution

Survey coverage and distribution of all Canada and white-fronted geese are shown both on transect and during low-level transit flights in Figs. 1 and 2. In all, 6071 Canada geese and 1888 white-fronted geese were encountered, of which 1318 and 733, respectively, were within 200 m of the aircraft along 2483 km of transect lines flown. Canada geese occurred in greatest numbers in Svartenhuk (71°N), Saqqaqdalen (southern Nuussuaq, 70°N) and throughout Disko Island (69–70°N), but were also very common throughout the mainland south-east of Disko Island, in Naternaq (68°N), and in the interior region closest to the ice cap south of Naternaq, especially just north of Kangerlussuaq, at ca. 67°N. White-fronted goose numbers were considerably sparser, with large numbers in eastern Svartenhuk, a large group on Ubekendt Ejland and in Saqqaqdalen, as well as lower densities in Naternaq and the interior area south as far as just south

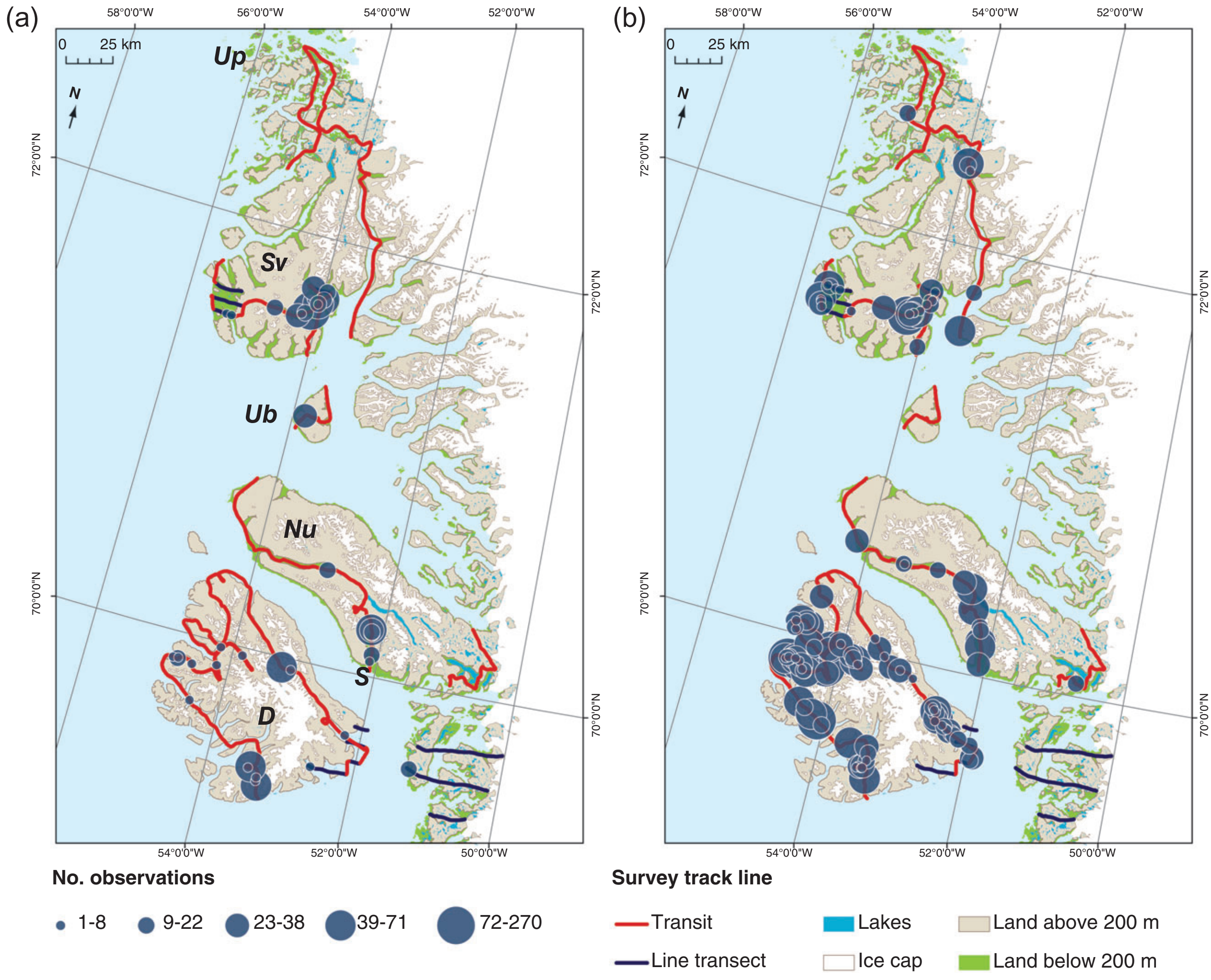

Fig. 2 Map showing the distribution of encounters of all (a) white-fronted geese (*Anser albifrons flavirostris*) and (b) Canada geese (*Branta canadensis*) during surveys undertaken in August 2007 between 69°30′ and 72°54′N in the West Greenland study area. All transects fall in area 4 as described by Malecki et al. (2000). Transect lines are marked in black; low-level transit flights where geese were encountered between transects are indicated in red. Abbreviations indicate places named in the text as follows: D, Disko Island; Nu, Nuussuaq Peninsula; S, Saqqaqdalen; Sv, Svartenhuk; Ub, Ubekendt Ejland; Up, Upernavik.

of Kangerlussuaq. Only 40 Canada geese were seen south of 66°N (32 in a single flock during transit); no white-fronted geese were seen this far south, so data are not plotted here.

Distribution on transects

The highest Canada goose densities were encountered in area 2, especially from Kangerlussuaq to Eqalummiut Nunaat (67–68°N), but densities were generally high (exceeding 1.25 birds km^{-2}) in all survey areas except area 1 (Table 1). Densities of white-fronted geese were highest in area 4, where they were double those found elsewhere; none were present in area 1 (Table 1).

Degree of association between the species

Occurrence of the two species differed significantly from the null hypothesis of complete association at the transect level ($\chi^2 = 5.41$, df = 1, $P < 0.05$) and that of dissociation ($\chi^2 = 41.6$, df = 1, $P < 0.05$). The distributions did not differ significantly from the null hypothesis of an even spread over transects where one or the other of the species occurred ($\chi^2 = 0.18$, df = 1, $P > 0.05$). On the individual count unit level (2.5-km segments), the mutual occurrence of the two species differed significantly from that expected under the null hypothesis of association ($\chi^2 = 45.1$, df = 1, $P < 0.05$) and of even distribution of the species where one or other occurs ($\chi^2 = 14.8$, df = 1,

Table 1 Summary results from the 2007 post-moulting aerial survey of geese in West Greenland. Numbered areas refer to those defined by Malecki et al. (1999), excluding area 2a (see Fig. 1), which was not covered in that survey. Columns show the number of transects flown in each area, the distance flown on the transect and the effective area covered out to 200 m either side of the aircraft, and the numbers of geese and their density encountered. Columns also indicate the percentage distribution of the totals between the five areas.

	Number of transects	Flown transect length (km)	Total census area covered (km^2)	Total white-fronted geese	Total Canada geese	% White-fronted geese in each area	% Canada geese in each area	White-fronted goose densities	Canada goose densities
Area 1	11	640.7	256.3	0	8	0	0.6	0	0.03
Area 2a	3	338.0	135.2	118	172	16.1	13.1	0.87	1.27
Area 2	4	260.9	104.3	73	326	10.0	24.7	0.70	3.12
Area 3	9	916.0	366.4	327	619	44.6	47.0	0.89	1.69
Area 4	14	327.6	131.0	215	193	29.3	14.6	1.64	1.47
Totals	41	2483	993	733	1318	100.0	100.0	0.74	1.33

$P < 0.05$), but there was no significant difference between the observed distributions and that expected if the species showed complete dissociation on this level ($\chi^2 = 0.0001$, df = 1, $P > 0.05$).

Discussion

After the wing moult, migratory geese must rapidly accumulate energy stores and potentially reconstruct body parts (such as heart and flight musculature) to migrate back to wintering quarters. Greenland white-fronted geese must cross the Greenland ice cap and open sea to stage in Iceland on the 2000–3000 km autumn migration to Ireland and the UK (Fox et al. 2003). Canada geese in West Greenland migrate 3000–4000 km to winter in the eastern USA, from Connecticut south to Maryland (Kristiansen et al. 1999). Greenland white-fronted geese cross the ice cap and Denmark Strait, and Canada geese cross Davis Strait, so neither can refuel on the first ca. 1500 and 1000 km, respectively. Both populations require undisturbed access to energy rich food at this time, and knowledge of the extent and use of areas exploited is important to their future management.

Overall numbers and distribution

Both species were encountered in greater numbers than in the June surveys (Malecki et al. 2000; Fox & Glahder, unpubl. ms), presumably as a result of greater aggregation into post-breeding flocks and less cryptic behaviour (compared with during nesting). We urge prudence in calculating goose densities from the transect data presented here because of the mobility of the geese at this time of year (unlike when pairs associate with nest sites in June), and the likelihood of differential detection probabilities of the two species may also affect measures of relative abundance on transect. Nevertheless, the ratio of 1318:733 Canada geese to white-fronted geese on transect potentially suggests there could be in excess of 41 500 Canada geese in West Greenland, given a global population of 23 200 Greenland white-fronted geese in the region surveyed (based on winter 2007/08 census data [Fox et al. 2008] and an equal probability of detecting both species). This is probably a conservative estimate, given the overall ratio of 6071:1888, including all transit flight observations, especially given the high August 2007 densities of Canada geese encountered off transect on Disko Island, where white-fronted geese were relatively scarce.

Differences in distribution compared with other periods of the summer

Canada and white-fronted goose distributions closely resembled that of both species from June surveys of breeding pairs (Malecki et al. 2000; Fox & Glahder, unpubl. ms). Areas south of Nuuk were not surveyed (no geese were found here in 1999, and there have been no reports since Malecki et al. 2000). Coverage from the Nordland Peninsula north of Nuuk Fjord north to the southern edge of the Sukkertoppen ice cap at 66°N found only two groups of Canada geese during 4 hours 18 minutes of transect and transit survey. Much of the northern section from 65° to 66°N suffers late spring lie, and is of relatively high altitude, with sparse vegetation and little attraction for feeding geese. Nordland Peninsula is richly vegetated and superficially looks attractive to geese, but experiences late snow cover in spring, and as in earlier surveys, supported no geese in 2007. The highest Canada goose densities were found inland from Kangerlussuaq (67°N) north to Naternaq and Ilulissat, which experiences a continental climate because of the geoclimatic effects of the proximity of the inland ice. This area hosts the highest breeding white-fronted goose densities (Malecki et al. 2000; Fox & Stroud 2002), although this species occurred out to the coast during the August 2007 survey, where Canada geese were absent (Fig. 2). Large numbers of Canada geese were seen in Naternaq and surrounding lowland areas out to the coast, where lesser numbers of white-fronted geese were also present. Both Eqalummiut nunaat–Nassuttuup nunaa (5000 km^2) and Naternaq (1500 km^2) are protected as Ramsar sites for their importance for summering white-fronted geese. Very few geese of either species were found on the mainland east of Disko Island, confirming earlier observations from spring staging, nesting and moulting surveys, but dense concentrations of Canada geese were present in Disko Island lowlands (with fewer white-fronted geese). Goose densities were high in Saqqaqdalen, but low in the central valley of Nuussuaq where large moulting concentrations, formerly of white-fronted geese (Glahder 1999) and latterly of Canada geese, have been reported (Boertmann 2004). The lack of geese here in August 2007 could result from a lack of suitable heathy, berry-bearing vegetation to support feeding geese post-moult, or could be a consequence of active mining exploration in summer 2007, especially at the western end where the fewest geese were seen. Large concentrations of Canada geese occurred in the lowland Svartenhuk Peninsula, with large numbers of white-fronted geese on the eastern side. Few Canada geese were encountered north of Svartenhuk during a brief reconnaissance of lowland areas south of Upernavik.

This pattern confirms areas previously identified as important for white-fronted geese during spring, nesting and moult periods, hold high post-moult densities of these and Canada geese, suggesting no major redistribution after the fledging of the young and the moult of the adults (Fox & Stroud 2002). The current extent of Ramsar sites therefore effectively covers the main areas used by post-moulting geese, but parts of Svartenhuk, Disko, Saqqaqdalen and Nuussuaq Peninsula (known to hold significant concentrations of geese at other times in summer) should be surveyed for the designation of further areas that qualify for Ramsar designation on the strength of moult and post-moulting concentrations that exceed international importance.

Habitat considerations

Although impossible to determine habitat use from the air, geese move onto heaths in late summer post-moult to feed on *Vaccinium uliginosum* berries (which grow on dry, sunny, well-drained soils) and especially *Empetrum hermaphroditum* fruit (which is often dominant or co-dominant on north-facing moss-rich slopes and late snow beds). White-fronted geese shot near Kangerlussuaq contained abundant berries in the oesophagus and crop in late August and early September (A. Reenberg, pers. comm.). It seems likely that post-moult, Greenland white-fronted geese switch to other habitats within the same summer range (namely berry-rich heaths) rather than moving between geographical areas post moult. This may not be the case where white-fronted geese were encountered between 67° and 68°N out towards the coast, in areas where this species has not been reported during earlier surveys, although they were reported doing so at the time of Salomonsen (1950). Generally, survey results suggested that Canada geese are distributed in a similar way, selecting similar areas to the indigenous white-fronted geese, which they now dominate numerically in West Greenland. Densities were especially high in the interior between 67° and 69°N, but the species was abundant everywhere where suitable goose habitat existed.

Degree of association between the species

Canada and white-fronted geese were distributed evenly throughout the flown areas, but rarely occurred together when distributions were analysed by 2.5 km × 400 m transect lengths, confirming segregation (potentially mutual avoidance) on a very local scale, as detected during both previous summer nesting surveys. The effect was insufficient to create single species concentrations that offered potential for an autumn Canada goose hunt, whilst avoiding disturbance to white-fronted geese. Nevertheless, Fig. 1 shows that in areas of western Svartenhuk and on the west side of Disko Island, Canada geese aggregate in large flocks where few white-fronted geese were encountered. This suggests the possibility of hunting Canada geese in these areas without adversely affecting the other species in these areas. Another August survey of these two areas should be undertaken to verify this situation before such a hunt can be recommended.

These surveys also provide an important baseline for future comparisons given the rapid increases in Canada geese since the mid-1980s, compared with the unfavourable conservation status of the Greenland white-fronted goose since 1999.

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