Disturbance effects of human activities on geese in Svalbard: implications for management of recreational activities

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Introduction

As a result of Norwegian political incentives to encourage tourism as a main business activity in Svalbard, there has been an increasing tourism activity during recent decades in the area, both in terms of organised trips by tour boats and snowmobiles as well as more unorganised individual trips (Governor of Svalbard 2006). Furthermore, there has been an increase in research and educational activities 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 in Svalbard (Overrein 2002).

Geese are regarded as one of the species groups being most vulnerable to disturbance. Three species breed in Svalbard: pink-footed goose *Anser brachyrhynchus*, barnacle goose *Branta leucopsis* and light-bellied brent goose *Branta bernicla hrota*. They constitute three distinct populations, wintering in different areas in Northwest 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. They breed in different parts of Svalbard, with a partial spatial overlap in some parts of the season (Mehlum 1998), and in terms of habitat use and behaviour they also have species-specific characteristics (Fox et al. 2006, 2007). In 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 with strict regulations of human access, geese are increasingly exposed to human disturbance, partly because they breed or moult in areas without strict regulations, partly because restrictions are not sufficient in existing reserves.

The aim of this paper is to compile existing knowledge concerning the disturbance effects of human recreational activities on the three species of geese in Svalbard, including an analysis of hitherto unpublished data. Here, we define disturbance as any human activity that constitutes a perceived predation risk, sufficient to disrupt normal activities. 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. Along with a brief status and description of the ecology of the three goose species, we also gather data on tourism activities in Svalbard, reported to Sysselmannen (www.sysselmannen.no), in order to assess the spatial and temporal overlap between recreational activities and geese during their summer cycle. We evaluate the potential effects in terms of behavioural reactions and impacts on the fitness of geese in terms of reproductive output. Based on the assessment we propose guidelines to regulate tourism and other human activities which may conflict with the long-term conservation of geese in Svalbard.

Material and methods

Data sources

Data on disturbance effects originate from various goose studies in Svalbard (Fig. 1). Disturbance reactions were recorded on an ad hoc basis in conjunction with other field activities:

Case 1: Studies of nesting brent geese and barnacle geese in Tusenøyane, southeast Svalbard, 1987, 1989 and 1991 (National Environmental Research Institute (NERI) in collaboration with the Norwegian Polar Institute)

Case 2: Studies of nesting barnacle geese on islets in Kongsfjorden, 1992 (Norwegian Institute for Nature Research (NINA))

Case 3: Studies of pre-nesting and nesting pink-footed geese and barnacle geese in Sassendalen, Isfjorden, 2003-2006 (NERI, NINA and Netherlands Institute of Ecology under the EU project FRAGILE)

Case 4: Circumstantial observations of pink-footed geese and barnacle geese carried out in connection to banding of geese at various sites in Isfjorden (Daudmannsøyra, Gipsdalen, Sassendalen) and the west coast of Spitsbergen (Recherchefjorden, Dunderbukta), July-August 2007 (NERI, J. Madsen unpublished data).

Study areas

Case 1: Tusenøyane

The study was carried out on Lurøya, Kalvøya and Hornøya islands in the Tiholmane island group of Tusenøyane (77°05'N, 22°00'E) in southeast Svalbard. The islets are low and rocky with varying degree of polar desert vegetation cover consisting of wet moss carpets with protruding *Cochlearia officinalis, Saxifraga hyperborea, Carex subspathacea* and *Phippsia* spp. and fjellmark dominated by mosses and lichens (Madsen, Bregnballe & Mehlum 1989, Bregnballe & Madsen 1990, Madsen, Bregnballe & Hastrup 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, Bregnballe & Mehlum 1989). In 1989, Arctic foxes were present on most of the islands, and virtually no geese bred (Madsen, Bregnballe & Hastrup 1992).

Case 2: Kongsfjorden

In Kongsfjorden (78°55'N, 12°15'E), near the settlement of Ny-Ålesund, there are several islets with breeding geese. In the present study we focus on the barnacle geese breeding on two islets, Storholmen (30 ha) and Prins Heinrichøya (3 ha), with 60 and 27 nests, respectively (Tombre et al. 1998a, b). 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: Sassendalen

Sassendalen (78°18'N, 17°00'E) lies 30 - 40 km east of Longyearbyen in central Svalbard and is a classic U-shaped glacial valley c. 4 km broad, with steep slopes rising on either side to 400-500 m a.s.l. divided by the braided fluvial channels of Sassenelva (see Fig. 1 in Wisz *et al.* 2008). The vegetation is high arctic tundra, typically patchy *Cassiope tetragona* and *Dryas octopetala* vegetation, but with well-developed fens with grass and *Carex* species not present in colder zones near the outer coast. 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 being Store Gåsdammen, c. 150 m in diameter is an important nursery area for barnacle geese). Peripheral river valley canyons empty 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 to c.60 pairs of barnacle geese which were restricted to steep cliff sides of Sassendalen. Nests of both species were loosely aggregated because of habitat, nests of the same species being as close as 5 metres (Fox & Bergersen 2006, Madsen et al. 2007, Wisz et al. 2008).

Field methods

We use the escape flight distance (EFD) as an expression of the behavioural tolerance limit by 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 only can be used as an indicator which should not be used on its own (Gill et al. 2001), but it is useful in a management context to regulate human access to sensitive areas (Fox & Madsen 1997). To supplement EFD, we have in some cases recorded 1) the distance at which geese stop their undisturbed behaviour and became alert and, 2) the distance over which geese flee before they settle, which indicates a cost in terms of energetics or the risk that the bird takes in terms of loosing the unprotected nest to predation. Furthermore, to estimate the impact of disturbance on reproduction, we have recorded egg losses or complete loss of the clutch to predation due to human induced departure from the nest.

We estimated EFD at 1 meter intervals for distances of 0-10 meter between source of disturbance and the flushing bird, at 10 meter intervals for 10-200 meter distances (except for the islets in Kongsfjorden where 1 meter interval was used up to 50 meters as there were good landmarks for these sites) and 50 meter or 100 meter intervals for more than 200 meter distances. EFDs were either paced out, judged by land marks with known distances or detailed field maps. We have 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 (equals 1 for nesting birds), state (categorised as non-breeding individuals capable of flight, incubating female, nest guarding male, family with goslings, or non-breeding moulting geese unable to fly). For incubating pairs, it was in most cases recorded by subsequent observation (having left the goose territory or a revisit to the nesting area within the next 24 hours) whether the geese returned to the nest or whether the nest was partially or fully predated, and by which predator. Potential predators were glaucous gulls *Larus hyperboreus*, Arctic skuas *Stercorarius parasiticus,* great skuas *Stercorarius skua* or Arctic foxes *Vulpes lagopus*. We never visited nests just to simulate disturbance events, but took advantage of situations when we 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 avoid predation and left the nest site as quickly as possible. In that respect, our activity may not be quite similar to an erratic human approach where 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. As source of disturbance, we have solely used human on foot, since this has been the way we have operated in the study areas. Hence, we have very limited information about the effect of other sources of disturbance (snowmobile, sledging. skiing, etc.).

Statistical analyses

Data on alert distances, EFD and fleeing distances are presented as mean ± standard error, as well as median, 25 and 75% quartile and range (in figures). Correlations among various variables were carried out by the use of linear regressions. For comparison among groups we use t-tests when two categories are involved and ANOVAs for three categories. To determine whether sex or breeding site have any effect on EFD we used a General Linear Model (GLM). Organisation of the data, statistics and the creation of figures were made by the use of SAS statistical software (SAS Institute 2004) and the statistical package R Development Core Team (2008).

Data on human activity

'Svalbard reiselivsråd', a consortium over the local tourism companies operating on land. and AECO, an umbrella company over the small coast cruise ships operating around Svalbard, have since 1996 reported travel statistics to The Governor of Svalbard (Governor of Svalbard 2006). These data give measures on trends in development of the tourism industry, both in abundance and distribution, as well as seasonal patterns. The best data with geographical resolution are reported on boarding from cruise ships, while data on land based activities are only reported according to management zones (ten different zones of variable size and protected status, see www.sysselmannen.no for details). For the present study we have access to all the reported data, and use the relevant statistics to evaluate potential temporal and spatial overlaps and conflicts between human activity and goose distribution and occurrence. It should be underlined that this only gives information on human activity by tourism and not measures the total "load of human traffic".

Status, distribution and ecology of the three goose species

Pink-footed goose

The Svalbard breeding population of pink-footed geese winters in Denmark, The Netherlands and Belgium. In spring, the population migrate through Norway with Nord-Trøndelag (Mid-Norway) and Vesterålen (northern Norway) as the main spring staging sites. The population size has increased from c. 20,000 in the 1970s to a hitherto unprecedented peak of c. 60,000 in 2007 (Madsen et al. 1999, J. Madsen unpubl. data). On arrival in Svalbard in mid May, the geese spent around one week before start of egg-laying. Adventdalen in Isfjorden is a major pre-nesting site from where the geese disperse to the nesting grounds (Glahder et al. 2006, Fox, Francis & Bergersen 2006). The geese nest in the lowland open tundra areas, preferring south-facing slopes as well as slopes under bird cliffs (Mehlum 1998, Madsen et al. 2007, Wisz et al. 2008). In Svalbard, the distribution is concentrated to western Spitsbergen, but 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 (Fox et al. submitted, J. Madsen unpubl. data). Unlike the other two species breeding in Svalbard, the pink-footed geese can defend themselves against Arctic foxes, which explain their dispersed inland nesting and post-hatching distribution. Some non-breeding pink-footed geese migrate to the east and northeast 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, J. 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 fiords of Spitsbergen, in the lowlands along the west coasts, especially under bird cliffs as well as in the lowlands of Edgeøya and Barentsøya (Mehlum 1998, Glahder et al. 2007).

Barnacle goose

The Svalbard breeding population of barnacle goose winters in south-west Scotland/north-west England, UK, with spring staging areas along the west coast of Norway (Helgeland in Mid-Norway and Vesterålen in northern Norway). The population numbered less than 1,000 individuals during the 1950s, but increased to around 14,000 in the start of the 1990s (Owen & Black 1999). Since then, the population has increased to reach a level around 25,000 to 30,000 since 2000 (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 (C. Glahder unpubl. data, Hübner 2006). Barnacle geese nest on islets along the west coast of Spitsbergen, in Storfjorden and Hinlopen. Furthermore, 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. Some of the oldest colony and associated brood-rearing areas along the west coast have reached saturation with apparent density-dependent regulation of 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 Northeast Atlantic flyway population, breeding also in low numbers in Northeast Greenland, and wintering in Denmark and Northeast England. The brent goose was probably the most numerous of the three species in the beginning of the 20th century, but the population crashed and numbered only 2-4,000 individuals in the 1960s. Subsequently, the population has increased to reach a population size varying between 6,000 and 9,000 in 2000-2007 (Clausen et al. 1999, P. Clausen unpubl. data). In Svalbard, pre-nesting congregation sites used during the last week of May are known from specific sites on the west coast. The majority of brent geese nest in small colonies on Tusenøyane in Southeast Svalbard, on Moffen in the north and scattered on islets along the west coast. In addition, small numbers of nests have been found in the interior of valleys in Spitsbergen, close to the glaciers (J. 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 fiords 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 been observed scattered all over Svalbard (Mehlum 1998).

Results

Human activities

Human activity related to tourism is categorized in winter and summer activities. The number of people boarding land from cruise ships has more than doubled over the last 10 years, while the number of new landing sites has more than tripled over the same period (Fig. 2). The increase is found for the whole archipelago, but the load of traffic differs between landing sites (Fig. 1). The official statistics reported from the tourist operators illustrate seasonal patterns of the various outdoor activities (Fig. 3). The winter season, with trips on snow mobiles and dog sledging last from January to May, with a peak in March and April. However, dog sledging has an extended season into May/June using the snow on the glaciers. The snowmobiles bring most people visiting Svalbard into the arctic landscape, while hiking is relatively limited during winter. The tourist activity peaks during summer time, concentrated to June, July and August (Fig. 3 and 4). Most people visit Svalbard staying on cruise boats; hence, in 2005 more than 90.000 people visited Svalbard going on cruise (Fig. 2), going on land on more than 190 different spots around the archipelago. Number of people on organized hiking, rubber boat trips or kayaking starting from Isfjorden is about 8700 visit days summed up from June to October (Fig. 3). Moreover, individual travellers which are concentrated to management area 10 (Isfjorden) add to the number registered at The Governor of Svalbard and AECO. Accordingly, the picture of geographical distribution of "traffic load" is blurred by the fact that the activities within management area 10 are not recorded fully (only activities through organized tourist companies are registered here).

Disturbance effects

Pre-nesting period

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

In general, pink-footed geese appear in larger flocks than barnacle geese and brent geese (pink-footed geese: average 18.1±2.7 (std), range 2-143, n=88, barnacle geese: average 7.0±1.4, range 1-

48, n=41, brent geese: 4.2±1.4, range 2-11, n=6), and the difference between pink-footed geese and barnacle geese was highly significant (t=-3.70, p=0.0003). Moreover, the pink-footed geese were alert to an approaching person at far longer distances than the barnacle geese in the same area, with extremes at 1500 meters distances (pink-footed geese: average 388±32, range 40-1500, n=88, barnacle geese: average 275±34, range 30-1000, n=38, t=-2.24, p=0.027, Fig. 5). The alert distance was highly correlated with the EFD (linear regression, pink-footed geese: R^2=0.80, n=75, p=0.0001, barnacle goose: R^2=0.87, n=38, p=0.0001) and EFD was significant larger for pink-footed geese than for barnacle geese (t=-2.48, p=0.015, Fig. 5). For pink-footed geese, there was a positive and significant relationship between flock size and EFD, where geese in large flocks becoming alert at longer distances than geese in small flock (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-values>0.8).

Nesting period

Escape distances. As there were, for neither of the sexes, no significant differences in EFD between the two islets in Kongsfjorden, Storholmen and Prins Heinrichøya (females: Storholmen=28.7 ±2.2, n=53, Prins Heinrichøya=23.6±3.4, n=25, t=-1.3, p=0.20, males: Storholmen=29.2 m±2.3, n=51, Prins Heinrichøya=23.3±3.7, n=25, t=-1.4, p=0.16), 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 EFD (Proc 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 EFD for the various species and sites are presented in Figure 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 escaping their nest spot at a significant longer distance than males from any other site or species, which did not differ in escape distances (Fig. 6). For females, differences were not only significantly different among sites, but also among the same species at different sites (ANOVA, F=7.51, df=3, 124, p=0.0001, Fig. 6). Average escape distances were, also for the females, longest for pink-footed geese in Sassendalen, but distances were not significant different from those found for females in Kongsfjorden (Fig. 6). The shortest escape distances were found for brent goose females at Lurøya (Fig. 6).

For the barnacle geese in Kongsfjorden, there was a highly significant and positive correlation in EFD among sexes (R^2=0.80, n=76, p=0.0001) meaning that, in general, individuals in a pair behaved similar 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 meters). For pink-footed geese in Sassendalen, the variation in EFD varied considerably (females: 8-100 meters, males: 35-200 meters, Fig. A) and no correlation among sexes was found (R^2=0.001, n=11, p=0.95). There was no correlation among sexes for the geese breeding at Hornøya and Lurøya (all p-values > 0.3), and variation in EFDs were also less at these sites (Fig. 6).

Fleeing distances. Fleeing distances are available for brent geese at Lurøya, pink-footed geese in Sassendalen and barnacle geese at Hornøya (Fig. 7). There were significant differences in 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 and departed their nests and flew several hundred meters away when a person approached the nest (Fig. 7). At Hornøya, the barnacle goose females followed their males after they departed the nest, giving similar fleeing distances for both sexes (Fig. 7a, b).

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 four percent 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 at Lurøya and barnacle geese at Hornøya samples are limited, but all pairs included in the study returned after they had departed their nests and no eggs were observed to be lost to predators (Table 1).

For pink-footed geese in Sassendalen, there were no significant differences in EFD for females among the predation categories no eggs lost vs. egg loss (t=0.51, 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.

Brood rearing period

Limited data exist for the brood rearing period, and records on the EFD and fleeing distance of families towards an approaching person were pooled in three categories based on species, viz. 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.

Significant differences were found among species in EFD (ANOVA, $F=67.81$, df, 2, 13, $p=0.0001$) with longest distances 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 in fleeing distance (pink-footed geese: 1502 m, n=5, barnacle geese: 500 m, n=1, brent geese: 340, n=5), but no significant differences were found among species (barnacle goose excluded; $t=-2.32$, $p=0.08$) although small sample sizes may limit the value of statistical tests.

Discussion

Measures on human activity

The recorded travel statistics on human activity have limited value for the study potential effects of disturbance since they do not include other activities than tourism and do not have a geographical resolution of relevance to estimate real overlaps with goose sites. The only exceptions are the records on cruise landing sites. They show that cruise landings occur all around Svalbard, although at highly variable intensities. We do not have data to suggest any relationships between intensity of human approaches and disturbance effects and impacts. However, at crucial times and places, such as during nesting or on islets during post-hatching, few visits can potentially severely influence nesting success or gosling survival. The seasonal pattern in tourist traffic gives us is a picture of potential conflict periods. Hence, there may be a potential conflict between snow mobile and dog sledging activities and pre-nesting geese in May. Cruise landings, other boating activities and hiking activity overlap with the nesting and post-hatching periods of geese, including the time when geese are flightless.

Escape flight distances

Behavioural measures as EFD's 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 document a negative impact, through increased predation rate at those nests where parent geese have been disturbed to fly off. 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 time of the season and site.

Pre-nesting. The pre-nesting period, i.e., the period between arrival to Svalbard and the start of egg-laying, is a regarded as a crucial period in the annual cycle of the geese, where they maintain or improve their body condition as a prelude to breeding. Both in barnacle and pink-footed geese it has been shown that geese, and females in particular, improve their body condition during that period (Hübner 2006, T. Fox unpubl. data). During pre-nesting, a large proportion of the tundra and hence the available vegetation used for feeding, may be snow covered or frozen (in case of pink-footed geese the latter is important because they rely on subterranean rhizomes and roots; Fox et al. 2007). Hence, the geese may be constrained in food availability, and displacement from feeding patches due to disturbance may reduce food intake rates in a critical way which can have repercussions for the subsequent breeding potential. We found that pink-footed geese in Sassendalen were very shy (average EFD of 388 m). This is in strong contrast to observations from Adventdalen where average EFD of flocks of pre-nesting pink-footed geese approached by a walking person was 35 m (n=5; T. Fox. unpubl. data). The difference may be due to habituation to human traffic in Adventdalen, close to the Longyearbyen settlement, which is in most cases restricted to road traffic. Road traffic is directional, relatively frequent and hence predictable, whereas people walking on the tundra in for example Sassendalen are more undirectional and infrequent and hence perceived as a higher risk. In situations with high degree of snow cover in Adventdalen it has been observed that geese feed along road sides and close to buildings with EFD's of less than 10 meters (N. Eide pers. obs.). This represents an extreme case, likely to reflect that birds are under strong pressure to find food and therefore make compromises between the risk of predation and food intake rates. The observations show that EFD's are highly variable between sites and snow conditions, depending on the predictability of human activity and the physiological state of the birds.

Nesting. In barnacle geese and brent we found that males and females had short EFD's and flew or ran short distances upon disturbance. In several cases it was observed that the geese were 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 EFD's of barnacle geese between Kongsfjorden and Hornøya is probably related to the state of the incubating females. Hence, on Hornøya the geese were probably close to hatching their clutches, when geese generally become more sedentary. In contrast to males of the other species, pink-footed goose males flushed at a long distance from the human intruder and often flew to a position out of view of the nest. Females stayed on the nest with an EFD similar to females of the other two goose species; however, females 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 were entered the goose colonies, gulls and skuas often followed, apparently cuing that the intrusion could elicit an access to the unprotected nests. The reaction by the pink-footed geese indicates a strong fear of humans which may be related to the fact that it is the only of the three species which is hunted (with an open season in Svalbard, mainland Norway and Denmark).

The inference of limited losses of eggs due to human intrusion in colonies of brent and barnacle geese is not that the nesting geese are not vulnerable to disturbance. Intruding humans, maybe entering a nesting island in a group and spreading out over the island, unaware of the presence of nesting geese and the importance of covering exposed nests, are highly likely to cause predation by gulls and skuas.

Brood rearing. Our datasets 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 on average 1717 m from the approaching human, while EFD's of families of barnacle geese and brent 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 but run inland, towards the river (in case of Sassendalen, Fox et al. 2007), or to the sea. In Gipsdalen it was observed twice that families feeding on the foot of a steep slope ran uphill to hide in the steep slopes at an elevation of 300-400 m a.s.l. Their behaviour is possibly an adaptation to the fact that they can defend themselves against Arctic foxes, while the extreme reaction towards humans only can be interpreted as a strong fear of humans. Barnacle goose families which are the most tolerant of the three species will run to the refuge lake in case of disturbance and will stay on the lake. In Ny Ålesund and more recently in Adventdalen, barnacle goose families have habituated to human activities and occur close to human settlements and traffic. In Ny Ålesund, the occurrence of Arctic foxes, which can predate heavily on the goslings, is the main factor constraining their flexibility in site use in the settlement, not humans (Loonen et al. 1998).

Due to their highly localised distribution in Tusenøyane, Moffen and 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 the access by boats in most years, although in some years, they can also get there in June (Madsen et al. 1998). Tourists walking over the small islands may potentially cause the families to leave and swim across to other islands, or even north to Edgeøya. On Tusenøyane, food resources are very limited (Madsen Bregnballe & Mehlum 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 EFD's in non-breeding moulting geese, but from observations from East Greenland it is known that especially pink-footed geese are extremely wary; human intrusion in lake moulting areas can elicit that the geese run across the tundra and do not return to the moulting site again. Again, barnacle geese were more relaxed and remain on the moulting areas (Madsen, Boertmann & Mortensen 1994). Because the geese are flightless, a disturbance that will elicit that the geese depart from the refuge and run across the tundra will highly increase the risk of predation by Arctic foxes, although quantitative data is missing.

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

Management implications

At the moment, probably none of the three goose species are critically threatened by human activity in Svalbard. However, with the potential for increasing pressure due to increased traffic at various times of the season and more widespread over the archipelago, this paper addresses some important precautions which may result in guidelines for recreational activities.

Pre-nesting. There is a potential conflict between snowmobile activities and pre-nesting geese which congregate in certain areas, such as Vårsolbukta and Adventdalen. However, we have little information about the actual disturbance effects, and recommend that a study is designed to address this particular potential conflict.

Nesting. Nesting areas are obviously vulnerable to disturbance. Pink-footed geese appear to particularly vulnerable due to their long escape flight and fleeing distances, exposing nests to predation. As these geese mostly breed in colonies both on islands and in inland tundra areas, guidelines for human traffic are easily suggested. Detailed maps on geese breeding colonies should be made available for visiting people. 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 to 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 in the most visited spots. In this relation it is relevant to underline the importance of having good geographical resolution on all traffic by humans (see also evaluations in Vistad et. al. 2008). Today, knowledge is limited on 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 own initiative (N. Eide & J. Madsen pers. obs.). Setting up a camp site in e.g. Sassendalen with hiking trips connected to the camp could have huge negative impacts on nest success for geese in this area if precautions are not taken.

Post-hatching. Goose families are highly vulnerable to hiking in the brood-rearing areas; brent and barnacle geese are limited to stay close to open water and can potentially be prevented from foraging for a long time due to visits. Again, families of pink-footed geese are particularly vulnerable due to extremely long escape flight distances. In case hikers walk along the valley floor of Sassendalen, the people will probably not be aware of geese fleeing in front of them, and people walking through the valley can unintentionally be pushing large numbers of geese all the way down the river, with loss of feeding time and potentially increased predation risk. Therefore, in high density brood rearing areas, precautions should be made to avoid mass disturbance by regulation of hiking routes.

Moult. Non-breeding moulting geese are highly sensitive to disturbance, and precautions should be made to avoid landings and hiking routes 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 to give advice on vulnerable areas.

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

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Fig. 1. Three study sites on Svalbard with data on disturbance effects on geese; Case 1: Tusenøyane, Case 2: Kongsfjorden, Case 3: Sassendalen. Red dots represent the geographical distribution of cruise ship tourists at different landing places 2006 (the year with peak recorded landing places). Data source: Governor of Svalbard.

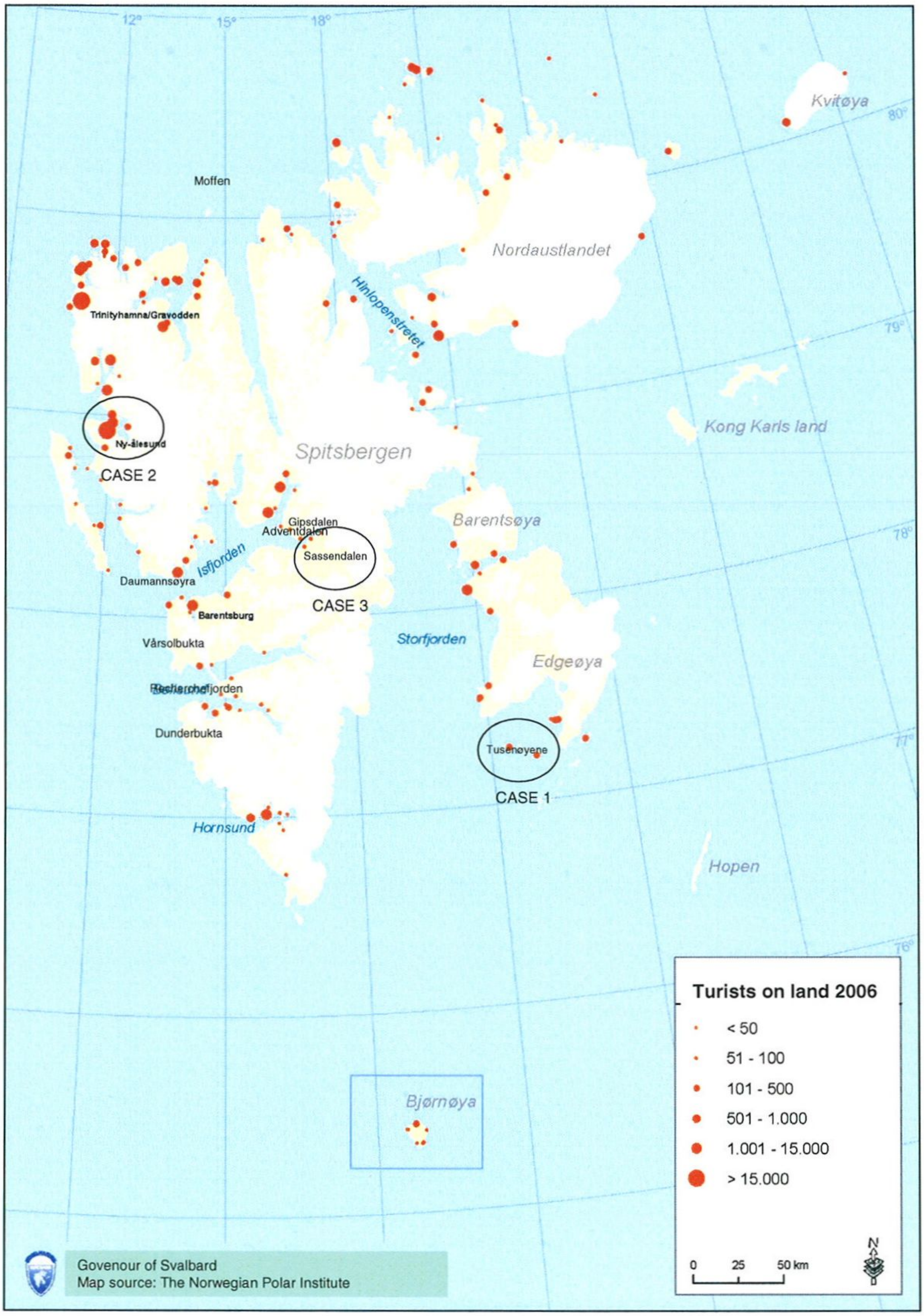


Fig. 2. The development of cruise ship activities in Svalbard, 1996-2006, expressed in the total annual numbers of cruise ship tourists and number of landing places used around Svalbard. Data from Isfjorden ("management area" number 10) are separated. Data source: Governor of Svalbard.

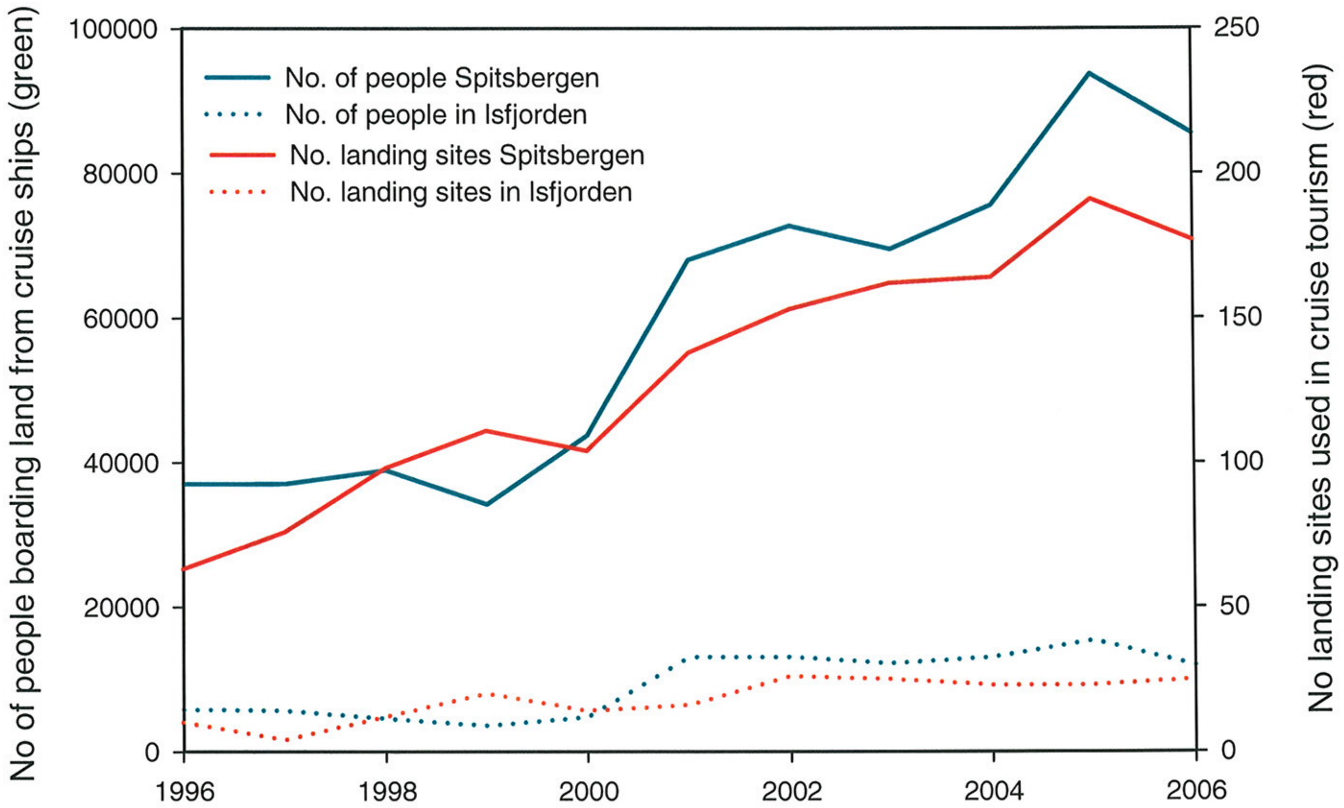


Fig. 3. Monthly numbers of reported recreational activities, divided in snowmobiles, dog sledging, people on foot/skis and other activities (rubber boats, kayaking, shorter hiking trips) on Svalbard. Numbers are averages for the years 2004-2006. Data source: Governor of Svalbard.

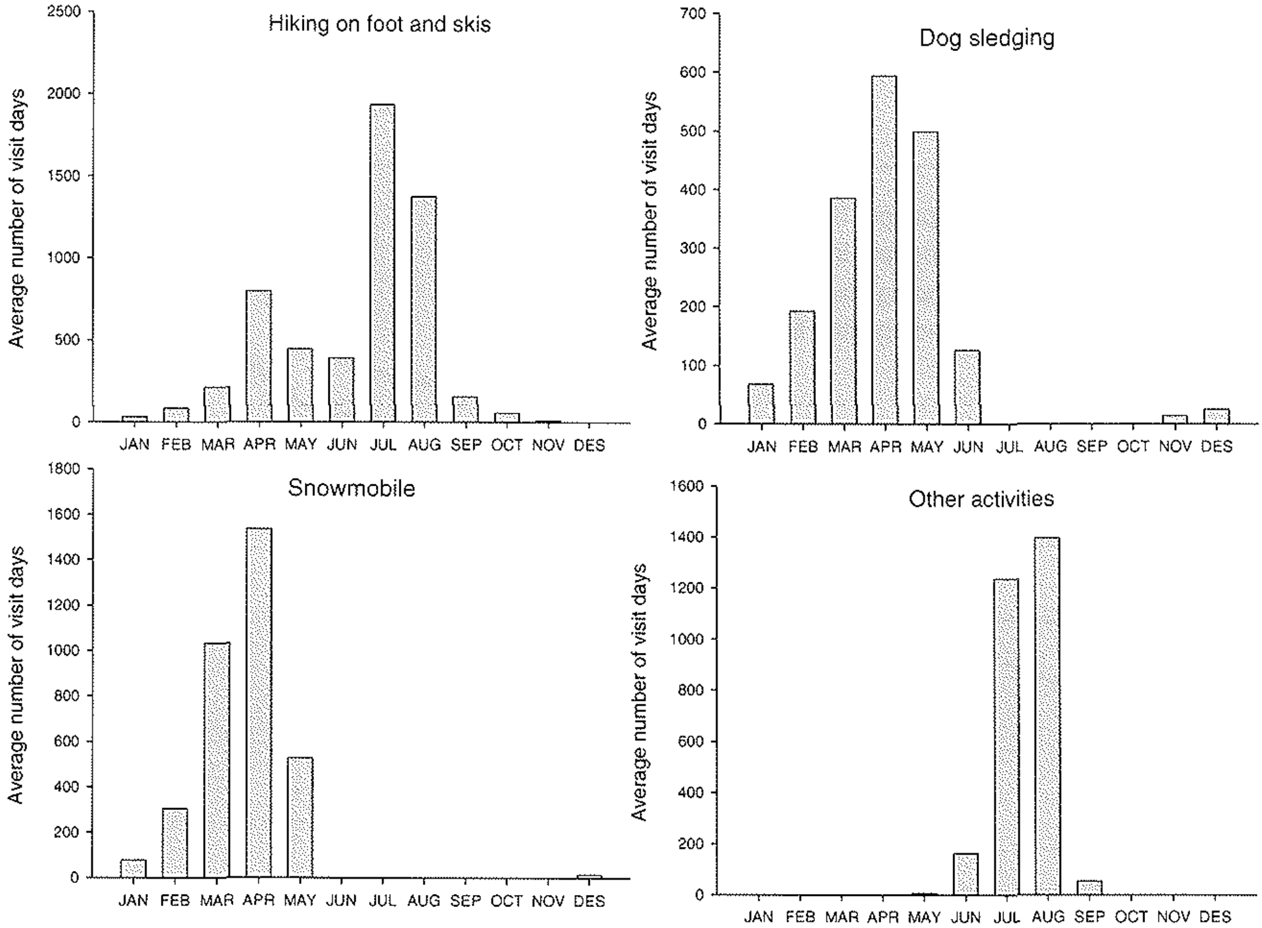


Fig. 4. Monthly numbers of planned landings by cruise ships on Svalbard in 2007. Data source: AECO

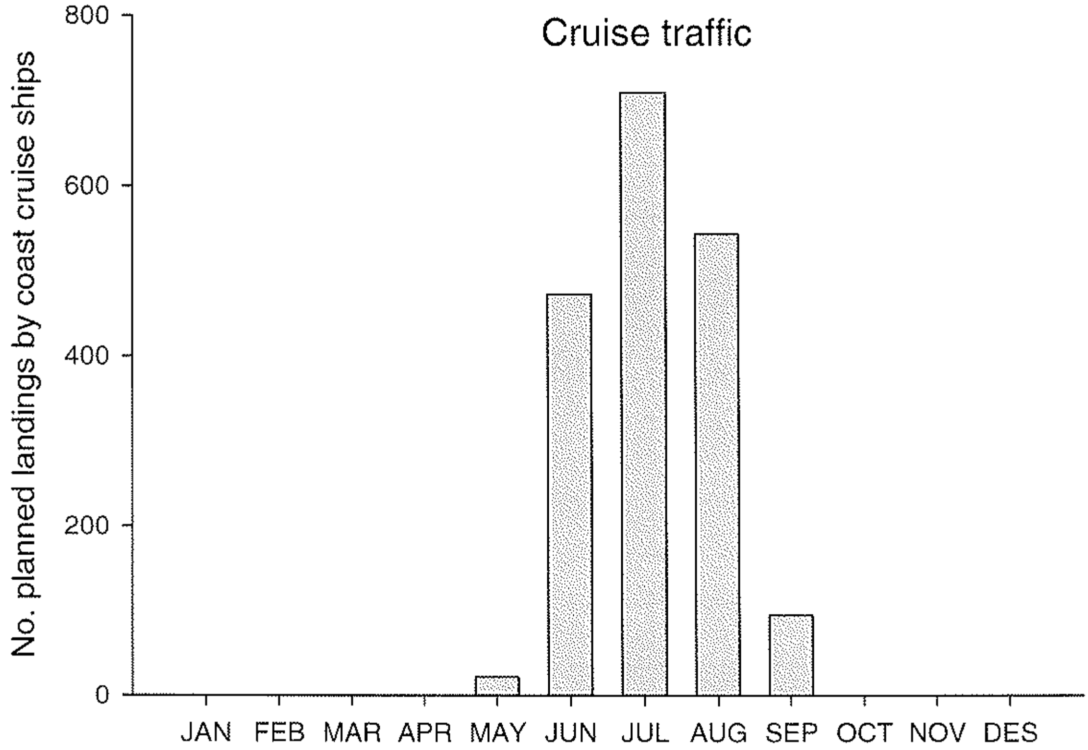


Fig. 5. Escape flight distance (white boxes) and alert distance (grey boxes) in response to an approaching person for three goose species in Svalbard during the pre-nesting period (no alert distances were recorded for brent geese). Plot shows median values (solid horizontal lines), 25 and 75% quartile (boxes) and range (dotted line). See text for statistics. Sample sizes are shown in brackets on top of each box.

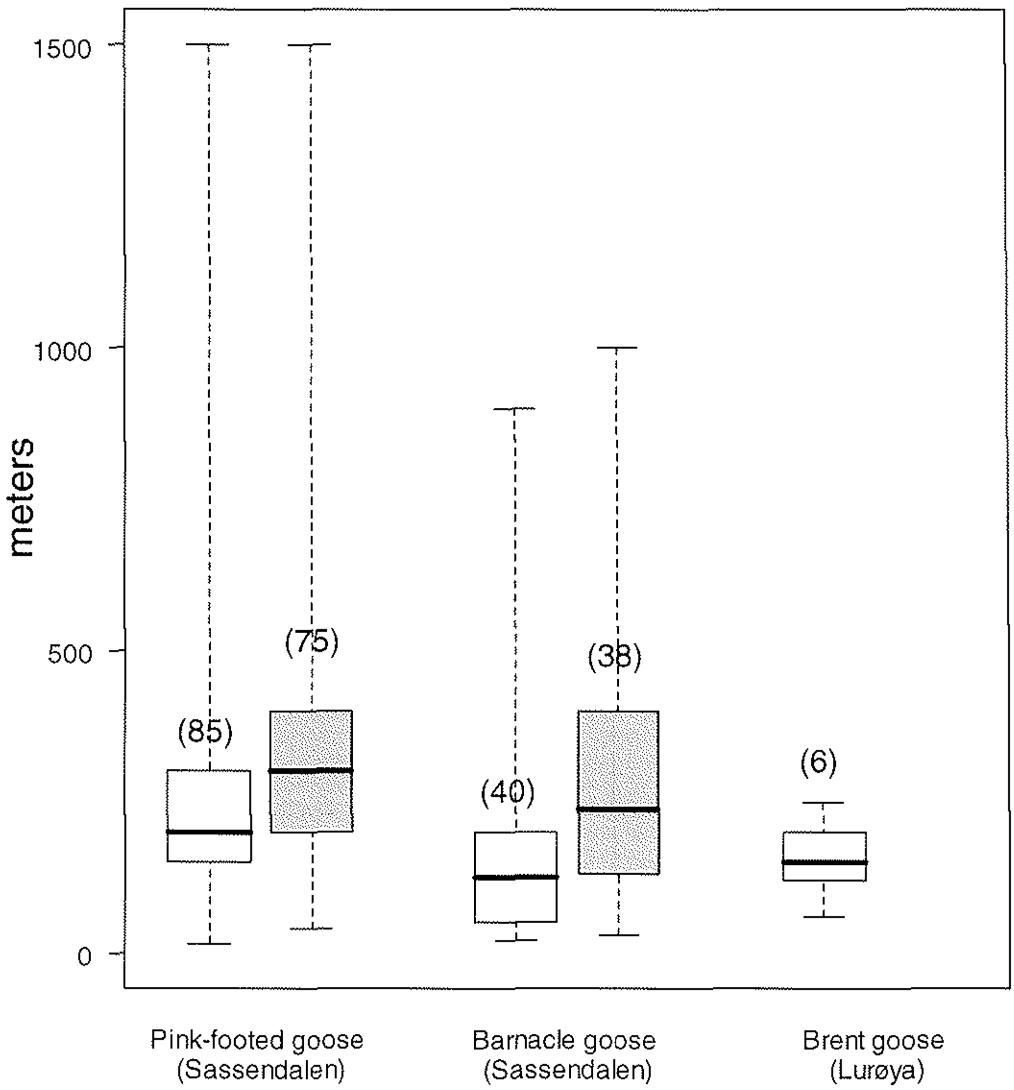


Fig. 6. Escape flight distances in response to an approaching person for geese nesting on Svalbard at different sites. Males a) and females b) are shown separately in box plots with median (solid horizontal lines), 25 and 75% quartile (boxes) and range (dotted lines). Similar letters on top of each box indicate no significant differences between sites, whereas different letters indicate that 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).

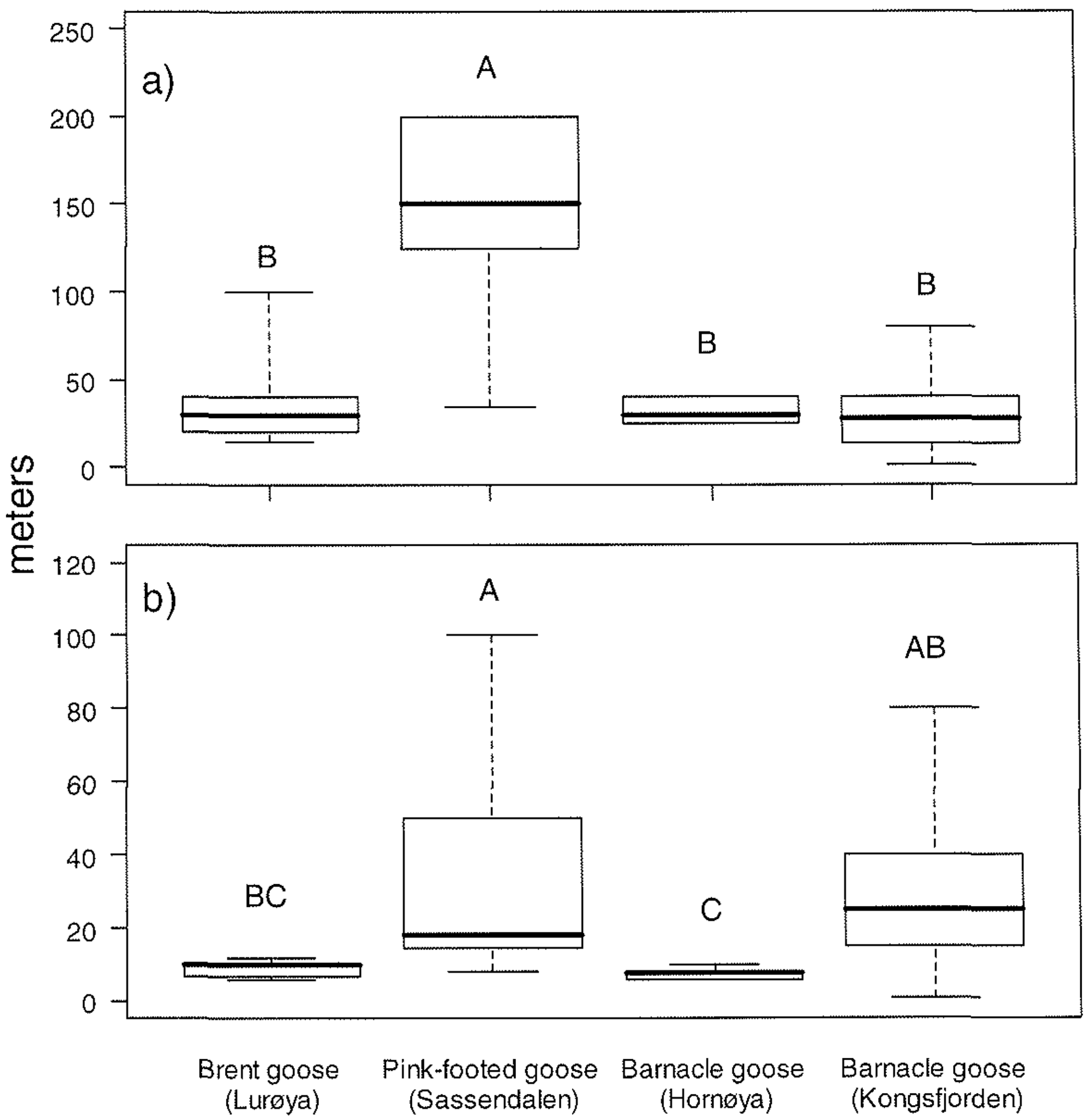


Fig. 7. Fleeing distances away from the nest after an approaching person for geese nesting on Svalbard at different sites. Males a) and females b) are shown separately in box plots with median (solid horizontal lines), 25 and 75% quartile (boxes) and range (dotted lines). Similar letters on top of each box indicate no significant differences between sites, whereas different letters indicate that 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). No data available for Kongsfjorden.

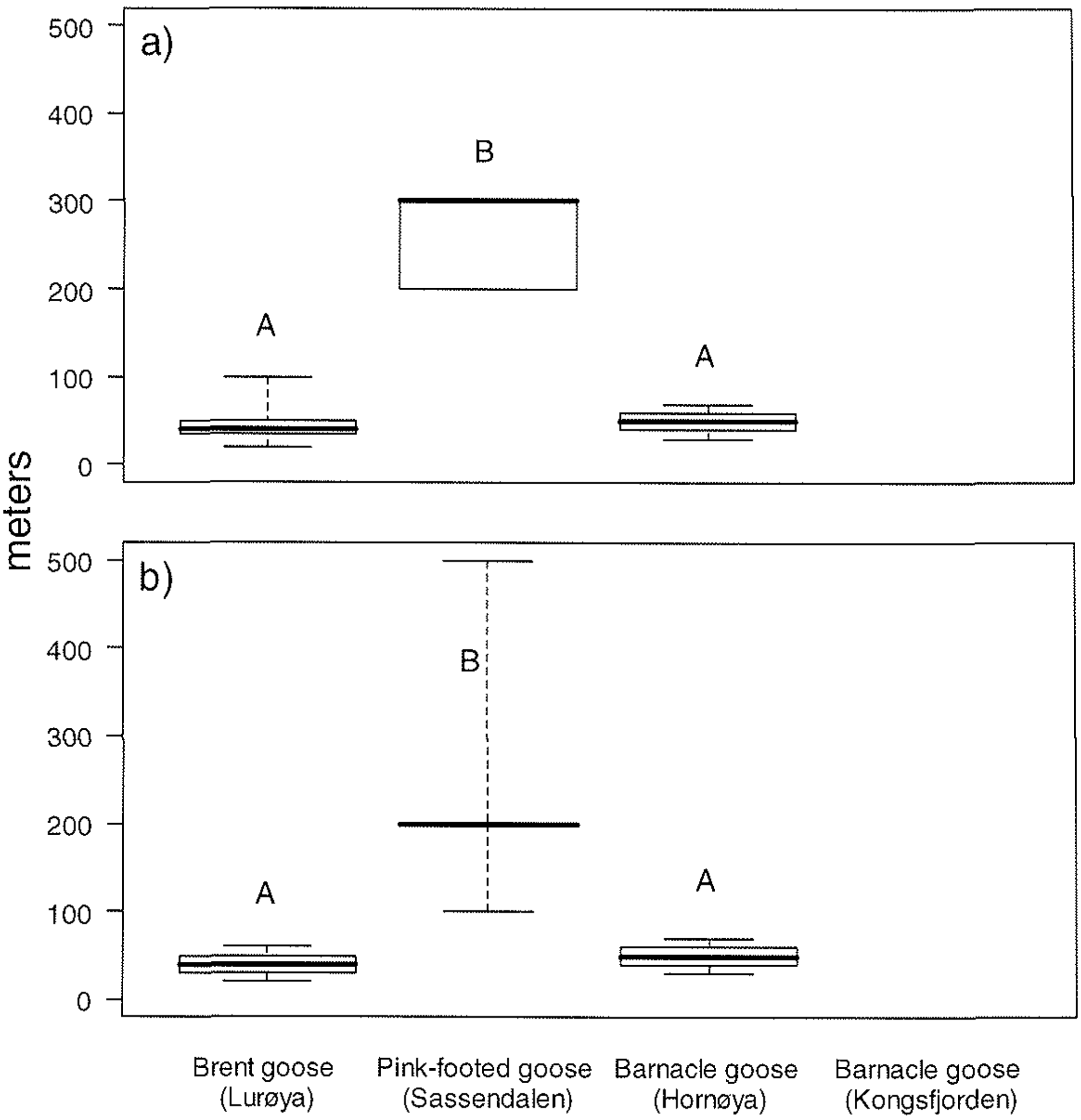
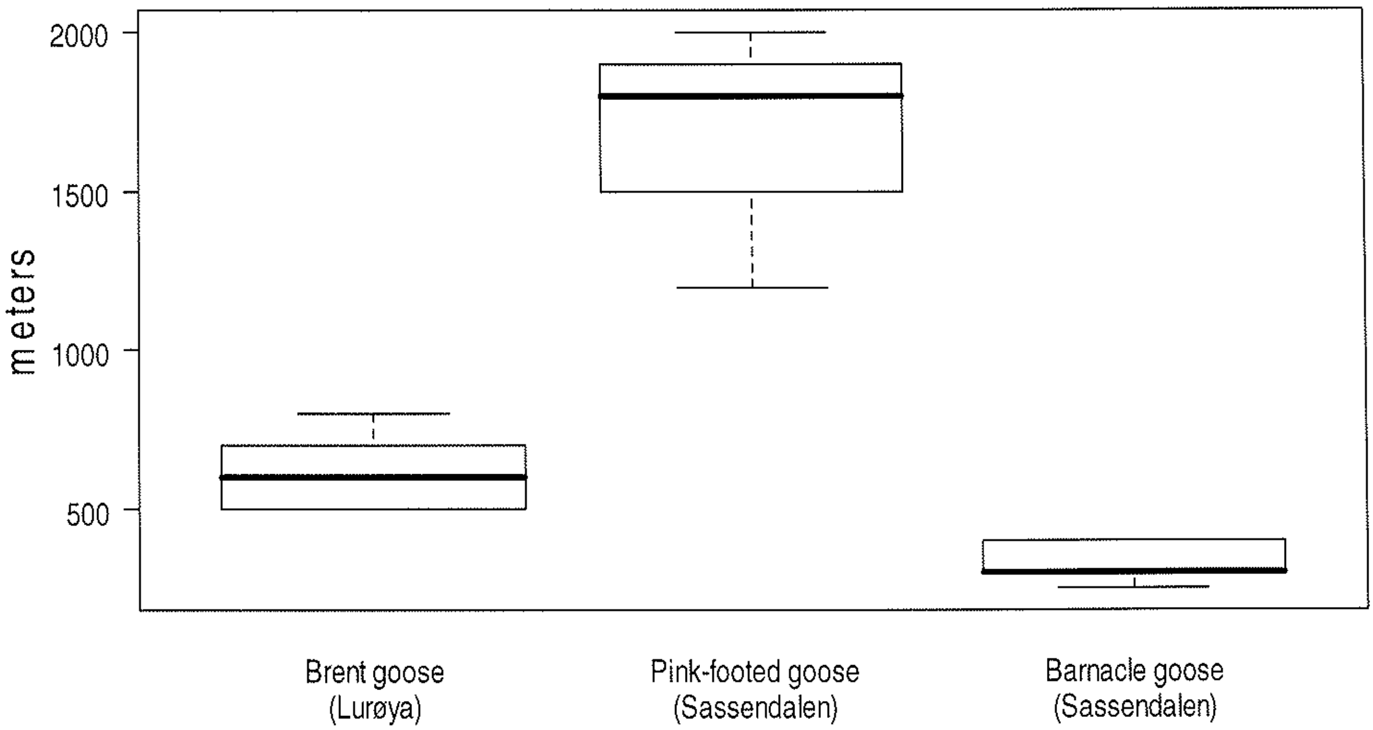


Fig. 8. Escape flight distances in response to an approaching person for family groups of the three species of geese on Svalbard at different sites. Box plot shows median (solid horizontal lines), 25 and 75% quartile (boxes) and range (dotted lines).



	No. of nests with no egg loss	No. of nests with partial egg loss	No. of nests with complete egg loss	Sex	EFD for pairs with no egg loss	EFD for pair with egg loss[1]
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)

[1] partial and complete clutch loss combined

Table 1. Egg predation for goose nests after provoked nest approaches by a walking person. Escape flight distances (EFD) are presented in meters as averages (± standard error). Sample sizes are given in parantheses.