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Effects of disturbance on geese in Svalbard: implications for regulating increasing tourism

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Abstract

Tourism in the Arctic archipelago of Svalbard, Norway, has increased significantly in the last decade. Cruise ships make landings all around the archipelago, and there are numerous snowmobile, boat and hiking excursions. We describe disturbance effects on the three geese species that breed in Svalbard: the pink-footed goose (*Anser brachyrhynchus*), the barnacle goose (*Branta leucopsis*) and the light-bellied brent goose (*Branta bernicla hrota*). All three are regarded as highly vulnerable to disturbance. Behavioural responses by geese to humans on foot were analysed by estimating the distances at which geese become alerted, the escape flight distances and the length of escape flights, during pre-nesting, nesting and brood-rearing periods. We evaluate the consequences of human intrusion on the reproductive success in breeding colonies. During all three phases, pink-footed geese responded at longer ranges, and flew/ran longer distances, than both brent and barnacle geese: when disturbed on the nest site, both male and female pink-footed geese flew far away, resulting in a high rate of nest loss to avian predators (35%), compared with the 4 and 0% losses among barnacle and brent geese, respectively. During brood rearing, families of pink-footed geese escaped at an average distance of 1717 m, compared with distances of 620 and 330 m for brent and barnacle geese, respectively. Even though bird sanctuaries have been established on several islets, with no human access during nesting, many core areas for the three species remain without restrictions, such as islets used by brent geese and slopes and valleys with nesting pink-footed geese, brood-rearing areas and moulting grounds for non-breeding geese. We propose regulations of human access to goose concentration areas, and address the need to better protect these significant areas. We also discuss the need for further research on the vulnerability of geese to human activity.

As a result of Norwegian political incentives to encourage the development of tourism as the primary business activity in Svalbard, tourism in the area has increased during recent decades in terms of boat and snowmobile trips organized by tour operators, as well as individual excursions not arranged by tour operators (Governor of Svalbard 2006). Furthermore, there has been an increase in research and educational activities in the area through the creation of research facilities, in the settlements of Ny-Ålesund and Longyearbyen in particular. However, there is limited information about the disturbance effect of these human activities on the fauna of Svalbard (review by Overrein 2002; Andersen & Aars 2008; Vistad et al. 2008) or the Arctic in general, except for some studies of the effects of relatively localized industrial development (e.g., Madsen 1984; Wolfe et al. 2000; Johnson et al. 2005).

Geese are regarded as one of the species groups that are most vulnerable to disturbance (Overrein 2002). Three species breed in Svalbard: the pink-footed goose (*Anser brachyrhynchus*), the barnacle goose (*Branta leucopsis*) and the light-bellied brent goose (*Branta bernicla hrota*). They constitute three distinct populations, wintering in different areas in north-west Europe (Madsen et al. 1999). All three populations have experienced increased population sizes in recent decades, but still remain small in comparison with other western Palearctic goose populations. The three species breed in different parts of Svalbard, with a partial spatial overlap occurring during parts of the breeding season (Mehlum 1998). The three species also exhibit specific characteristics in terms of habitat use and behaviour (Fox et al. 2006; Fox et al. 2007). As a consequence, they have a different exposure and vulnerability to human activity, which, in turn, means that disturbance effects and potential consequences for the populations may vary. Even though many of the geese breed in reserves or national parks in Svalbard, in which human access is strictly regulated, geese are increasingly exposed to human disturbance, partly because they breed or moult in areas without regulations, and partly because restrictions may not be sufficient in the existing reserves.

In this paper we describe the ecology of the three goose species, and assess the spatial and temporal overlap between recreational activities and geese in Svalbard during the summer. We evaluate the potential effects of tourism on geese in terms of the behaviour and reproductive output of the birds, and propose guidelines to regulate tourism and other human activities that may otherwise conflict with the long-term conservation of geese in Svalbard.

We define disturbance as any human activity that constitutes a perceived predation risk that is sufficient to disrupt normal activities (Frid & Dill 2002). Furthermore, we distinguish between disturbance effects, i.e., changes in behaviour or local displacement in response to human activity, and impacts, i.e., fitness consequences of disturbance in terms of reduced body condition, reproductive potential or survival.

Material and methods

Study populations

Pink-footed goose. The Svalbard breeding population of pink-footed geese winters in Denmark, the Netherlands and Belgium. In spring, the population migrates via Norwegian stopover sites to the breeding grounds. The population size has increased from ca. 20 000 in the 1970s to a hitherto unprecedented peak of ca. 60 000 in 2007 (Madsen et al. 1999; Madsen unpubl. data). On arrival in Svalbard in mid-May, the geese spend around one week intensively foraging before they start laying eggs. Adventdalen in Isfjorden is a major pre-nesting site, from where the geese disperse to the nesting grounds (Fox et al. 2006; Glahder et al. 2006). The geese nest in the lowland open tundra areas, preferring south-facing slopes and slopes under bird cliffs (Mehlum 1998; Madsen et al. 2007; Wisz et al. 2008). In Svalbard, the distribution is concentrated in western Spitsbergen, with small colonies occurring in the north and south of Spitsbergen, as well as on the west side of Edgeøya. The present distribution seems to be limited by the length of the frost-free period during summer (Jensen et al. 2008). After hatching, families feed in lowland marshes and moss fens, under bird cliffs, and often move far inland, away from open water (Jepsen et al. 2002; Fox et al. 2007; Fox et al. 2009; Madsen unpubl. data). Some non-breeding pink-footed geese migrate to the east and north-east of Svalbard, where they congregate in flocks along the coast to moult flight feathers from late June to late July; some non-breeders stay within the breeding range, and congregate on larger lakes, rivers and along the shoreline (Mehlum 1998; Glahder et al. 2007; Madsen unpubl. data). Little information exists about the distribution of pink-footed geese prior to autumn departure, but it seems that large flocks congregate in the northern fjords of Spitsbergen, in the lowlands along the west coasts, especially under bird cliffs, and in the lowlands of Edgeøya and Barentsøya (Mehlum 1998; Glahder et al. 2007).

Barnacle goose. The Svalbard breeding population of barnacle geese winters in south-west Scotland/north-west England, with spring staging areas along the west coast of Norway. The population numbered less than 1000 individuals during the 1950s, but increased to around 14 000 at the start of the 1990s (Owen & Black 1999). Since 2000, the population has increased to reach a level of around 25 000–30 000 (Griffin & Mackley 2004). During the second half of May, barnacle geese arrive along the west coast of Svalbard, with known major pre-nesting congregation sites in Hornsund and Vårsolbukta (Glahder unpubl. data; Hübner 2006). Barnacle geese nest on islets along the west coast of Spitsbergen, in Storfjorden and Hinlopen. Many colonies have been established on cliffs along coasts and in valleys. Brood-rearing areas are found in association with coastal lagoons and lakes, and families stay in close proximity to open water to avoid predation by Arctic foxes (*Vulpes lagopus*). Some of the oldest colonies and associated brood-rearing areas along the west coast have reached saturation, with an apparent density-dependent regulation of bird numbers (Loonen et al. 1997; Drent et al. 1998). Non-breeding barnacle geese congregate in separate flocks, but appear to remain within the breeding range. During late summer, large flocks occur in several places in the lowlands along the west coast of Spitsbergen (Mehlum 1998).

Light-bellied brent goose. The Svalbard breeding population of light-bellied brent geese is part of the north-east Atlantic flyway population, which also breeds in low numbers in north-east Greenland, and winters in Denmark and north-east England. The brent goose was probably the most numerous of the three species at the beginning of the 20th century, but the population then crashed, and numbered only 2000–4000 individuals in the 1960s. The species is classed as being near threatened in the Norwegian Red List (Kålås et al. 2006). Subsequently, the population has increased to reach a population size varying between 6000 and 9000 in 2000–07 (Clausen et al. 1999; Clausen unpubl. data). In Svalbard, the pre-nesting congregation sites used during the last week of May occur on the west coast. The majority of brent geese nest in small colonies in Tusenøyane in south-east Svalbard, on Moffen in the north and are scattered on islets along the west coast. In addition, small numbers of nests have been found in the interior valleys in Spitsbergen, close to the glaciers (Madsen unpubl. data). In Tusenøyane, families stay on the islets, feeding along the shorelines or in moss carpets around ponds. Flocks of non-breeding moulting geese have been observed in the northern fjords of Spitsbergen and along the west coast of Edgeøya. During late summer, brent geese appear to congregate in the northern fjords of Spitsbergen and Edgeøya, but flocks have also been observed scattered all over Svalbard (Mehlum 1998).

Geese are monogamous, and are generally faithful to their natal nest site. Only the female incubates the eggs. Clutch sizes vary between two and six eggs, which are incubated for approximately 25 days. During the nesting period, the female only leaves the nest for short periods to drink and feed. Males are slightly larger than females, and defend the territory and nest against intruding avian predators and other geese. Pink-footed geese are slightly larger than barnacle and brent geese, and can defend themselves against Arctic foxes, which explains their dispersed inland nesting and post-hatching distribution. Nesting brent and barnacle geese are confined to islets and cliffs where foxes have no access, and during the brood-rearing period goose families stay close to open water, which offers an easy escape.

Study areas

The data on disturbance effects originate from various goose studies performed in Svalbard (Fig. 1), where disturbance reactions were recorded on an ad hoc basis in conjunction with other field activities.

Case 1. Brent and barnacle geese nesting in Tusenøyane (77°05′N, 22°00′E), a group of small islands in south-east Svalbard, were studied in 1987, 1989 and 1991. Fieldwork was carried out on the Lurøya, Kalvøya and Hornøya islets in the Tiholmane island group of Tusenøyane. The islets are low and rocky, with varying degrees of polar desert vegetation cover, consisting of wet moss carpets and fjellmark dominated by mosses and lichens (Madsen et al. 1989; Bregnballe & Madsen 1990; Madsen et al. 1992; Madsen et al. 1998). In 1987, a total of 98 nests of brent geese and 17 nests of barnacle geese were found in Tiholmane (Madsen et al. 1989). In 1989, there were Arctic foxes on most of the islands, and virtually no geese bred there (Madsen et al. 1992).

Case 2. Barnacle geese nesting on islets in Kongsfjorden (78°55′N, 12°15′E) were studied in 1992. Geese breed on several islets near the settlement of Ny-Ålesund. In the present study we focus on barnacle geese breeding on two islets, Storholmen (30 ha) and Prins Heinrichøya (3 ha), with 60 and 27 nests, respectively (Tombre, Black et al. 1998; Tombre, Mehlum et al. 1998). Common eider (*Somateria mollissima*) also breed on the islets, which have exposed ridges and heterogeneous vegetation, including moss tundra (Tombre & Erikstad 1996; Alsos et al. 1998).

Case 3. Pre-nesting and nesting pink-footed geese and barnacle geese in Sassendalen (78°18′N, 17°00′E) were studied in 2003–06. Sassendalen lies 30–40 km east of Longyearbyen, in central Svalbard, and is a classic U-shaped glacial valley. It is ca. 4 km broad, with steep slopes rising on both sides to 400–500 m a.s.l. The vegetation is High-Arctic tundra, with well-developed fens supporting grass and *Carex* species. The valley floor supports a matrix of moss tundras, fens, marshes and unstable vegetation on braided melt rivers and river banks, with dry ridge areas and a few small lakes (the largest, Store Gåsdammen is ca. 150 m in diameter, and is an important nursery area for barnacle geese). Peripheral river valley canyons run into Sassendalen, three of which contain sympatric nesting barnacle and pink-footed geese. Some 380 pairs of pink-footed geese nested in loosely aggregated colonies on the open tundra in the outer part of the valley, compared with ca. 60 pairs of barnacle geese restricted to the steep cliff sides of Sassendalen. Nests of both species were loosely aggregated because of habitat, with nests of the same species being as close as 5 m from one another (Fox et al. 2009; Madsen et al. 2007; Wisz et al. 2008).

Case 4. Opportunistic observations of pink-footed and barnacle geese were carried out in connection with banding of geese at various sites in Isfjorden (Daudmannsøyra, Gipsdalen and Sassendalen) and the west

Fig. 1 The three study sites in Svalbard where data on disturbance effects on geese were collected are encircled: case 1, Tusenøyane: case 2, Kongsfjorden; case 3, Sassendalen. The blue dots represent the geographical distribution of cruise ship tourists at different landing places in 2007 (the most recent year with geographical data). Data source: Governor of Svalbard (2006, 2007, unpubl. data).

coast of Spitsbergen (Recherchefjorden and Dunderbukta) in July–August 2007 (Madsen unpubl. data).

Field methods

We used the escape flight distance (EFD) as an expression of the behavioural tolerance limit of geese towards approaching humans. It is well known that EFD varies with species, flock size, site and physiological state (Madsen 1985, 1998; Beale & Monaghan 2004; Laursen et al. 2005), and hence can only be used as an indicator, which should not be used on its own, to assess disturbance effects (Gill et al. 2001); however, it is useful in a management context to regulate human access to sensitive areas (Fox & Madsen 1997; Blumstein et al. 2003). To supplement EFD, in some cases we recorded (1) the distance at which geese stopped their undisturbed behaviour (typically resting or foraging) and became alert (standing up, looking with stretched neck towards the intruders), and (2) the distance over which geese fled before they settled. The latter indicates a cost in terms of energetics or the risk that the bird takes in terms of losing eggs or chicks in the unprotected nest to predation.

We estimated the EFD at 1-m intervals for distances of 0–10 m between source of disturbance and the flushing bird, at 10-m intervals for 10–200-m distances (except for the islets in Kongsfjorden, where a 1-m interval was used up to 50 m, as there were good landmarks for these sites), and 50- or 100-m intervals for distances greater than 200 m. After having flushed the birds, EFDs were paced out, judged by landmarks with known distances or gauged using detailed field maps. The distances at which geese became aware or the fleeing distances were estimated using landmarks and from detailed field maps. We only used EFD records where the geese were approached in full openness in advance of the escape. In each case, we recorded the date, species, flock size (which was one for nesting birds) and status, categorized as non-breeding individuals capable of flight, incubating females, nest-guarding males, families with goslings or non-breeding moulting geese unable to fly.

Humans on foot were the sole source of disturbance, in congruence with how work was carried out in the study areas. Geese were approached by a single person or two people walking together. As data was mostly collected opportunistically as additional information collected during other work, there was no strict protocol for the selection of geese for study. Data were primarily collected by the authors. EFDs and fleeing distances were calibrated between JM and NEE in Sassendalen, whereas there was no calibration between JM/NEE and IMT. However, IMT paced out all EFDs. Hence, we are confident that the estimated EFDs and fleeing distances are comparable between studies.

To estimate the impact of disturbance on reproduction, we recorded egg loss to predation resulting from human-induced departure from the nest. Revisiting the nesting area within the next 24 h gave us an opportunity to note whether the geese returned to the nest (this could be observed from a distance) or whether the nest had been predated (observation based on a closer inspection of the nest), and, if so, by which predator (judged by eggshell remains). Potential predators were glaucous gulls (*Larus hyperboreus*), Arctic skuas (*Stercorarius parasiticus*), great skuas (*Stercorarius skua*) and Arctic foxes. We never visited nests solely to simulate disturbance events, but also checked clutch sizes or collected eggs for scientific purposes. When we scared a nesting female off the nest, we always covered the eggs with down to maintain the egg temperature and to lower the risk of predation, and we left the nest site as quickly as possible. In this respect, our activity may not simulate an erratic human approach, in which the intruder may not notice the goose nest, nor be aware of the need to cover the nest. Therefore, our estimates of egg loss due to human intrusion are conservative.

Statistical analyses

Data on alert distances, EFDs and fleeing distances are presented as means ± standard errors, as well as medians, 25 and 75% quartiles and ranges. Correlations among various variables were carried out by the use of linear regressions. For comparison among groups we use Student's *t*-tests when two categories are involved, and use ANOVAs for three categories. To determine whether sex or breeding site have any effect on EFDs, we used a general linear model (GLM, type III, sum of squares). The organization of data, statistics and the creation of figures were achieved using SAS statistical software (SAS Institute 2004) and the statistical package R Development Core Team (2008).

Tourism data

The Svalbard Tourism Council, a consortium of local tourism companies operating on land, and the Association of Arctic Expedition Cruise Operators (AECO), an umbrella company of the small coastal cruise ships operating around Svalbard, have reported travel statistics to the Governor of Svalbard since 1996 (Governor of Svalbard 2006, 2007, unpubl. data). Some of these data have also been reported to *Miljøovervåkningen av Svalbard og Jan Mayen* (*The environmental monitoring of Svalbard and Jan Mayen* [MOSJ]; Sander et al. 2005). These data reveal trends in the development of the tourism industry in terms of abundance and distribution, as well as seasonal patterns. The data with the best geographical resolution were reported landings from cruise ships, whereas data on land-based activities were only reported according to management zones (there are 10 different zones of variable size and protected status; see http://svalbard.miljostatus.no for details.) Statistics on the seasonal number of cruise-ship landings were only available for 2007. For the present study we had access to all the reported data, and have aggregated the data in time (sums per months, years) and space (regionally) to evaluate potential temporal and spatial overlaps, and conflicts between human activity and goose distribution and occurrence. It should be emphasized that this only gives information on tourism activity and does not measure the overall level of human traffic.

Results

Human activities

Tourism was categorized in winter and summer activities. Most visitors to Svalbard stay on cruise boats. More than 50 000 people visited Svalbard during the summer months of 2007 (Governor of Svalbard 2007). There were 95 000 landings that year (Fig. 2). The cumulative number of landings from cruise ships has more than doubled over the last 10 years, whereas the number of new landing sites has more than tripled over the same period (Fig. 2). In recent years, visitors landed at more than 160 different locations (Fig. 2). Landings took place all around the archipelago, but the load of traffic differed between landing sites (Fig. 1).

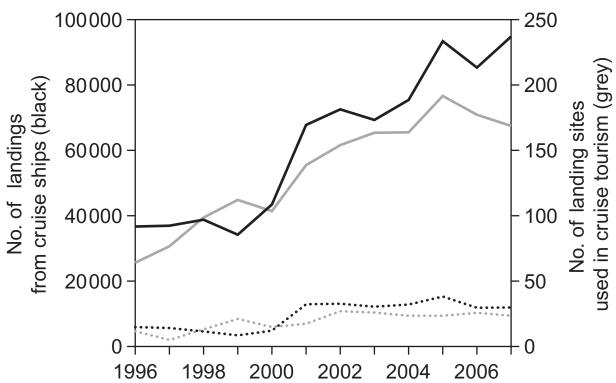

Fig. 2 The development of cruise ship activities in Svalbard, 1996–2007, expressed as the total annual numbers of cruise ship landings and number of landing places used around Svalbard. The data from Isfjorden (management area 10) are separated (dotted lines). Data source: Governor of Svalbard (2006, 2007, unpubl. data).

The official statistics covering the period 2003–07, based on reports from tourist operators, illustrate the seasonal patterns of various outdoor activities (Fig. 3). The winter season, during which visitors engage in snowmobile and dog-sledging excursions, lasts from January to May, with a peak in March and April. However, dog sledging extends into May/June, as tour operators take advantage of snow-covered glaciers. Snowmobiles bring most people visiting Svalbard into the Arctic landscape, whereas hiking is relatively limited during winter. Tourist activity peaks during the summer: June, July and August (Figs. 3, 4). Summed from June to October, there are 8700 visitor-days spent in organized hikes and rubber boat and kayak excursions starting from Isfjorden (Fig. 3).

Individual travellers visiting management area 10 (Isfjorden) added to the number registered at the office of the Governor of Svalbard and the AECO. Accordingly, the picture of the geographical distribution of tourism activity was blurred by the fact that activities within management area 10 were not fully recorded: only activities through organized tour companies were registered.

Disturbance effects: pre-nesting period

From the pre-nesting period, data were available from Lurøya (brent geese) and Sassendalen (barnacle and pink-footed geese) over the period from 24 May to 9 June. Only six records of brent goose flocks were made. Hence, in statistical tests only data from pink-footed geese and barnacle geese were included (with sample sizes of between 40 and 88).

Pink-footed geese were found in larger flocks than barnacle geese and brent geese (pink-footed geese, 18 ± 2.7 geese, range 2–143, $n = 88$; barnacle geese, 7 ± 1.4 geese, range 1–48, $n = 41$; brent geese, 4 ± 1.4 geese, range 2–11, $n = 6$). The difference in flock size between pink-footed geese and barnacle geese was highly significant (Student's *t*-test, $t = -3.70$, $df = 122$, $P = 0.0003$). Moreover, the pink-footed geese were alert to an approaching person at greater distances than the barnacle geese in the same area, with extremes at distances of 1500 m (pink-footed geese, 388 ± 32 m, range 40–1500 m, $n = 88$; barnacle geese, 275 ± 34 m, range 30–1000 m, $n = 38$; Student's *t*-test, $t = -2.24$, $df = 111$, $P = 0.027$; Fig. 5). The alert distance was highly correlated with the EFD for both pink-footed and barnacle geese (linear regression, pink-footed geese, $R^2 = 0.80$, $n = 75$, $P = 0.0001$; barnacle geese, $R^2 = 0.87$, $n = 38$, $P = 0.0001$), and the EFDs were significantly greater for pink-footed geese than for barnacle geese (Student's *t*-test, $t = -2.48$, $df = 101$, $P = 0.015$; Fig. 5). For pink-footed geese, there was a positive and significant relationship between flock

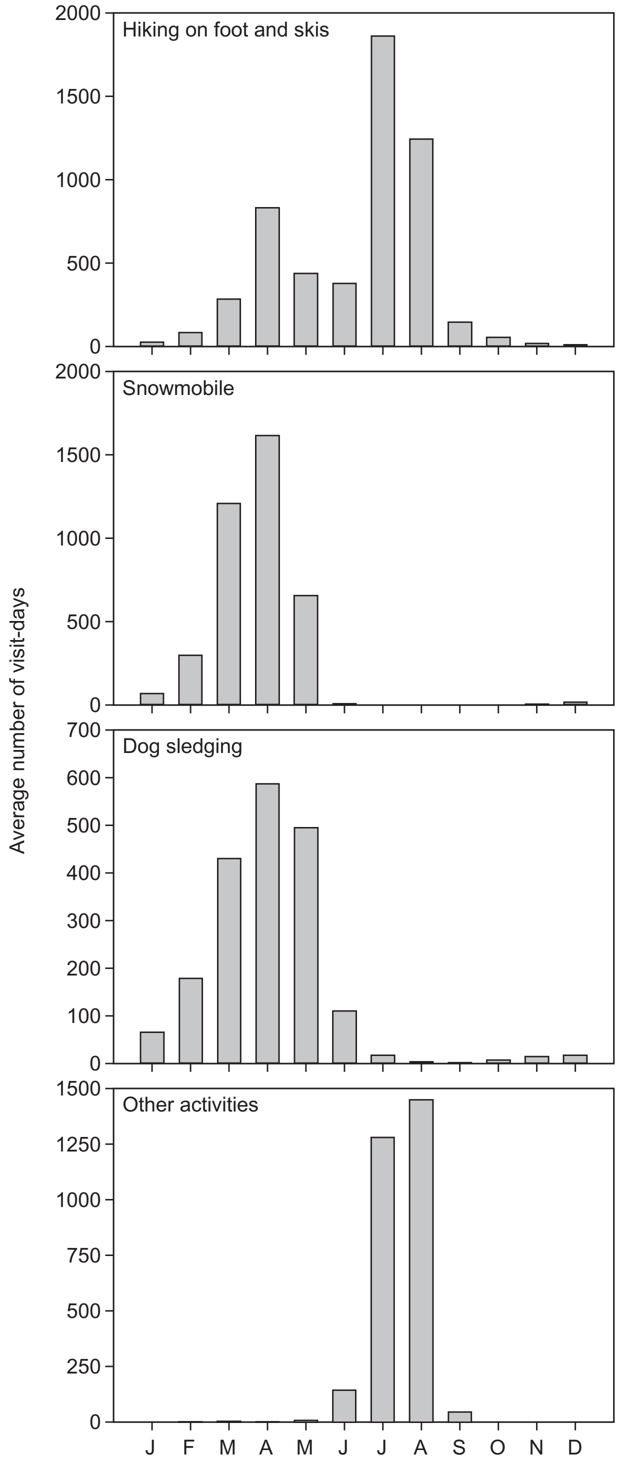

Fig. 3 Monthly numbers of reported recreational activities in Svalbard. "Other activities" include excursions in rubber boats, kayaking and shorter hikes. The numbers are the averages for the years 2003–07. Data source: Governor of Svalbard (2006, 2007, unpubl. data).

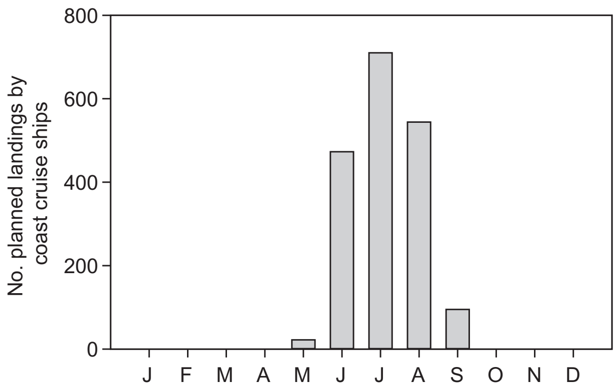

Fig. 4 Monthly numbers of planned landings by cruise ships in Svalbard in 2007. Data source: Association of Arctic Expedition Cruise Operators (unpubl. data).

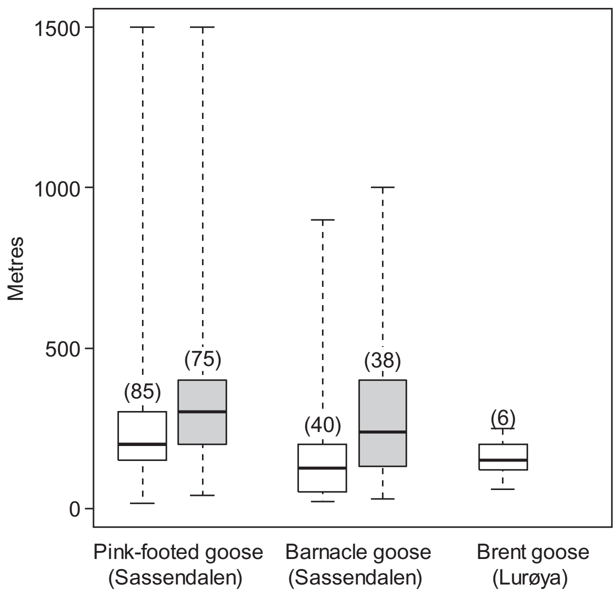

Fig. 5 Escape flight distance (white boxes) and alert distance (grey boxes) in response to an approaching person for three goose species in Svalbard during the pre-nesting period (no alert distances were recorded for brent geese). The plot shows the median values (solid horizontal lines), the 25 and 75% quartiles (boxes) and ranges (dotted lines). See text for statistics. The sample sizes are shown in parentheses above each box.

size and EFD, with geese in large flocks becoming alert at greater distances than geese in small flocks ($R^2 = 0.10$, $n = 85$, $P = 0.004$). No relationship between flock size and EFD was found for barnacle geese or brent geese ($P > 0.8$).

Disturbance effects: nesting period

Escape distances. For barnacle geese, there were no significant differences in EFDs between birds from the

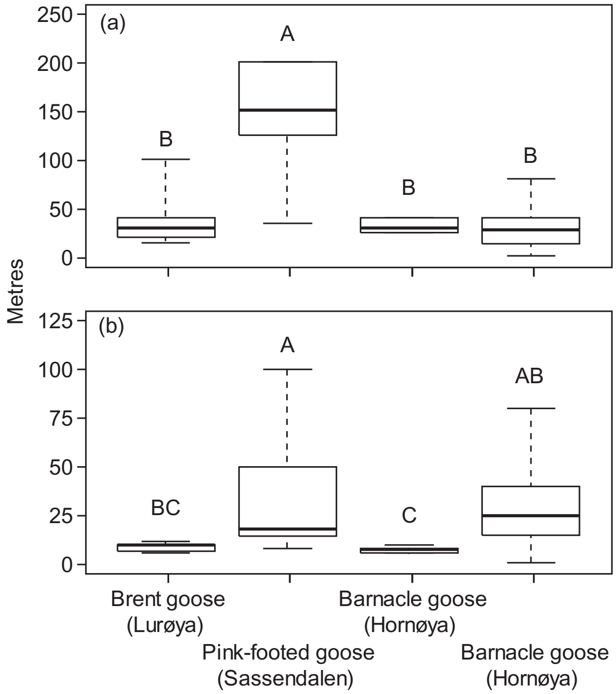

Fig. 6 Escape flight distances in response to an approaching person for geese nesting at different sites in Svalbard. (a) Males and (b) females are shown separately in box plots with medians (solid horizontal lines), 25 and 75% quartiles (boxes) and ranges (dotted lines). The same letters above each box indicate no significant differences between sites, whereas different letters indicate that the differences are significant (ANOVA, Duncan grouping: males, $F = 92.96$, $df = 3, 103$, $P = 0.0001$; females, $F = 7.51$, $df = 3, 124$, $P = 0.0001$).

two islets in Kongsfjorden (Storholmen and Prins Heinrichøya), nor were there differences in the response of male and female birds (females, Storholmen, 28.7 ± 2.2 m, $n = 53$; females, Prins Heinrichøya, 23.6 ± 3.4 m, $n = 25$; Student's t-test, $t = -1.3$, $df = 44.8$, $P = 0.20$; males, Storholmen, 29.2 ± 2.3 m, $n = 51$; males, Prins Heinrichøya, 23.3 ± 3.7 m, $n = 25$; Student's t-test, $t = -1.4$, $df = 74$, $P = 0.16$). Therefore, data from the two islets were pooled, and the site was termed "Kongsfjorden" in further analyses.

Both the breeding site and sex had a significant effect on the EFD (GLM, type III, sum of squares: site, $F = 28.7$, $df = 3, 1$, $P = 0.0001$; sex, $F = 31.7$, $df = 3, 1$, $P = 0.0001$). The average EFDs for the various species and sites are presented in Fig. 6. For males, there was a significant difference between the sites (ANOVA, $F = 92.96$, $df = 3, 103$, $P = 0.0001$), with pink-footed goose males in Sassendalen fleeing the nest site at significantly greater distance than males from any other site, or than males from the other two species, which did not differ in escape distances. For females, differences were not only significant among sites, but also within the same species at different sites (ANOVA, $F = 7.51$, $df = 3, 124$, $P = 0.0001$; Fig. 6). The average escape distances were greatest for pink-footed goose females in Sassendalen and barnacle goose females in Kongsfjorden. The shortest escape distances were found for brent goose females on Lurøya (Fig. 6).

For the barnacle geese in Kongsfjorden, there was a highly significant and positive correlation in the EFD among sexes ($R^2 = 0.80$, $n = 76$, $P = 0.0001$), meaning that, in general, individuals in a pair behaved similarly towards an approaching person. Females and males in the most tolerant and most shy pair departed their nests at exactly the same distance, giving similar ranges in EFD (both sexes: 1–80 m). By contrast, for pink-footed geese in Sassendalen, the variation in EFD varied considerably (females, 8–100 m; males, 35–200 m; Fig. 6), and no correlation among sexes was found ($R^2 = 0.001$, $n = 11$, $P = 0.95$). There was no correlation among sexes for the barnacle geese breeding on Hornøya and Lurøya (all $P > 0.3$), and variation in the EFD was also less at these sites (Fig. 6).

Fleeing distances. Fleeing distances are available for brent geese on Lurøya, pink-footed geese in Sassendalen and barnacle geese on Hornøya (Fig. 7). There were significant differences in the fleeing distances among the three species/sites (ANOVA, females, $F = 29.17$, $df = 2, 28$, $P = 0.0001$; males, $F = 110.41$, $df = 2, 27$, $P = 0.0001$). Pink-footed geese in Sassendalen had the longest fleeing distances, departing their nests and flying several hundred metres away when a person approached the nest (Fig. 7). At Hornøya, barnacle goose females followed their males after they departed the nest, giving similar fleeing distances for both sexes (Fig. 7).

Predation rate. A summary of the consequences for goose eggs after the provoked nest approaches is presented in Table 1. Sample sizes are largest for Kongsfjorden, where only 4% of the nests (4 of 79) were predated by gulls within the first day after the provocation (Table 1). For pink-footed geese in Sassendalen this was rather different, as almost 35% of the nests (16 of 46) included in the analyses lost their complete clutch after a similar approach (Table 1). For brent geese on Lurøya and barnacle geese on Hornøya, samples are limited, but all pairs included in the study returned after they had departed their nests, and no eggs were observed to have been lost to predators (Table 1).

For pink-footed geese in Sassendalen, there were no significant differences in EFDs for females among the predation categories no eggs lost vs. egg loss (Student's t-test, $t = 0.51$, $df = 15$, $P = 0.62$; Table 1). Data on males are too limited for statistical tests, and small and skewed sample sizes also limit statistical tests for the other sites.

Disturbance effects: brood-rearing period

Limited data exist for the brood-rearing period. Because of insufficient data, records on the EFDs and fleeing distances of families towards an approaching person were pooled in three species-based categories: pink-footed goose records from Daudmannsodden, Gipsdalen and Sassendalen; brent goose records from Hornøya, Kalvøya and Lurøya in Tusenøyane; and barnacle goose records from Sassendalen. A visual inspection of the data did not show signs of site-specific differences. Significant differences were found among species in EFD (ANOVA, $F = 67.81$, $df = 2, 13$, $P = 0.0001$), with the longest distances being recorded for pink-footed geese (average 1717 m, $n = 6$), followed by brent geese (average 620 m, $n = 5$) and barnacle geese (average 330 m, $n = 5$) (Fig. 8). Pink-footed geese also had the longest average fleeing distance (pink-footed geese, 1502 m, $n = 5$; barnacle geese, 500 m, $n = 1$; brent geese, 340 m, $n = 5$), but no significant differences were found among species (barnacle goose excluded, Student's *t*-test, $t = -2.32$, $df = 4.08$, $P = 0.08$), although small sample sizes limit the value of the statistical tests.

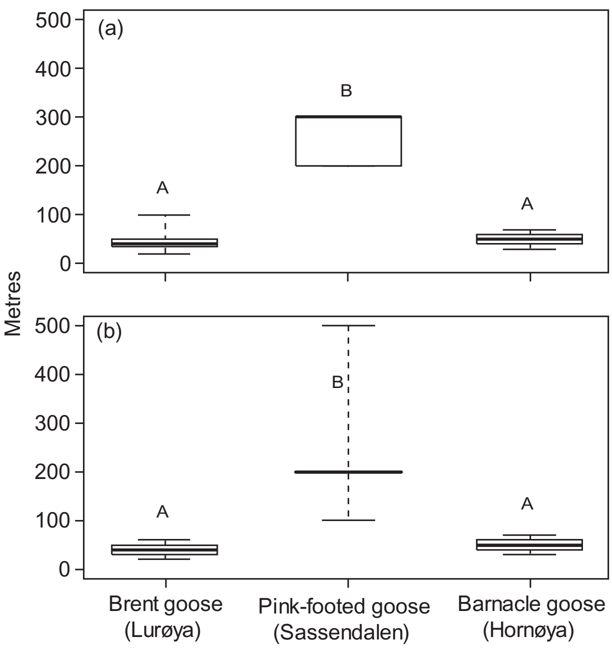

Fig. 7 Fleeing distances from the nest after the approach of a person for geese nesting at different sites in Svalbard. (a) Males and (b) females are shown separately in box plots with medians (solid horizontal lines), 25 and 75% quartiles (boxes) and ranges (dotted lines). The same letters above each box indicate no significant differences between sites, whereas different letters indicate that the differences are significant (ANOVA, Duncan grouping: males, $F = 110.41$, $df = 2, 27$, $P = 0.0001$; females, $F = 29.17$, $df = 2, 28$, $P = 0.0001$). There were no data available for Kongsfjorden.

Discussion

Measures of human activity

The travel statistics on human activity have limited value for studying the potential effects of disturbance, as they do not include activities other than tourism, and therefore do not reflect the total load of human activity

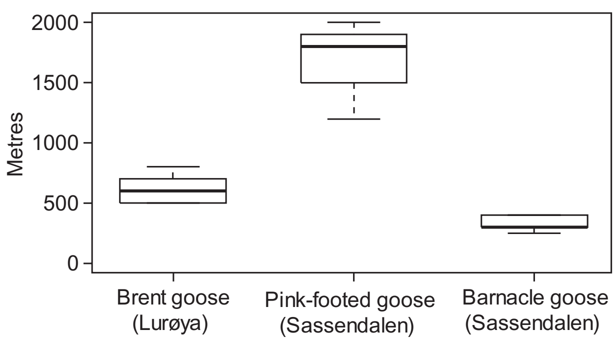

Fig. 8 Escape flight distances in response to an approaching person for family groups of the three species of geese at different sites in Svalbard. The box plot shows medians (solid horizontal lines), 25 and 75% quartiles (boxes) and ranges (dotted lines).

Table 1 Egg predation in goose nests after provoked nest approaches by a walking person. The average escape flight distances (EFDs) are presented in metres (± standard error). The sample sizes are given in parentheses.

	No. of nests with no egg loss	No. of nests with partial egg loss	No. of nests with complete egg loss	Sex	EFD (m) for pairs with no egg loss	EFD (m) for pairs with egg loss[a]
Brent	13	0	0	Females	9.1 ± 0.6 (13)	—
(Lurøya)				Males	35.8 ± 7.1 (13)	—
Pink-footed goose	30	—	16	Females	47.1 ± 9.5 (8)	39.4 ± 11.3 (9)
(Sassendalen)				Males	175.0 ± 25.0 (2)	150.0 ± 22.4 (5)
Barnacle goose	6	0	0	Females	7.5 ± 0.6 (2)	—
(Hornøya)				Males	31.7 ± 2.8 (6)	—
Barnacle goose	75	1	2	Females	27.0 ± 1.8 (75)	27.0 ± 15.6 (3)
(Kongsfjorden)				Males	27.3 ± 2.0 (73)	27.7 ± 15.1 (3)

[a]Partial and complete clutch loss combined.

(Vistad et al. 2008). Furthermore, the tourism data that are available do not have a geographical resolution that permits accurate estimations of overlaps with goose sites. The only exceptions are the records of cruise landing sites. They show that landings occur all around Svalbard, although at highly variable intensities. We do not have data to suggest any relationships between the load of human activity and disturbance effects and impacts. However, at crucial times and places, such as during nesting or on islets during the post-hatching period, our results from the provoked human approaches suggest that just a few visits can potentially severely influence nesting success or gosling survival in cases where families flee to the sea, and have to swim long distances. The seasonal pattern in tourist traffic gives us a picture of potential conflict periods. There may be a potential conflict between snowmobile and dog-sledging activities and the arrival of pre-nesting geese in May; however, we do not have any data that would elucidate this. Cruise landings, other boating activities and hiking overlap with the nesting and post-hatching periods of geese, including the time when geese are flightless.

To better understand the potential temporal and spatial conflicts between human activity and geese, we recommend that more detailed information is collected on the nature and extent of not only tourism, but all human activities that have the potential to impact geese as well as other wildlife in Svalbard.

Escape flight distances

Behavioural measures such as EFDs only give an indication that disturbance caused by human activity could have a negative effect, although not necessarily with any fitness consequences (Gill et al. 2001; Gill 2007). However, in this study we have documented a negative impact, through increased predation rates at nests from which parent geese fled. As data was collected opportunistically over a long time period, in various places and by different observers, the results and interpretations must be treated with some caution, and should primarily be used to suggest guidelines for regulating tourism. Nevertheless, the results show that there are significant differences in behavioural reactions towards human disturbance by the three species of geese, and that reactions vary with the timing and the site.

Pre-nesting. The pre-nesting period, i.e., the period between the arrival of the birds in Svalbard and the start of egg-laying, is regarded as a crucial period in the annual cycle of the geese. During this period, they maintain or improve their body condition as a prelude to breeding. In barnacle and pink-footed geese it has been shown that adults, in particular females, improve their body condition during this period (Hübner 2006; Fox unpubl. data). During the pre-nesting period, a large proportion of the tundra and its vegetation may be snow-covered or frozen, inhibiting pink-footed geese from feeding on the subterranean rhizomes and roots upon which they rely (Fox et al. 2007). Hence, the geese may be constrained in food availability, and displacement from feeding patches as a result of disturbance may reduce food intake, with negative repercussions for the subsequent breeding potential. We found that pink-footed geese in Sassendalen were very shy, with an average EFD of almost 400 m. This is in strong contrast to observations from another valley in Svalbard, Adventdalen, where the average EFD of flocks of pre-nesting pink-footed geese approached by a walking person has been registered at 35 m ($n = 5$; Fox unpubl. data). The difference may result from habituation to human traffic in Adventdalen, close to the Longyearbyen settlement, which is in most cases restricted to road traffic. Road traffic is directional, frequent and hence relatively predictable, whereas people walking on the tundra are infrequent and move relatively randomly, and hence may be perceived as a higher risk. In situations with greater snow cover in Adventdalen, geese feeding along roadsides and close to buildings have been observed with EFDs of less than 10 m (Eide, pers. obs.). This represents an extreme case, and probably indicates that the birds are under a strong pressure to find food, and therefore make compromises between avoiding predation and feeding. The observations show that EFDs are highly variable between sites and snow conditions, and that the nature of human activity as well as the physiological state of the birds may influence their responses.

Nesting. In barnacle and brent geese we found that males and females had short EFDs and flew or ran short distances upon disturbance. In several instances we observed the geese attacking avian predators during our stay in the territory, and that they returned to the nest as soon as we had left the territory. The observed difference in EFDs of barnacle geese between Kongsfjorden and Hornøya is probably related to the state of the incubating females. On Hornøya, where data were collected in late June and early July, the geese were close to hatching their clutches, when geese become more sedentary (Kongsfjorden was visited earlier, in mid-June). In contrast to the males of other species, male pink-footed geese were flushed at a long distance from the human intruder, and often flew to a position out of view of the nest. Female pink-footed geese stayed on the nest with an EFD similar to females of the other two goose species;

however, female pink-footed geese also flew away, often landing in positions out of view of the nest. The consequence of the intrusion was manifest in a high rate of predation of eggs by glaucous gulls or skuas, even though we carefully covered the eggs with down. We noticed that when we entered the goose colonies, gulls and skuas often followed. The reaction by the pink-footed geese indicates a strong fear of humans, which may be attributed to the regulated hunting of the species, with an open season in Svalbard, mainland Norway and Denmark.

The inference of the limited losses of eggs as a result of human intrusion in colonies of brent and barnacle geese does not mean that the nesting geese are not vulnerable to disturbance. Intruding humans, perhaps landing on a nesting island in a group and then spreading out over the island, and who are possibly unaware of the presence of nesting geese and the importance of covering exposed nests, are more likely to increase the risk of predation by gulls and skuas.

Brood rearing. Our data sets for all three species are small; nevertheless, significant interspecific differences were found. Families of pink-footed geese showed an escape response at a distance of almost 2 km from the approaching human, whereas the EFDs of families of barnacle and brent geese were shorter. Brent and barnacle goose families always feed in close proximity to open water, where they can seek protection in case of disturbance. In contrast, pink-footed geese often feed far inland, and will not seek protection on lakes; instead, they run inland, towards the river (in Sassendalen; Fox et al. 2007; Fox et al. 2009) or retreat to the sea. In Gipsdalen it was twice observed that families feeding at the foot of a steep slope ran uphill to hide at an elevation of 300–400 m a.s.l. (Madsen, pers. obs.). Their behaviour is possibly an adaptation to the fact that they can defend themselves against Arctic foxes, whereas the extreme reaction towards humans can only be interpreted as indicating a strong fear of humans. Families of barnacle geese, the most tolerant of the three species, will run to the refuge lake in the case of a disturbance, and will then stay on the lake. In Ny-Ålesund, and more recently in Adventdalen, barnacle goose families have habituated to human activities, and now occur close to human settlements and traffic. In Ny-Ålesund, it is not humans, but the occurrence of Arctic foxes, which can predate heavily on the goslings, that is the main factor constraining their flexibility in site use in the settlement (Loonen et al. 1998).

As a result of their highly localized distribution in Svalbard, i.e., in Tusenøyane, Moffen and a few other areas, brent geese are highly vulnerable to disturbance, especially during the brood-rearing period, when cruise boats can reach the islands. During the nesting period, dense drift ice prevents access by boats in most years, although in some years they can get there in June (Madsen et al. 1998). People walking on the small islands may potentially cause the families to leave and swim across to other islands, or even north to Edgeøya. In Tusenøyane, food resources are very limited (Madsen et al. 1989; Madsen et al. 1998), and a displacement of the geese may have repercussions for the growth, and, ultimately, survival of goslings.

Moult. During the flightless period, geese are highly restricted in their site use and stay in close proximity to open water (Madsen & Mortensen 1987). We have very limited information about EFDs in non-breeding moulting geese, but from observations from east Greenland it is known that pink-footed geese are extremely wary: human intrusion in lake moulting areas can cause geese to run across the tundra and abandon the moulting site (Madsen et al. 1984). Barnacle geese were more relaxed and remained on the moulting areas (Madsen et al. 1984). Although quantitative data are lacking, it seems likely that because the geese are flightless, a disturbance that will cause the geese to depart from the refuge and run across the tundra will greatly increase the risk of predation by Arctic foxes.

Post-breeding. During the late summer, when non-breeding geese, goslings and parents have gained powers of flight, and before heavy snowfall sets in, they are highly flexible and can find food over vast expanses of Svalbard that were not exploitable earlier in the season on account of snow cover or the behavioural constraints of the geese. We have no quantitative information about their reactions to disturbance during this period, but the geese must be regarded as less vulnerable during this period. The hunting season for pink-footed geese starts on 20 August, and this may constitute a local disturbance; however, the number of hunters in Svalbard is low and the hunting is very localized, and cannot be regarded as a critical source of disturbance in the wider Svalbard area.

Management implications

Currently, probably none of the three goose species are critically threatened by human activity in Svalbard. However, this paper highlights some important issues, which may result in guidelines for human activities in the context of the potentially increasing disturbances of geese resulting from heavier and more widespread traffic at various times of the season.

Pre-nesting. There is a potential conflict between snowmobile activities and pre-nesting geese that congregate in areas such as Vårsolbukta and Adventdalen. Because there is little information about disturbance effects during pre-nesting, we recommend that a study address this particular potential conflict.

Nesting. Nesting birds are vulnerable to disturbance. The major colonies of barnacle geese (on islands along the west coast) and brent geese (on Moffen) are refuges with no human access during the nesting period. Pink-footed geese appear to be particularly vulnerable because of their long escape flight and fleeing distances, which exposes nests to predation. As these geese mostly breed in colonies on islands and in inland tundra areas, guidelines for human traffic are easily suggested. Detailed maps of known goose breeding colonies should be made available to visitors. Guidelines should include information on what consequences disturbance could have, as well as advice on appropriate behaviour. People should not walk closer than 1 km from the dense nesting areas. For pink-footed geese, verification of predictions of suitable nesting areas by Wisz et al. (2008) and Jensen et al. (2008) should be confirmed by more ground-truthing fieldwork in the most visited spots. In this connection, the importance of having good geographical resolution on all human traffic must be emphasized (also see the evaluations made by Vistad et al. 2008). We have limited knowledge of the distribution of human traffic in the most visited areas around Isfjorden (management area 10), where several breeding colonies are located. Traffic in this area has increased, and more people are visiting the interior of Isfjorden (e.g., Sassendalen) on their own initiative (Eide & Madsen, pers. obs.). Setting up a campsite, in Sassendalen, for example, with hikes radiating out from the camp, could have severe negative impacts on nest success for geese in this area if the appropriate precautions are not taken.

Post-hatching. Goose families are highly vulnerable to hiking in the brood-rearing areas; brent and barnacle geese are confined to staying close to open water, and can potentially be prevented from foraging for a long time on account of the presence of humans. Again, families of pink-footed geese are particularly vulnerable because of their extremely long EFDs. Hikers traversing the valley floor of Sassendalen may be unaware of geese fleeing at long distances in front of them, and people walking through the valley can unintentionally drive large numbers of geese all the way down the river, resulting in lost feeding time and potentially increased predation risk. In high-density brood-rearing areas, hiking routes should be regulated to avoid mass disturbance.

Moult. Non-breeding moulting geese are highly sensitive to disturbance, and precautions should be made to avoid landings and hiking in high-density moulting sites. At present, there is no good Svalbard-wide overview of existing moulting grounds, but known major moulting sites should be marked on maps made available to visitors, along with the appropriate advice.

Post-breeding. The period before departure seems to be relatively undisturbed, and geese appear to be less vulnerable on account of their regained ability of flight and the widespread availability of food resources. No particular precautions appear necessary for the time being.

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