

Goose distribution in relation to SPAs in Grampian





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COMMISSIONED REPORT

Commissioned Report No. 546

Goose distribution in relation to SPAs in Grampian

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COMMISSIONED REPORT

Summary

Goose distribution in relation to SPAs in Grampian

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Background

There are currently many applications for small-scale wind farms in Grampian, often in areas associated with significant levels of flight and/or feeding activity by pink-footed and greylag geese. The aims of this review are (i) to collate existing knowledge on goose feeding sites and flight activity in Grampian; and (ii) to examine whether it is possible to define zones of risk for goose activity around designated sites in Grampian.

Main findings

- Data from goose feeding surveys at different sites, and from radio-tracking of individual birds, indicated that the median foraging distance from roosts lay between 4 and 5 km, with the maximum distance typically up to 20 km.
- The number of foraging geese recorded 5 – 10 km from the Loch of Strathbeg roost was only slightly lower than the number recorded in the 0 – 5 km zone, with the drop in density explained largely by the increase in land area available to the birds in the farther zone. Far fewer geese were found beyond 10 km, although the land available to geese was only slightly smaller there. This suggests that similar numbers of geese flew out to 0 – 5 km and to 5 – 10 km, but that fewer went beyond 10 km.
- Flight activity declined progressively with increasing distance from roosts, falling to around 7-8 geese km⁻² h⁻¹ beyond 20 km, which may be the 'background' level for the region. However, there was considerable variation in flight activity at all distances, possibly caused by differences in the attractiveness of fields to geese according to changes in the rotation of cropping. Similarly, for the small number of sites with flight data from more than one year, considerable between-year variation in flight activity occurred.

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Table of Contents	Page
1. INTRODUCTION	1
1.1 Aims	1
2. METHODS	2
2.1 Sites	2
2.2 Goose feeding distribution	2
2.3 Radio tracking	7
2.4 Goose flight height	7
2.5 Goose flight activity	8
3. RESULTS	10
3.1 Variability in goose numbers and flight height	10
3.2 Distribution of flight activity	11
4. GOOSE FEEDING DISTRIBUTION AROUND THE LOCH OF STRATHBEG	16
5. GOOSE USE OF REFUGES IN THE STRATHBEG GOOSE MANAGEMENT SCHEME	18
6. CONCLUSIONS	19
6.1 Goose density in relation to distance from the roost	19
6.2 Zonation	19
7. FUTURE WORK	21
8. REFERENCES	22
ANNEX 1: THE DATA ON WHICH THE ANALYSES WERE BASED	23

1. INTRODUCTION

Geese can be affected by wind farms through disturbance, displacement from feeding sites and collision mortality. Disturbance during construction is short-term in relation to the life of the wind farm and will be minimal if the work takes place over the summer, as is often the case. Disturbance from routine maintenance will generally be for short periods and will be similar in scale to that from normal agricultural activities. Displacement from feeding areas will result from avoidance of the turbines by foraging geese, which tend to stay around 100m away from single turbines and those in lines and around 200m away from clusters of turbines (Larsen & Madsen, 2000). Collision mortality tends to be low in geese, which appear to be efficient in avoiding turbines (Patterson, 2006), and current SNH advice is to use a 99.8% avoidance rate in collision risk calculations. However, even if the predicted number of collision casualties is low at any given wind farm development, the cumulative impact could become significant if large numbers of turbines were to be built in areas with high densities of geese. This will be especially significant in the areas around Special Protection Areas (SPAs) which include major goose roosting sites.

There are currently numerous applications for small-scale wind farms, typically of 1-3 turbines each, in Grampian. These potentially affect large numbers of pink-footed geese *Anser brachyrhynchus* and greylag geese *Anser anser* at roosts or in foraging areas. As most of these birds spend at least part of the winter on one or more SPAs in Grampian, there is a need to make robust assessments of the effects of these turbines on geese. However, dedicated impact assessments for each proposal can be onerous to developers, and create heavy workloads for SNH and planners when reviewing them. In the future, SNH wishes to develop more sophisticated approaches to this casework, with the early identification of benign applications that do not require in-depth bird assessments.

1.1 Aims

The aims of this review are to (i) collate existing knowledge on goose feeding sites and flight activity in Grampian; and (ii) examine whether it is possible to define zones of risk for goose activity around designated sites in Grampian.

2. METHODS

Information on the feeding distribution of geese was obtained from published surveys and studies, including those commissioned in connection with the Loch of Strathbeg Goose Management Scheme, while goose flight height information was collated from unpublished data collected by the author. Goose flight activity at different distances from roosts was collated mainly by searching Environmental Statements submitted in support of individual wind farm projects, with some additional data from the author's own observations.

2.1 Sites

In North-East Scotland, the following SPAs are designated for pink-footed and/or greylag geese and were included in this review:

- Loch of Strathbeg SPA
- Ythan Estuary and Meikle Loch SPA
- Loch of Skene SPA
- Moray and Nairn Coast SPA (including Spey Bay SSSI and Findhorn Bay SSSI). The latter is the principal goose roosting site in the SPA
- Montrose Basin SPA
- Loch Spynie SPA
- Muir of Dinnet SPA

These SPAs are all in Grampian, apart from Montrose Basin, which is close to the regional boundary. The geese are a qualifying interest of these sites, either individually named on the citation or named as part of the waterfowl assemblage.

2.2 Goose feeding distribution

Bell (1988)

In the 1980s, Bell (1988) carried out a goose distribution survey of Grampian north of the River Dee and east of the River Deveron. This included the feeding areas of the main pink-footed goose roosts at Loch of Strathbeg and the Meikle Loch/Ythan estuary. The results were expressed as 1 km squares in which geese were recorded.

In the Strathbeg area, pink-footed geese were concentrated to the north-west and to the south of the roost, with a median distance of 5 km between the roost and squares where geese were recorded. In most years, no geese were found more than 14 km from the Loch of Strathbeg, although in autumn 1985, when there were unusually high numbers at the roost, geese were found feeding 17 – 20 km away (Figure 1).

Around the Meikle Loch and Ythan estuary, the median distance between the roost and squares where pink-footed geese were recorded was 6 km, with a maximum distance of 13.5 km (Figure 1). The birds were concentrated to the north and north-west of the roost and in the area to the south-west of the town of Ellon.

The distribution of pink-footed geese differed between the two areas, with birds from Strathbeg concentrated closer to the roost but also ranging further away than birds from the Ythan (Figure 1).

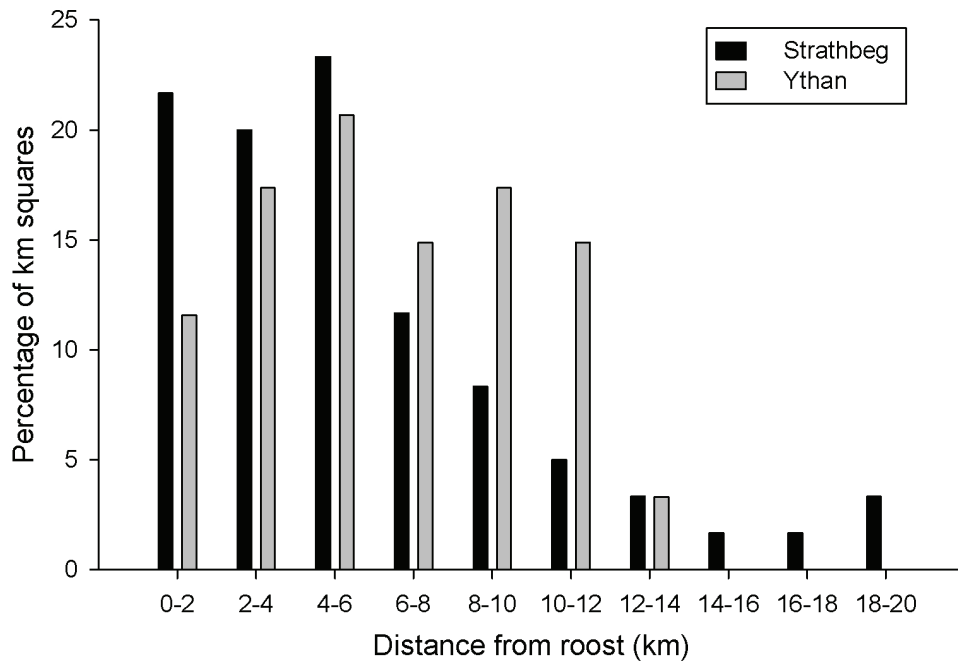


Figure 1. The distance from the Loch of Strathbeg and Ythan area roosts of km squares occupied by pink-footed geese. Redrawn from Bell (1988).

Patterson *et al.* (1989)

Patterson *et al.* (1989) surveyed the feeding distribution of geese around the Ythan estuary from October 1984 to April 1986, as part of an investigation of goose damage to winter cereals. The boundary of the survey area is not defined in their paper, but extended at least 14 km from the roost sites at the Meikle Loch and Ythan estuary. Feeding sites were located by following flight lines from the roost at dawn, by traversing all the roads within the survey area searching for goose flocks and by watching the behaviour of small groups of flying geese, which tended to land where other flocks were already feeding. The last of these techniques was effective in revealing feeding sites which were not easily visible from roads.

Patterson *et al.* (1989) found that feeding sites used by greylag and pink-footed geese were clustered to the north-east and to the south-west of the roosts (Figure 2), with other sites further away to the north-west, beyond a gap in the distribution around the town of Ellon. In the late winter and spring, the geese foraged closer to the Ythan estuary, where most of the birds roosted after shooting ended there in late February (Figure 2, b).

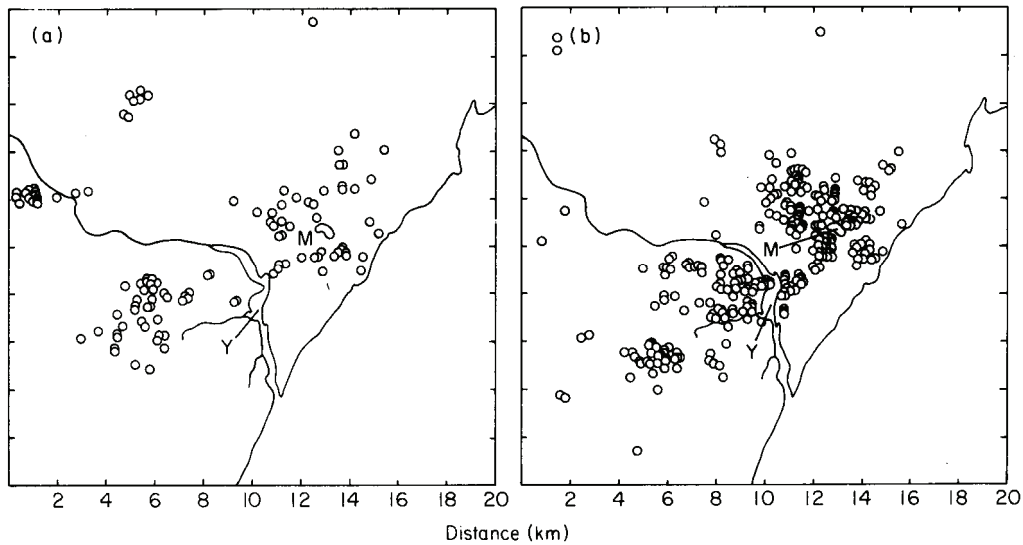


Figure 2. Feeding sites used by pink-footed and greylag geese in (a) October to December 1985 and (b) January to April 1986, in relation to roost sites at the Meikle Loch (M) and the Ythan estuary (Y). From Patterson et al. 1989. (Reproduced with permission of Wiley Publishers).

The median distance from the roost of pink-footed goose feeding sites varied between 4.0 km and 4.9 km (Table 1), apart from distances from the Meikle Loch in January to April 1985, when the median distance was 3.1 km. The median distances from the roost in late winter and spring 1984/85 (3.1 and 4.0) were lower than the distance in autumn and early winter (4.9), but there was no such difference in 1985/86 (Table 1).

Table 1. Median distance of pink-footed goose feeding sites from the Meikle Loch and Ythan roosts. From Patterson et al. (1989).

Roost site	Time period	Median (km)	Sample size
Meikle Loch	Oct. – Dec. 1984	4.9	82
Meikle Loch	Jan. – Apr. 1985	3.1	305
Ythan estuary	Jan. – Apr. 1985	4.0	305
Meikle Loch	Oct. – Dec. 1985	4.7	100
Meikle Loch	Jan. – Apr. 1986	4.6	179
Ythan estuary	Jan. – Apr. 1986	4.8	179

Keller et al. (1997)

Keller et al. (1997) surveyed an area around the Loch of Strathbeg, bounded by a line joining Rosehearty, Strichen, Mintlaw and Peterhead, by driving along all of the roads in the area every week from 15 March to 19 April 1989 and from 20 February to 25 April 1990. Goose density was analysed by plotting the number of geese within 500m of each intersection of a 500m x 500m grid. The birds' distribution was concentrated to the north-west and to the south of the loch, with smaller centres of activity in the Ugie valley and in an area to the south-west of Fraserburgh (Figures 3a, 3b).

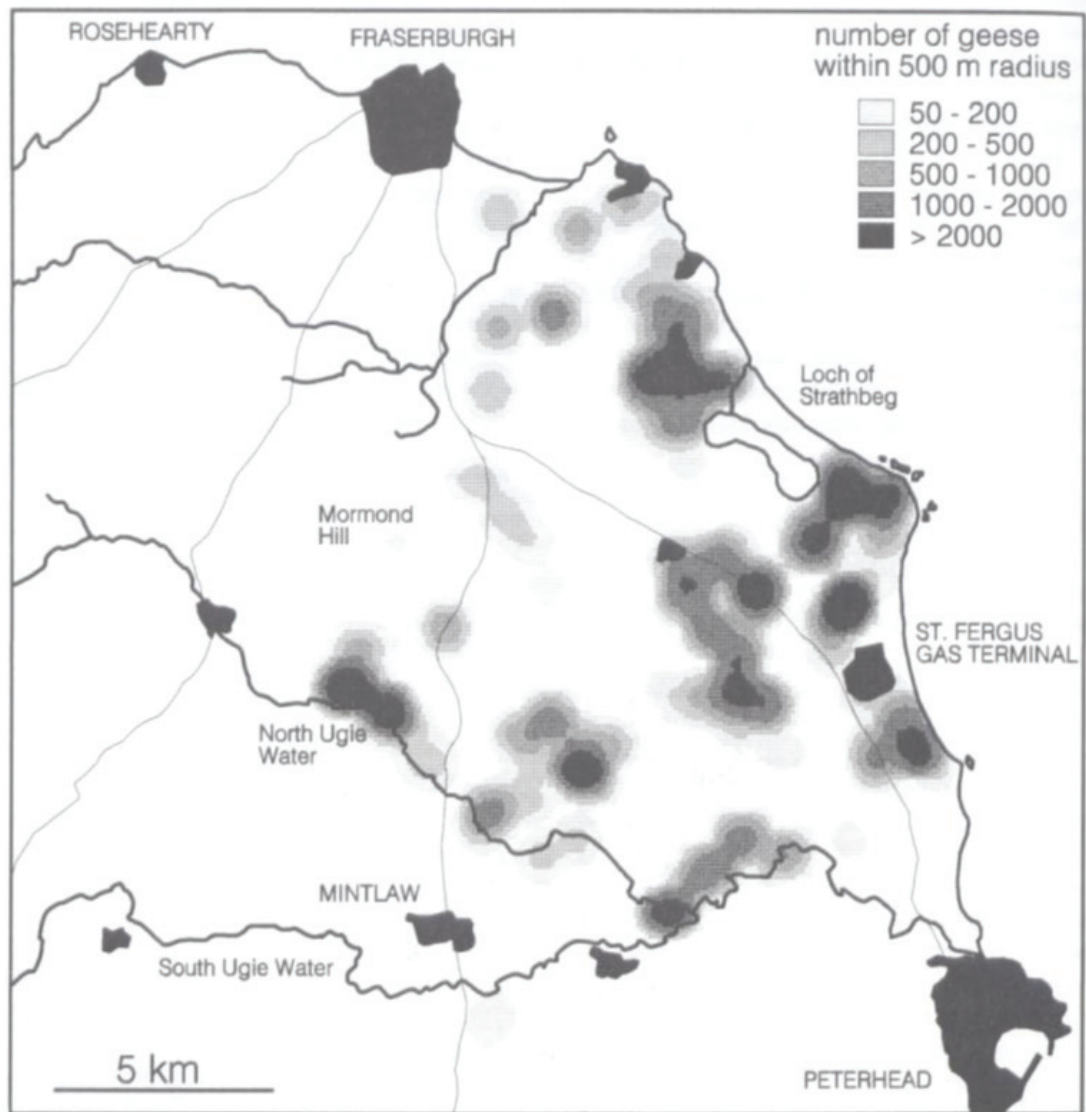


Figure 3a. Distribution of feeding areas used by pink-footed geese in the area around the Loch of Strathbeg in February to April 1989. From Keller et al. (1997).

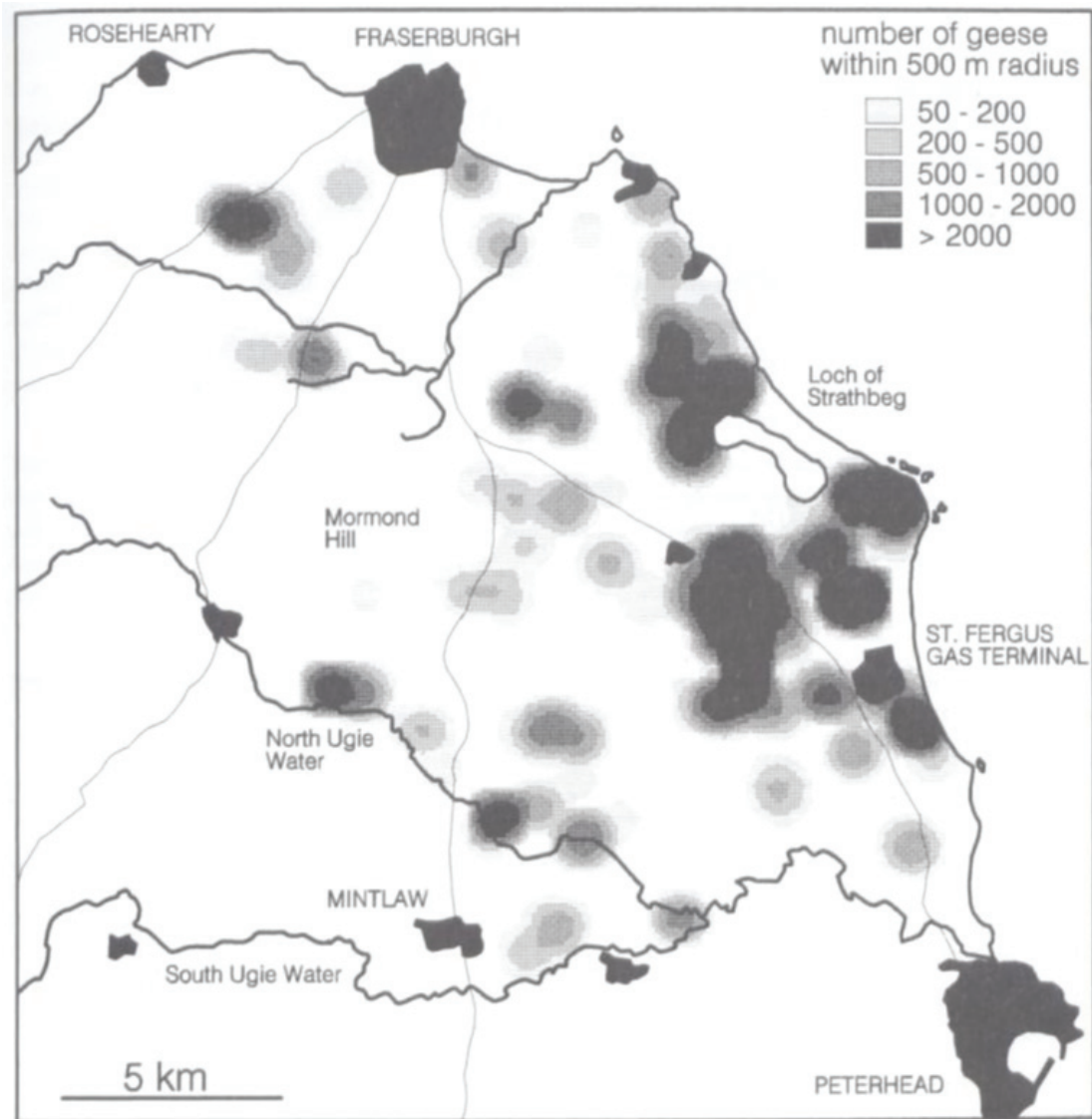


Figure 3b. Distribution of feeding areas used by pink-footed geese in the area around the Loch of Strathbeg in February to April 1990. From Keller et al. (1997).

The overall median distance of pink-footed goose flocks from the roost was 4.3 km, decreasing from 4.6 km in February to 4.3 km in March and 3.8 km in April (Table 2).

Table 2. Median distance of pink-footed goose feeding sites from the Loch of Strathbeg roost. From Keller et al. (1997).

Month	Median (km)	Interquartile range	Sample size
February	4.6	3.6 – 8.0	118
March	4.3	3.2 – 6.8	243
April	3.8	2.3 – 5.0	235
Overall	4.3	2.9 – 6.5	596

Urquhart (2002)

Urquhart (2002) tested the effects of field characteristics on the sites used by foraging geese in central Scotland, with a view to the construction of a predictive model of goose feeding distribution. She found a significant decrease in field use by geese with increasing distance from the roost ($R^2 = 0.326$, $p < 0.01$). The proportion of fields used by geese showed no decrease up to 5 km from the roost, before declining. Beyond 7 km, very few fields were used.

2.3 Radio tracking

Giroux (1991); Giroux and Patterson (1995)

Giroux & Patterson (1995) tracked 11 pink-footed geese, caught near the Meikle Loch and fitted with tail-mounted radio transmitters, from 6 January to 27 April 1988. One individual at a time was selected at the roost before dawn and was followed all day until its return to the roost in the evening. The maximum distance that the geese were from the roost during the day had a median value of 4.8 km, ranging from 0.5 km to 11.4 km. The maximum distance did not change significantly over the study period but varied significantly between individual geese. The bird which travelled furthest had a mean maximum distance of 7.6 km ($n = 3$ days) while the one which travelled the shortest daily distances had a mean of 1.9 km ($n = 9$ days).

Five of the 11 geese left the Ythan area on a total of 12 occasions for periods of 1 – 20 days before returning (Giroux 1991). Attempts were made to locate the birds during their absence by checking the neighbouring roost sites after nightfall. Four movements were traced to Strathbeg and one to Montrose, but the other birds could not be located. Two other geese moved to Strathbeg immediately before their departure on spring migration.

Keller et al (1997)

Keller *et al.* (1997) tracked seven pink-footed geese, caught near the Loch of Strathbeg, from February to April 1990 and a further 11 birds from November 1990 to April 1991. In spring 1990, the whole Strathbeg feeding distribution survey area (Figure 3) was searched systematically for radio-tagged geese, while in 1990/91 individuals were selected at the roost before dawn and followed all day.

Most of the radio-tagged geese (all of them in spring 1990) were located within the concentration areas identified by the survey of feeding distribution (the shaded areas in Figure 3, above). However, in 1990/91, some tagged geese were found outside the boundary of the feeding distribution survey area, to the north-west and south-west of Strichen, and in an area to the south-west of Fraserburgh. Both of these areas were approximately 16 km from the roost.

Three of the radio-tagged geese moved to the Ythan area immediately after being caught and four others spent several weeks there before returning to Strathbeg. One bird was found at Montrose, 90 km to the south.

2.4 Goose flight height

The risk of geese colliding with wind turbines will be affected not only by the number flying over the wind farm but also by the height at which they are flying. Information on flight height during different activities (e.g. on foraging flights or on longer-distance movements) is important in assessing the risk in different parts of the birds' range.

Flight heights of pink-footed geese engaged in different activities were measured by the author, using a Leica LAF 1200 laser rangefinder with a simple clinometer attached to it to determine range and angle. These measurements were then used to calculate the vertical height of each goose flock. The maximum range of the instrument when used on goose flocks was found to be around 350m. The heights of flocks flying higher than this were estimated by eye to the nearest 100m, using the measured heights of other flocks as a guide.

Pink-footed geese on local flights between the roost and feeding sites, or between fields within the foraging areas, mainly around the Strathbeg area, were found on average to be flying at just over 100m (Table 3). More than two-thirds of the flocks (69%) were flying at heights below 150m and so were at risk of collision with the larger turbines now in operation.

The heights of goose flocks on longer-distance movements were measured mainly as they flew over the west edge of Aberdeen, presumably travelling between the Meikle Loch roost, 29 km to the north and Montrose, 52 km to the south. These flocks were flying on average at heights over 250m (Table 3), with only 12.5% under 150m.

Flocks of geese returning to roost, apparently from fairly distant feeding areas in calm weather or with a following wind, were found to be flying at over 160m (Table 3), even when very close to the roost, before descending steeply when almost over the loch. When returning from nearby feeding areas, especially against strong adverse winds, geese were seen to fly much lower, at or below the flight heights usually observed in foraging areas (I.J. Patterson, unpublished observations).

Table 3. Flight heights of pink-footed geese, measured by laser rangefinder. I.J. Patterson, unpublished data.

Activity	Median height (m)	Mean height (m)	Sample size
Foraging	114	122	123
Long-distance	268	310	40
Returning to roost	165	174	15

It is clear from these measurements of flight height that geese are at most risk of collision when they are flying between the roost and feeding areas or are flying between foraging sites within the feeding area. Geese on longer-distance flights, which will include journeys between roosts and distant feeding areas, tend to fly above the zone of collision risk.

2.5 Goose flight activity

Data sources

Data on goose flight activity at different distances from SPA roosts were obtained from surveys carried out at proposed wind farm sites within 30 km of each SPA. The information was found mainly by searching for Environmental Statements (ESs) or equivalent documents submitted in support of planning applications and posted on local council websites. The Aberdeenshire Council website allowed searches by site name (obtained from the SNH map of wind farm sites in Scotland), by the name of the applicant's agent or by the word "turbine" in the application. Some ESs gave lists of nearby wind farms in connection with their assessment of cumulative impact; these lists were used to check for any sites missed by the other searches.

For flight activity around Findhorn and Loch Spynie and around Montrose, the Moray Council and Angus Council websites were examined. However, these websites were either not

easily searchable (Angus) or did not post the relevant documents (Moray), so ESs from these areas were provided by SNH, who, as consultees, held copies of the documents.

In an initial screening of the applications found, developments which proposed turbines smaller than 50m maximum tip height were omitted from further consideration since a sample of these did not include surveys of goose flight activity. Any of the remaining applications which did not include an ES were listed, along with the grid references of the sites, but no further data were collected. For applications with an ES or equivalent document, the ornithological section was downloaded and examined for the presence of vantage point observations of goose flight activity. Some were found to include a breeding bird survey but no vantage point observations and were also merely listed, along with the grid references of the sites.

Of the ESs with vantage point surveys, nine were found to cover only part of the goose wintering season, usually autumn only or spring only, and were again only listed, with their grid references, since the data would not be comparable with surveys which covered the whole season. The remaining documents, with vantage point surveys carried out over at least one whole goose wintering period, provided a total sample of 42 surveys, including seven at sites still at the pre-application stage, the data for which are held by the author. The data from the latter, on goose flight activity in relation to distance from the nearest SPA, are used in the following numerical analyses but their names and locations must remain confidential, so the sites are not plotted on the map at Figure 4.

Data extraction

The principal data extracted from the ESs were the numbers of geese recorded flying over the sites, usually from tabulated data but sometimes from values in the text when data tables were not included. Since the number of geese recorded at a site will depend not only on flight activity but also on survey effort and the size of the area being observed, the number of hours of observation and the size of the survey area were also extracted. Very few of the surveys in the ESs defined the survey area boundary on their flight line maps, so it was not clear whether all of the records in the accompanying data tables were of geese flying over a defined survey area. Consequently, where no survey area was defined, the size of the observed area was derived from the maximum extent of the mapped flight lines (assuming that the surveyors did not extrapolate lines beyond the point where they were visible).

Both greylag and pink-footed geese have been included in the calculation to give values for total goose flight activity at each site. However, since numbers of greylag geese in Grampian have decreased greatly in recent years (with large numbers now wintering in Orkney), the great majority of geese recorded were pink-footed geese. The omission of greylags would make a negligible difference to the analysis.

Since most of the surveys in the ESs reported very few geese flying at heights greater than 100m (with a number stating that no geese were observed to fly above turbine height), to ensure that all of the data are comparable, the analysis has been based on the number of geese recorded at heights up to 100m only. An exception was applied in the case of a few surveys which recorded flight heights in bands up to 120m or 130m but with no separate 100m height band; for these surveys it was not possible to exclude flocks flying between 100m and the upper limit of the height band, so all of the flights in the band have been included. All geese flying at heights below 100m (or to the upper limit of the 120m or 130m band, as described above) are assumed to be at collision risk height.

The data on which the analysis of the relationship between goose flight activity and distance from the nearest roost were based are tabulated in Appendix 1.

3. RESULTS

3.1 Variability in goose numbers and flight height

The total number of pink-footed geese and the height at which they were flying varied considerably between five small wind farm sites situated close together near Strichen, Aberdeenshire, around 10 km from Strathbeg (Table 4). All of the five survey areas were of similar size and each was observed for 36 hours in two consecutive winters by the same observer (I.J. Patterson), using a rangefinder to measure flight height.

Table 4. Numbers of pink-footed geese recorded at five proposed wind farms near Strichen, Aberdeenshire and the percentage flying at heights up to 100m.

Site	Year	Total geese	0 - 100m	0 - 100m (%)
Auchtygills	2007/08	11,524	244	2.1
Clayfords	2007/08	1,236	303	24.5
Site A	2007/08	3,248	2,577	79.3
Site B	2008/09	3,477	2,227	64.1
Site C	2008/09	2,939	663	22.6
All sites		22,424	6,014	26.8

Auchtygills and Clayfords are 2 km apart, and were surveyed on consecutive days throughout the goose wintering season. Auchtygills was on a major flight line to and from a very well-used feeding site, while Clayfords was not. In spite of the difference in the total number of geese recorded, numbers flying at heights below 100m were similar. Sites A and C are also 2 km apart, but were surveyed in different years.

Similar variation was found where surveys were carried out at the same site in different years. At Aultmore, the number of geese recorded per km² per hour of observation was 4.73 in 2004/05, 0.42 in 2005/06 and 0.49 in 2006/07. Variation at Montreathmont was also considerable, with 3.65 geese per km² per hour of observation in 2003/04 and 21.45 in 2005/06. In such cases, the mean value of goose flight activity over the two or three years of survey was used in the analyses.

Some of the variation between years in the numbers of geese recorded may be attributable to differences in the total numbers of birds roosting in the area, which will inevitably affect the general level of flight activity within the feeding range. However, most variation, particularly between different sites in the same year, is likely to be associated with changes in the location of food sources in the areas immediately surrounding the sites. Especially in autumn, some fields (e.g. stubble fields with a plentiful supply of spilt grain) attract very large numbers of geese. If a wind farm survey area is on a direct flight line between such a field and the local goose roost, very high numbers of geese may be recorded passing over the site. Another site just off the flight line may record very few geese at the same time. This has been observed frequently around Strichen in Aberdeenshire (I.J. Patterson, unpublished observations).

In addition to variation in the total number of geese passing over a survey area, the number recorded at turbine height will depend on how high the birds are flying. In general, geese flying over a site and passing on towards more distant feeding areas fly higher than geese which land on fields fairly near the site. This appeared to be the main reason for the difference in flight heights recorded at Auchtygills and Clayfords (Table 4), two sites close together near Strichen in Aberdeenshire (I.J. Patterson, unpublished observations).

These variations in the numbers and flight heights of geese recorded at a site, depending on the year when the observations are made and on local variation in feeding opportunities, have implications for the validity of a survey carried out at a site over only one goose wintering season. However, in terms of the present review, it can probably be assumed that local, largely crop-based variation in goose flight activity should average out over the life of a wind farm. The average amount of goose flight activity over all of the sites within a given distance zone from an SPA should be a reasonable proxy for this.

3.2 Distribution of flight activity

Most of the wind farm sites from which goose flight activity data were obtained lie in a large area to the west of the Loch of Strathbeg (Figure 4), with only a small number of sites close to Montrose, Spynie or Ythan SPAs. There were no data from wind farms close to Dinnet, Findhorn or Skene SPAs. In contrast, wind farm sites with no data on goose flight activity were concentrated in an area to the west of the Ythan (Figure 5).

In general, wind farm sites with low levels of goose flight activity were further from the nearest roost SPA than were sites with higher activity (Figure 4). However, in some areas (e.g. around 10 km to the west of Strathbeg), wind farm sites with high levels of goose flight activity occurred close to sites with much lower levels.

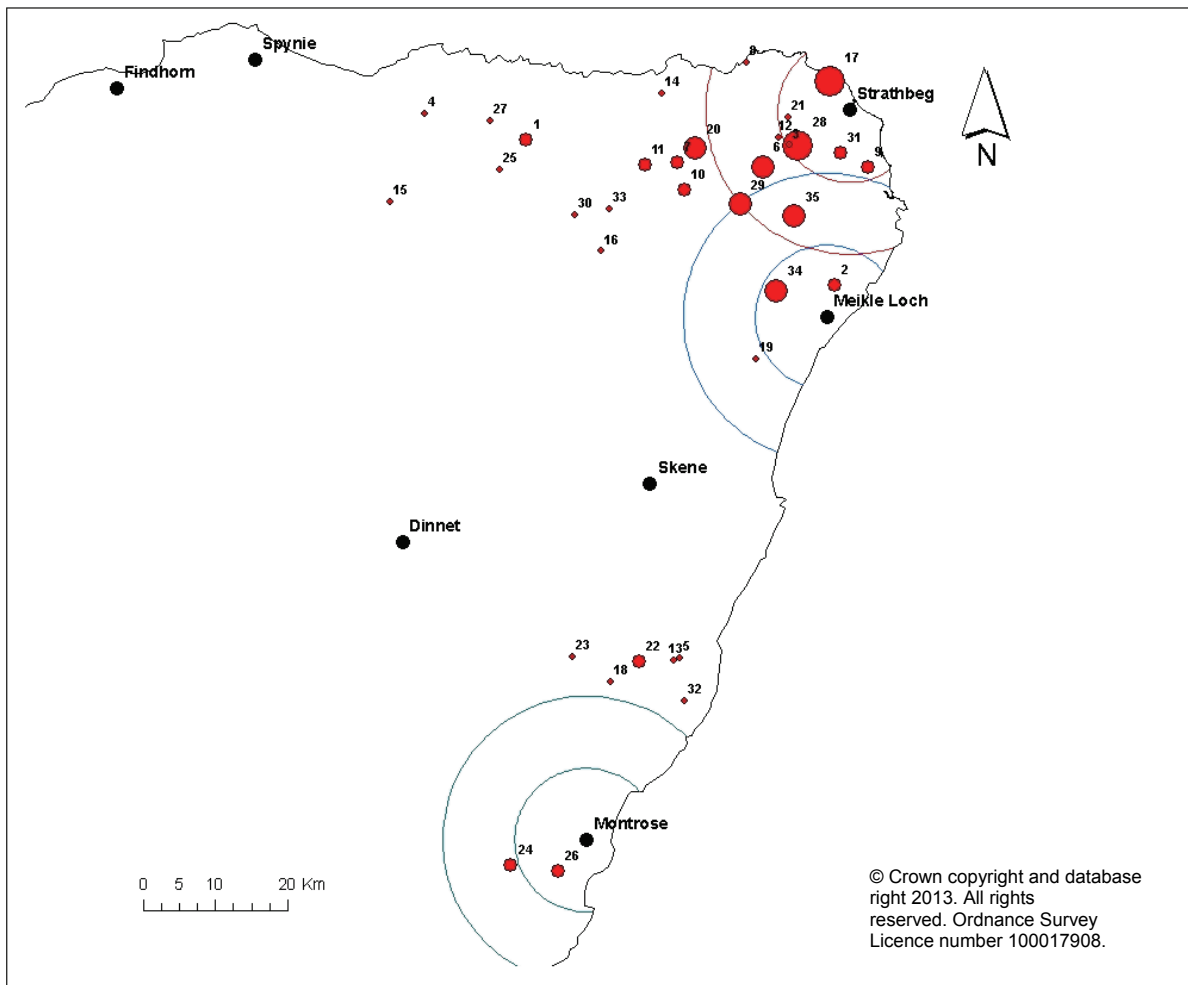


Figure 4. Distribution of goose flight activity (number of geese at collision risk height per km² per hour of observation) at wind farm sites in Grampian. The spot sizes show different levels of goose flight activity, in four equal divisions over the range from 0.0 to 40.9. The circular lines show 10 km and 20 km zones around the SPAs and the numbers refer to the data in Appendix 1.

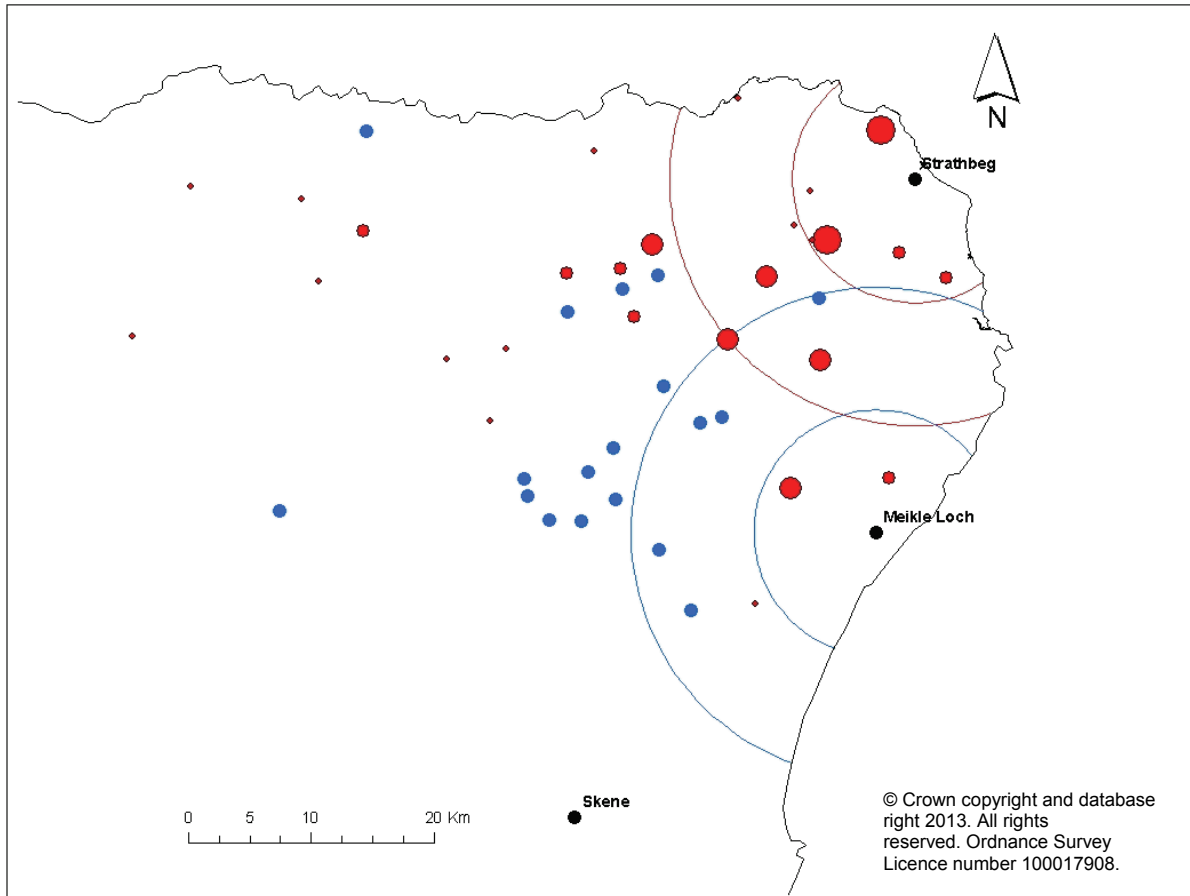


Figure 5. The location of sites with turbines of maximum tip height greater than 50m at which no vantage point surveys were carried out (blue dots) in relation to the location of sites at which such surveys were carried out (red dots). The spot sizes show different levels of goose flight activity, in four equal divisions over the range from 0.0 to 40.9 geese at collision risk height per km² per hour of observation. The circular lines show 10 km and 20 km zones around the SPAs.

The numerical data (Figure 6) show a clear decrease in the level of goose flight activity with increasing distance from the nearest SPA goose roost, although there is considerable variation, especially within 20 km of the roost. The decrease in flight activity with distance appears to be effectively linear, with no obvious step decrease at any particular distance, and is statistically significant ($r = 0.459$, $p = 0.002$). Only two surveys were carried out within 5 km of an SPA, at distances only just short of 5 km (4.6 km and 4.9 km) so it was not possible to assess flight activity in the 0 – 5 km zone.

Although no wind farm sites within 5 km of an SPA were found in the review of planning applications in Grampian, information on a site elsewhere in Scotland was provided by SNH. At Forthbank, a small site within 1 km of the Forth SPA, 67.82 geese per km² per hour were recorded, a much higher level of goose flight activity than at any of the sites in Grampian, where the maximum was 40.91 at Redbog, 8.8 km from Strathbeg SPA.

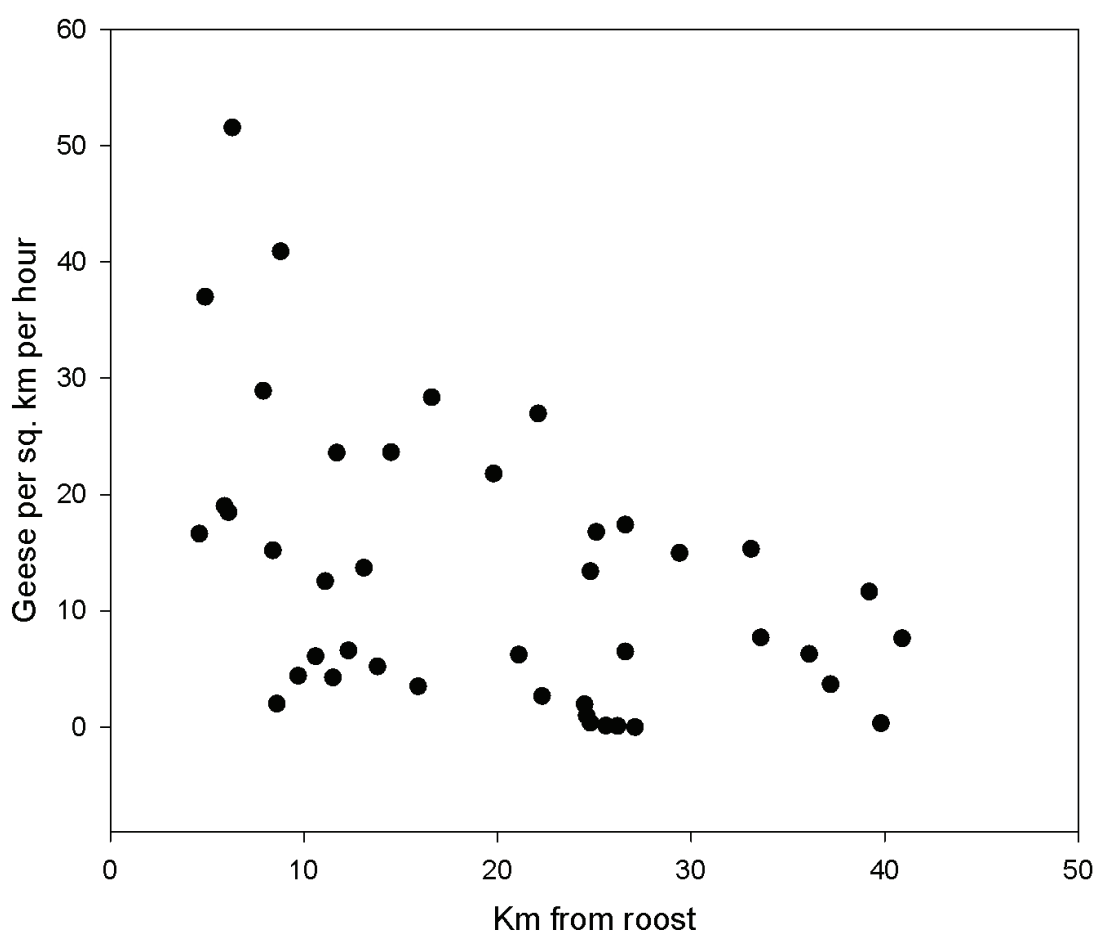


Figure 6. The number of geese (flying at turbine height) per km² of survey area per hour of observation, in relation to the distance between the site and the nearest SPA goose roost.

The data plotted in Figure 6 were analysed in distance zones (Table 5), which are 10 km wide since there were too few sites in some 5-km zones, particularly the 0 – 5 km (with the nearest sites to an SPA at 4.6 and 4.9 km), and the 15 – 20 km one.

Table 5. The mean and median numbers of geese (flying at turbine height) per km² of survey area per hour of observation, in relation to the distance between each site and its nearest SPA goose roost.

Distance zone (km)	Geese km ⁻² h ⁻¹		Sites
	Mean	Median	
0 - 10	23.4	18.8	10
10 - 20	13.6	12.5	11
20 - 30	7.7	4.5	14
> 30	7.5	7.6	7
All distances	13.0	13.1	42

The data suggest a drop in goose flight activity from the 0 – 10 km zone to the 10 – 20 km one and from the 10 – 20 km zone to the 20 – 30 km one, but no decrease thereafter. This suggests that there may be a 'background' level of around 7 – 8 geese per km² per hour of observation, probably due to the presence of roost sites other than SPAs (for example Middlemuir, near New Pitligo, around 15 km from Strathbeg, where several thousand geese have been recorded). There may also be geese moving around the area, not necessarily roosting in the same place on consecutive nights. Giroux & Patterson (1991) and Keller *et al.* (1997) recorded radio-tagged geese moving between roosts (see section 2, above), especially between Strathbeg and the Ythan area.

4. GOOSE FEEDING DISTRIBUTION AROUND THE LOCH OF STRATHBEG

A survey of goose feeding distribution in an area extending 12 – 15 km from the Loch of Strathbeg was carried out in March and April 2004 (Patterson & Thorpe 2004), to define core feeding areas in which to establish refuges in a goose management scheme.

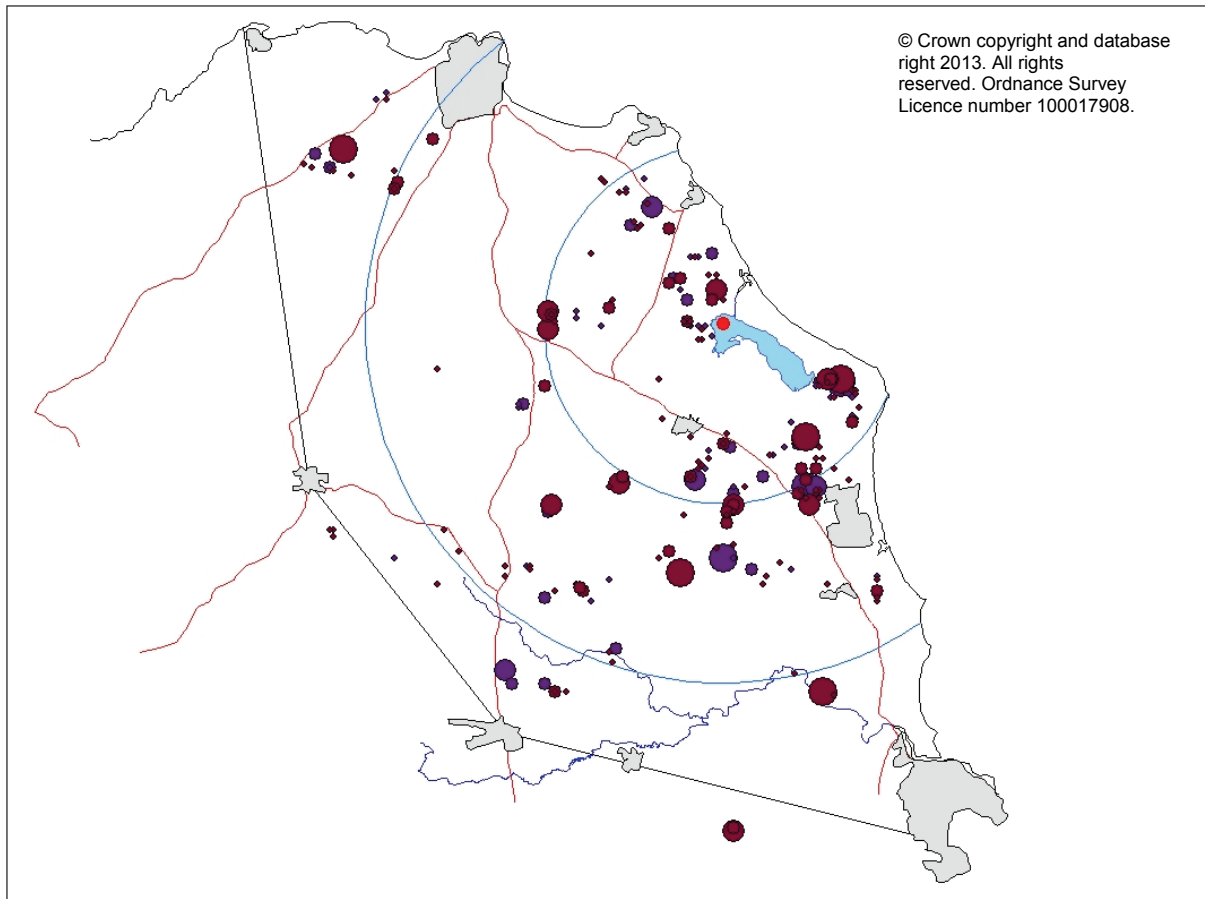


Figure 7. The distribution of flocks of foraging geese around the Loch of Strathbeg in March (red dots) and April (purple dots) 2004. The sizes of the dots indicate relative flock size, in four equal divisions from 1 to 3,100 in March and from 1 to 2,500 in April. Grey areas show towns, red lines show main roads and blue lines show rivers. The concentric circles show 5 km zones outward from the main roost (red dot in the Loch of Strathbeg) and the black line shows the survey area boundary.

The survey showed that the goose foraging distribution was very uneven (Figure 7), with a clear clustering of foraging sites just to the north-west of the loch and in a broad area to the south, with an isolated cluster further to the north-west, just south-west of Fraserburgh. In contrast, there were substantial areas where no geese were found. The distribution pattern was very similar to that found by Keller *et al.* (1997); see section 2 (above).

The data collected by Patterson & Thorpe (2004) were re-analysed to calculate the density of flocks and geese in different distance zones from the roost site. It was not possible to calculate a reliable density value for a 1 km zone around the loch, since most of the area within it is loch, sand dune, marsh and former airfield, and so is not suitable for goose foraging. The data show a clear drop in goose foraging density with increasing distance from the roost loch (Table 6).

Table 6. The numbers of flocks, geese and the density of geese in different distance zones outward from the Loch of Strathbeg in March and April 2004.

Zone (km)	March			April		
	Flocks	Geese	Geese/ km ²	Flocks	Geese	Geese/ km ²
0 – 5	67	38,798	838.9	41	21,818	471.8
5 – 10	57	35,947	319.5	27	18,230	162.1
Over 10	14	8,859	98.4	10	5,382	59.8

The number of geese recorded in the 5 – 10 km zone in both months was only slightly lower than the number recorded in the 0 – 5 km zone, with the drop in density explained largely by the increase in land area available to the birds in the 5 – 10 km zone compared to the closer one. Many fewer geese were found in the zone beyond 10 km, although the area available within the survey boundary was only slightly smaller (90.0 km² compared to 112.5 in the 5 – 10 km zone). This suggests that similar numbers of geese flew out to the 0 – 5 km and 5 – 10 km zones, but that fewer went beyond 10 km.

The numbers of flocks recorded in the various distance zones (Table 6) differed significantly from the numbers expected on the basis of the areas of the zones, both in March (Chi Sq. = 38.535, $p < 0.001$) and in April (Chi Sq. = 21.630, $p < 0.001$), with more flocks than expected found in the 0 – 5 km zone and fewer than expected in the zone beyond 10 km. The median distance of flocks from the roost was 5.2 km in March ($n = 145$ flocks) and 4.7 km in April ($n = 81$ flocks).

It must be emphasised that the data on goose grazing around the Loch of Strathbeg are confined to only 2 months at the end of the 7-month goose wintering period and are restricted to one SPA out of the seven being considered in the review.

5. GOOSE USE OF REFUGES IN THE STRATHBEG GOOSE MANAGEMENT SCHEME

The amount of goose grazing on refuge fields of a goose management scheme in the area around the Loch of Strathbeg has been carried out each year since 2002. The survey is based on measurement of dropping density in late March and in late April, with the densities converted to goose days per hectare from known dropping rates and corrected for known rates of loss of droppings due to rainfall. There are two types of refuge field in the scheme; 'feeder' fields, where nitrogenous fertiliser is applied in late February and no stock grazing is allowed, and 'buffer' fields, where no fertiliser need be applied and where stock grazing is permitted.

With measurements in two months each year (although only in April in 2002), in two types of refuge, there were 34 data sets available for analysis of the relationship between the amount of goose grazing and the distance of the refuge from the Loch of Strathbeg. There was no significant relationship between the amount of grazing and distance from the roost in any of the 34 data sets. In the 24 data sets in the last six years (2005 – 2010), none of the correlation coefficients approached significance, with the lowest p-value 0.381. There was little sign of a consistent trend; 13 of the 24 coefficients were negative (the expected decrease in goose grazing with increasing distance) while 11 coefficients were positive. There was therefore no evidence of any decrease in the amount of goose grazing with increasing distance from the roost within the 5 – 8 km zone covered by the goose management scheme.

It must again be emphasised that, like the survey of feeding distribution around Strathbeg (section 5, above), the data on goose grazing in the Loch of Strathbeg goose management scheme are confined to only two months at the end of the seven month goose wintering period and are restricted to one SPA out of the seven being considered in the review.

6. CONCLUSIONS

6.1 Goose density in relation to distance from the roost

The surveys of feeding distribution reported in the published literature gave very consistent results, with median distances of feeding sites from the roost of 4 – 5 km and maximum distances of up to 20 km. These results were confirmed by radio tracking of individual geese, which also ranged mainly 4 – 5 km from the roost during their daily foraging activity, with a maximum of around 16 km. The survey of goose feeding distribution around the Loch of Strathbeg gave very similar results, with a median distance of flocks from the roost of 5.2 km in March and 4.7 km in April, with some flocks recorded as far as the survey area boundary, at around 15 km from the roost.

Within a range of 5 km from the roost, there is no evidence of a decrease in the density of foraging geese with increasing distance. Bell (1988) showed no decline from the 0 – 2 km zone to the 4 – 6 km one around the Loch of Strathbeg and an increase in density over this distance range around the Ythan (Figure 1, above). Urquhart (2002) similarly showed a decrease in the proportion of fields used by geese only beyond 5 km of the roost. In refuges in the Loch of Strathbeg goose management scheme (2002 – 2010), there was no relationship between the amount of goose grazing and distance from the roost within the 5 – 8 km range covered by the scheme.

At the other end of the distance scale, the review of goose flight activity showed no difference in flight density between the 20 – 30 km zone and the zone beyond 30 km (Table 5). This suggests that beyond 20 km from a roost, goose flight activity is at a “background” level for the whole region, determined by the presence of minor roosts and of geese moving around the area, some in the process of flying between major roost sites.

Within 20 km of the roost, the review of goose flight activity showed a decrease in between the 0 – 10 km zone and the 10 – 20 km zone (Table 5). The decrease was statistically significant and essentially linear, with no evidence of a step decrease at any specific distance (Figure 6). The analysis of feeding distribution around the Loch of Strathbeg, carried out on a finer spatial scale (5 km zones) showed a similar decrease in goose density with increasing distance from the roost, from the 0 – 5 km zone through the 5 – 10 km one to the 10 – 15 km one (Table 6).

6.2 Zonation

It is clear that the original assumption that there should be a very high risk zone close to the roost, say within 1 km, is not supported by the data in the review, since there is no evidence of a decrease in goose feeding density within 5 km of the roost site, either in the data in the published literature or in the data from the Strathbeg goose management scheme. However, it could be argued for a given roost that in theory, since all of the goose flights to and from feeding areas are centred on the same site, the density of flights must inevitably increase close to the roost as the available area decreases. The areas of successive 1 km wide zones inward from 4 – 5 km to 0 – 1 km are 28.3, 22.0, 15.7, 9.4 and 3.1 km². This means that for a given number of geese, the flight density in the 0 – 1 km zone (area, 3.14 km²) is predicted to be almost 10 times higher than in the 4 – 5 km zone (area, 28.27 km²), with presumably an equivalent increase in the risk of collision. This increase would be progressive, however, with no obvious way to define a point at which the risk suddenly changes.

The zone beyond 20 km from the roost could be regarded as relatively low risk, since by that distance goose flight activity appears to be at a background level for the region. It would be prudent, however, to confirm that collision risk is low in this zone by reviewing risk assessments for wind farm sites located more than 20 km from the nearest major roost site.

It is difficult to define zones within the 5 – 20 km range from the roost, since although there is good evidence within this range for a decrease in both feeding density and flight activity with increasing distance from the roost, the decrease is progressive, with no evidence of any natural breaks which could be used to define zones. The mean level of goose flight activity in the 10 - 20 km zone was just over half (58%) of that in the 0 – 10 km one (Table 5). Goose feeding density around the Loch of Strathbeg in spring 2004, in terms of the percentage of the density in the 0 – 5 km zone, was 38.1% in the 5 – 10 km zone and 11.7% in the zone beyond 10 km (from Table 6). The equivalent percentages for April were 34.4% and 12.7%. These values show that the rate of decrease in density from the 0 – 5 km zone to the 5 – 10 km zone was very similar to the decrease from the 5 – 10 km zone to the zone beyond 10 km.

Since the decrease in goose density with increasing distance from the roost is gradual and progressive, division of the area into distinct zones of different risk must inevitably be arbitrary. For example, it would be possible to suggest a very high risk zone extending 1 km from the roost, based on the argument of increasing density of converging flight lines into a decreasing area. Further zones could be delimited at 5 km and 10 km, with the area beyond 20 km of a goose roost SPA regarded as low risk. It should be emphasised, however, that this would involve the arbitrary division of an essentially continuous variation in goose density.

7. FUTURE WORK

It would be desirable for the survey of goose feeding distribution in the area around the Loch of Strathbeg, which was restricted to March and April, to be extended by carrying out a survey throughout the whole goose wintering period from late September to late April (7 months). It would also be desirable for the survey to extend at least 20 km from the roost, to test the suggestion that the geese range further in autumn than in spring.

Since the aim of the present review was to investigate the distribution of goose feeding sites and flight activity, rather than the direct impact of wind farms on the birds, it would be desirable to review estimates of rates of collision mortality per turbine in relation to distance from the nearest SPA goose roost. If sufficiently detailed data are presented in the collision risk calculations, they could be re-analysed to estimate mortality at a standard turbine, to eliminate variation due to different sizes of turbine at different sites.

Further similar reviews based on ESs would be greatly aided by the provision of guidelines on the production of reports and collision risk calculations. For example, as a minimum, reports should always include flight line maps in which the survey area and vantage points are clearly shown, with a label on each flight line referring to its record in a data table. Flights which cross the defined survey area and so are included in the collision risk assessment should be mapped and tabulated separately from flights which pass outside the boundary. Many other similar recommendations could be made.

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ANNEX 1: THE DATA ON WHICH THE ANALYSES WERE BASED

The data are: GIS coordinates; site name; reference number; distance (km) to the nearest SPA; number of geese per km² per hour of observation.

X	Y	Site	No	Distance	Geese/km ² /hr
361276	855385	Auchenderran	1	39.2	11.65
404113	835284	Auchenten	2	4.6	16.63
397865	854679	Auchtygills	3	9.7	4.41
347130	859023	Aultmore	4	24.5	1.96
382615	783413	Auquhirie	5	24.6	0.98
394115	851684	Bogenjohn	6	14.5	23.64
382218	852283	Bogenlea	7	25.1	16.78
361276	855385	Braco Park	8	15.9	3.50
408739	851558	Bruxiehill	9	8.4	15.19
383285	848431	Cairncake Farm	10	26.6	17.40
377852	851942	Cairnhill	11	29.4	14.97
396374	855824	Clayfords	12	10.6	6.09
381769	782985	Clochnahill	13	24.8	0.37
380104	861933	Cushnie	14	26.2	0.09
342392	846805	Edintore	15	27.1	0.00
371585	839940	Gordonstown Hill	16	39.8	0.33
403433	863573	Gowanfold	17	4.9	37.00
372963	780124	Herscha Hill	18	22.3	2.67
393231	825003	Hill of Fiddes	19	11.5	4.26
384775	854287	Hillhead (Pitsligo)	20	22.1	26.96
397649	858612	House o Hill	21	8.6	2.01
376921	782872	Jacksbank	22	24.8	13.40
367617	783505	Mid Hill Extension	23	25.6	0.12
359112	754485	Montreathmont	24	11.1	12.54
357598	851293	Mossford Farm	25	37.2	3.68
365608	753686	Mountboy	26	5.9	19.01
356210	858023	Muirake	27	33.6	7.71
399038	854602	North Redbog	28	8.8	40.91
390975	846494	Old Maud	29	19.8	21.80
368052	844964	Shielburn	30	40.9	7.63
404900	853633	St Fergus Moss	31	6.1	18.48
383296	777350	St John's Hill	32	26.6	6.49
372845	845786	Towie Barclay	33	36.1	6.29
396050	834453	Upper Ardgrain	34	7.9	28.91
398494	844840	West Knock Farm	35	16.6	28.36
		Confidential site	A	11.7	23.59
		Confidential site	B	12.3	6.58
		Confidential site	C	6.3	51.55
		Confidential site	D	33.1	15.32
		Confidential site	E	21.1	6.22
		Confidential site	F	13.8	5.21
		Confidential site	G	13.1	13.69

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