Feeding areas used by individual Pink-footed Geese *Anser brachyrhynchus* around the Loch of Strathbeg, North-east Scotland

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The aim of the study was to determine whether individual Pink-footed Geese had restricted feeding ranges within the whole area used by the local population, so as to assess whether refuges were likely to experience a rapid turnover. In spring 1989 and 1990 the feeding distribution of Pink-footed Geese roosting at the Loch of Strathbeg, Grampian, UK was determined by driving along a fixed transect route twice each week. Distinct core feeding areas, which remained consistent between the two years, could be identified. Mean densities of goose droppings in areas at different distances from the roost did not differ in March, but in April densities in areas far from the roost were significantly lower than those in areas close to the roost. Tracking of radio-tagged Pinkfeet in 1990-91 showed that individual geese were not confined to particular core feeding areas, but that most used several different ones and even moved between adjacent roosts. This suggests that refuge management must take into account a rapid turnover in the individual geese using a particular site.

Keywords: Pink-footed Geese, Feeding Distribution

The Iceland/Greenland population of Pink-footed Geese *Anser brachyrhynchus*, which winters mainly in Scotland, has increased steadily over the last 30 years and is continuing to do so (Fox *et al.* 1987). Since the birds feed almost exclusively on agricultural land, this increase has led to concern among farmers about damage to crops, which can be a serious local problem in areas with high goose densities (Patterson *et al.* 1989, Patterson 1991). In the main part of the birds' range in the UK, east-central Scotland, most concern is expressed about losses to grass and autumn-sown cereal through goose grazing in spring.

One possible way to reduce damage is to establish alternative feeding areas or refuges, such as those for Barnacle Geese *Branta leucopsis* on the Solway (Owen 1977) and for Pink-footed Geese at the Loch of Strathbeg in north-east Scotland, where in 1988 the Royal Society for the Protection of Birds (RSPB) bought a large area of farmland adjacent to the roost with the aim of managing it as a feeding refuge. However, in both of these areas, many of the geese continue to feed and cause damage in non-refuge areas, so that provision of additional feeding areas away from the roost would be desirable.

Before such reserve areas can be designated, however, it is necessary to identify the main goose feeding areas and to find out whether the same ones are used consistently from year to year. For north-east Scotland the feeding distribution of Pink-footed Geese has been described on a relatively large scale by Bell (1988). For the establishment of refuges, however, a more detailed knowledge of the use of the feeding area is needed.

Since the geese have to learn the location of the undisturbed refuges, it is important to know whether each localised feeding area is used by the whole local population or by a consistent part of it. The latter situation, which would make it easier to train the geese to avoid crops in favour of the refuge areas, could be detected by monitoring the use of feeding areas used by individual geese.

The aims of the present study were to identify the core feeding areas of the geese roosting at the Loch of Strathbeg, to measure the relative intensity of grazing by geese in these areas, to examine consistency of use of areas between years and to describe the areas used by individual radio-tagged geese in relation to the feeding distribution of the whole population.

Study area and methods

The study area, based on preliminary surveys of

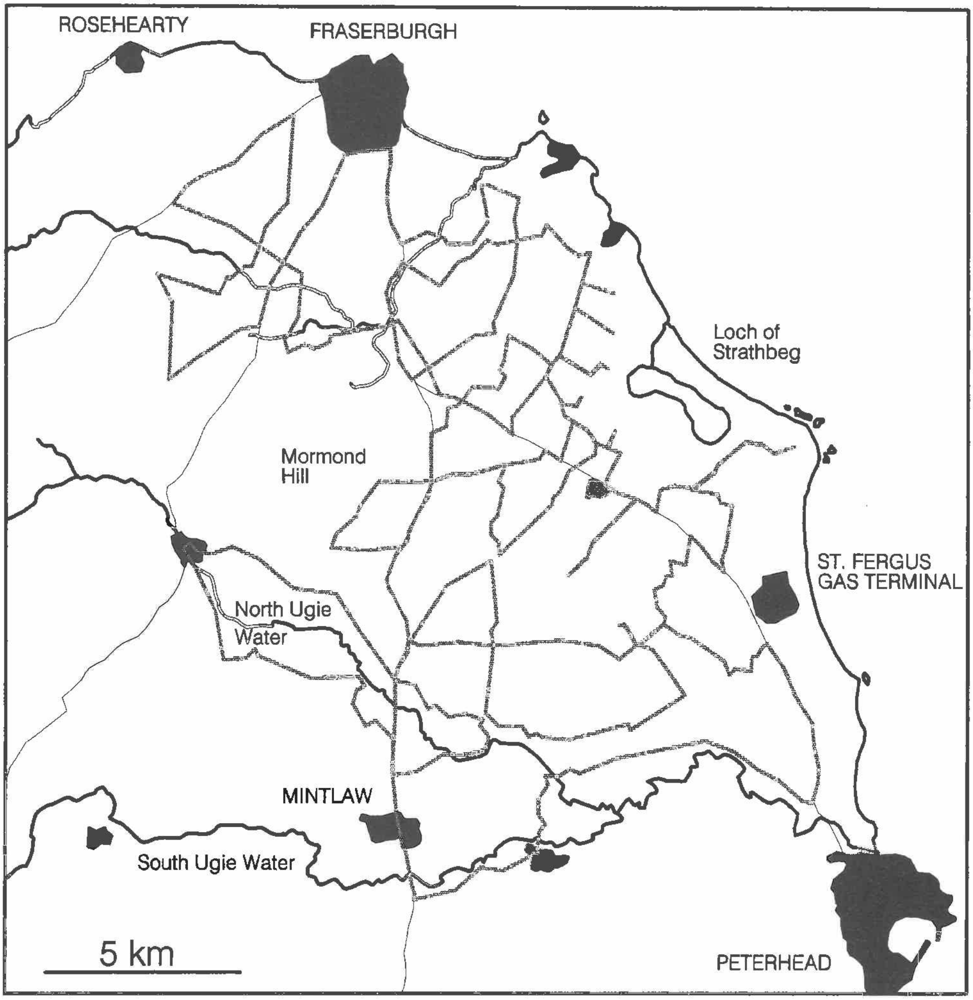

Figure 1. Study area, showing the RSPB reserve (horizontal hatching), roads used on transects (solid lines) and the areas where dropping densities were measured. Horizontal lines: 'adjacent' to roost, stippled: 'near' roost, hatched: 'intermediate' distance, cross-hatched: 'far' from roost.

the goose feeding distribution, was bounded by the coast between Peterhead and Rosehearty (west of Fraserburgh, Grampian) and by a line connecting Rosehearty, Strichen, Mintlaw and Peterhead (**Figure 1**). In 1990 the surveyed area extended approximately 5 km further towards the north-west than in 1989.

The feeding distribution was determined by driving along a fixed transect route (total length 218 km, **Figure 1**), stopping regularly to look out for goose flocks. The transect route was divided into a northern and a southern circuit; within each circuit the starting point and the direction followed were determined at random to avoid any bias due to visiting the same areas repeatedly at the same time of day. Two transects were carried out on consecutive days each week, starting with the southern circuit on the first day and the northern one on the second day. The study periods were 15 March to 19 April 1989 and 20 February to 25 April 1990. A small proportion of the area (under 10%) was not visible from the transect route, but since this was scattered in small patches, it was unlikely to have affected the results of the overall survey of the distribution.

For all goose flocks found, their location, the field crop and the total number of Pink-footed Geese were noted. A flock was defined as the number of geese on a particular field, *ie* geese on two adjacent fields were regarded as two separate flocks. No account was taken of movements during the survey period since distribution and not the total number of geese in the area was being assessed.

Centres of grazing activity were identified by a simple kernel estimation procedure (Worton 1989, 1995), since the alternative harmonic mean analysis (Dixon & Chapman 1980) frequently includes areas with no records and so overestimates the area used (Naef-Daenzer 1993, Worton 1995). An estimation of utilisation density was calculated using a superimposed grid, so that the distribution pattern of flock locations was translated into a matrix containing density values, using flock sizes as well as their locations. For each intersection of a grid of 500 x 500 m cells, the total number of geese recorded within a radius of 500 m was used as an estimate of the local utilisation density. A Pascal programme was written by B. Naef-Daenzer to calculate the density matrices, GRID software (Naef-Daenzer 1993) was used to calculate contours of equal utilisation density and maps were plotted with Micrografx Charisma software.

The amount of grazing on individual fields in different parts of the feeding area was assessed by measuring the density of goose droppings. In 1989 counts of goose droppings were carried out at the end of April, in 1990 at the end of March and at the end of April. Each count represented the amount of grazing for approximately the preceding month, since in 1989 individually-marked goose droppings were shown to remain identifiable for about that length of time.

Dropping densities were determined on fields where geese had been seen on transects during the preceding four weeks. Counts were restricted to grass fields, since this crop type was used most frequently by geese and was available to them during the whole study period. Fields selected for counts were chosen in areas at different distances from the roost (**Figure 1**): 'Adjacent' to the roost, mainly fields on the RSPB reserve, 'Near', two areas at approximately 2 km from the roost, 'Intermediate', about 4 km from the roost, 'Far', about 11 km from the roost. The areas 'Intermediate' and 'Far' were sampled only in 1990.

In each field, droppings were counted on 20 sample areas of 5 m^2 each, which was found to be an adequate sample size in tests carried out in 1989 (Patterson & Keller unpublished). Samples were distributed in a grid across the whole field, except for a zone of about 150 m around any edges adjacent to roads or farms which the geese usually avoided. Four people carried out the counts, having first had training sessions to agree on criteria for identifying a single defaecation (eg when an old dropping appeared to have broken into fragments). Piles of droppings, presumably produced by a goose while sitting down for some time, were counted as single droppings since such geese were unlikely to have been grazing actively. Geese were caught for marking by setting an elastic-powered clap net with a 10 x 4 m catching area close to a roosting pool at the Loch of Strathbeg (**Figure 1**). The net was pre-baited with grain for several weeks then set in the late afternoon and released from a concealed lookout point at dawn the following morning if geese moving from the pool congregated at the bait. Captured geese were given individual combinations of coloured plastic leg rings and some were fitted with tail-mounted radio transmitters (Biotrack SS-1, Giroux 1991, Kenward 1987). Juveniles, which had weaker tail feathers than adults, were not radio-tagged and female adults were also avoided when an adult male was caught at the same time, to reduce the chance of having radios on both members of a pair.

The radio-tagged geese were tracked using a Mariner receiver with a hand-held 4-element Yagi antenna. In spring 1990 the whole area was searched systematically for radio-tagged geese during the two whole-day transects each week between 20 February and 19 April. During the 1990-91 winter and in spring 1991, an individual goose was selected at the roost at dawn each morning and if possible was tracked throughout the day until its return to the roost at dusk. In both years the fields used by the birds were defined by the grid references of their centres.

Results

Feeding distribution

Completeness of the survey

An assessment of the completeness of the survey was made by determining for each transect the percentage of occupied fields where Pink-footed Geese had not previously been seen in the same year (excluding newly-sown cereal fields which were available only from the end of March). In both years the percentage of new fields generally decreased from week to week until it fell below 10% in the last two weeks (**Figure 2**). Thus, the data from a 60-70 day observation period can be considered a representative sample of goose distributions.

Surveys of goose dropping densities gave results which were consistent with the transect

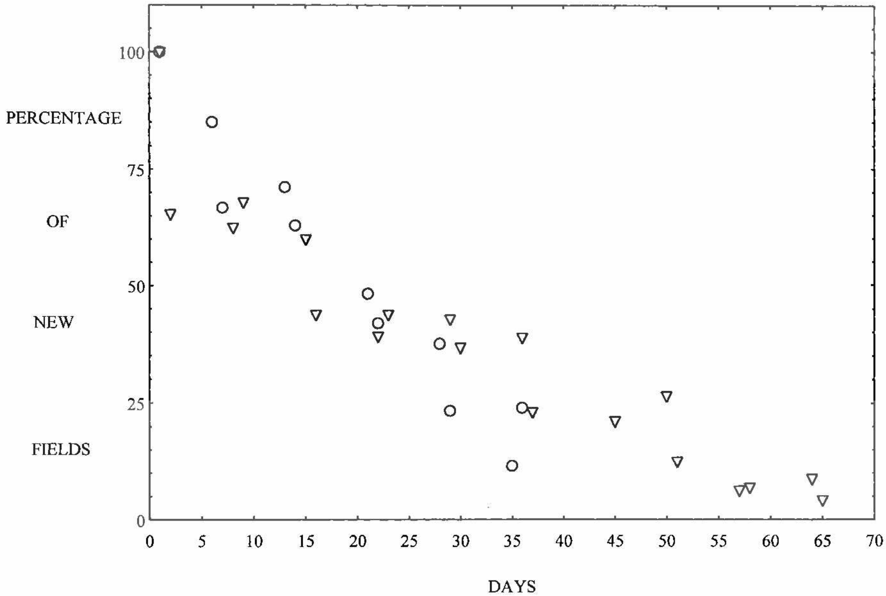

Figure 2. Percentage of fields on each transect day which were 'new', ***ie*** **which had not previously been recorded as used by geese in the same year.** Circles show data from 1989 and triangles those from 1990.

data, in that fields where geese had not been seen were found to contain only low densities of droppings. In March 1990, 13 grass fields where geese had never been seen on transects (although they were in well-used areas and were adjacent to fields used by geese) were found to have significantly lower goose dropping densities than had fields where geese had been seen (mean 0.62 ± 0.18 (SE) droppings per m^2 compared to 3.63 ± 0.31, Mann-Whitney U-test, $P < 0.01$). A further sample of 14 fields in an area to the west of the loch, where geese had not been seen during the preceding four weeks, and seven fields where geese had never been seen at all during the study period, had very low mean dropping densities (0.30 ± 0.11, n=7, and 0.09 ± 0.05, n=7).

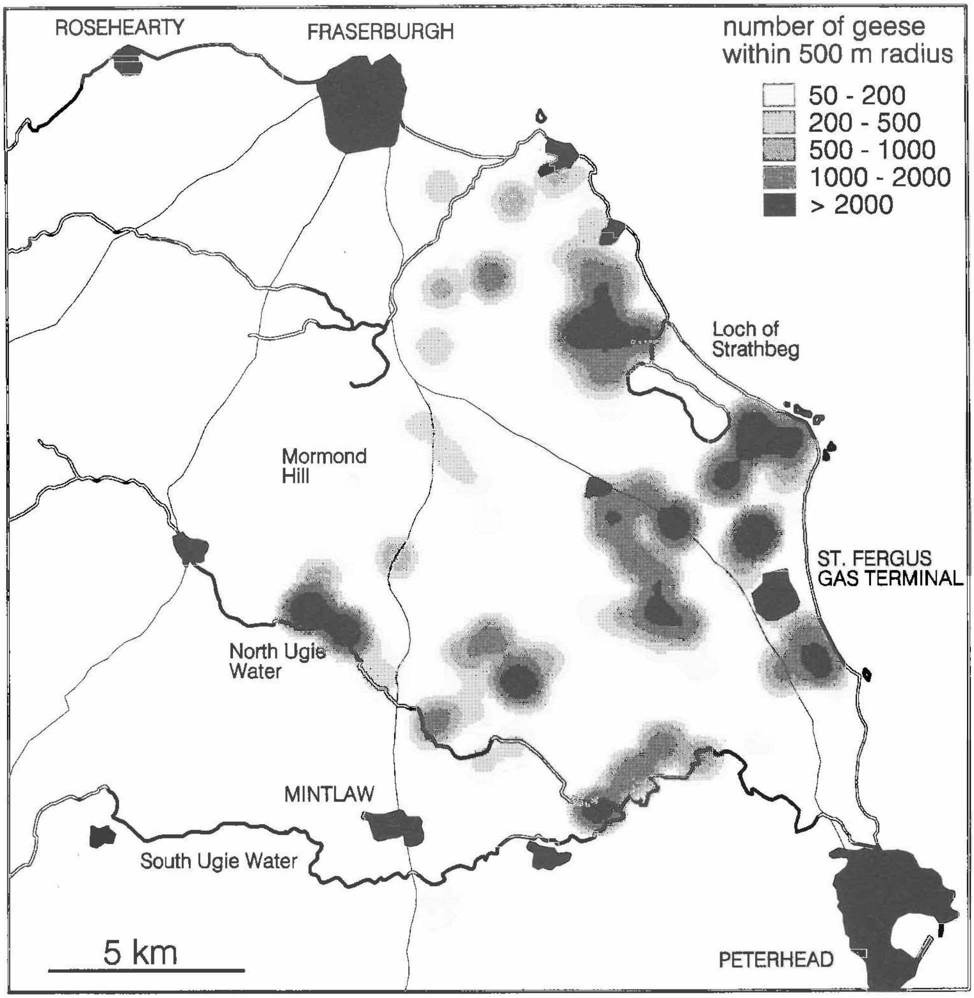

Figure 3. Feeding areas used by Pink-footed Geese in February to April 1989, from GRID analysis. Shaded areas show built-up areas, heavy lines show rivers and thin lines show main roads.

Feeding distribution

The feeding area of Pink-footed Geese extended as far south and south-west as the Ugie valley, where the fields used were all close to the north and the south Ugie Waters (**Figures 3 & 4**). The fields used by the geese were clearly clustered in particular parts of the whole feeding range, clusters of fields used by geese were separated by areas where geese were never seen. Geese were found to be concentrated close to the north-west and the south-east ends of the loch and in the area south of it. The distribution changed slightly between 1989 and 1990, but the main centres of activity remained the same (an area to the north-west, used in 1990, was not covered by the survey in 1989). In both years, geese were recorded in 36% of the area covered by the survey. The intensity of grazing was restricted to an even smaller proportion of the total area; the area where more than 1,000 geese were recorded in a 500 m radius (equivalent to *c.* 10

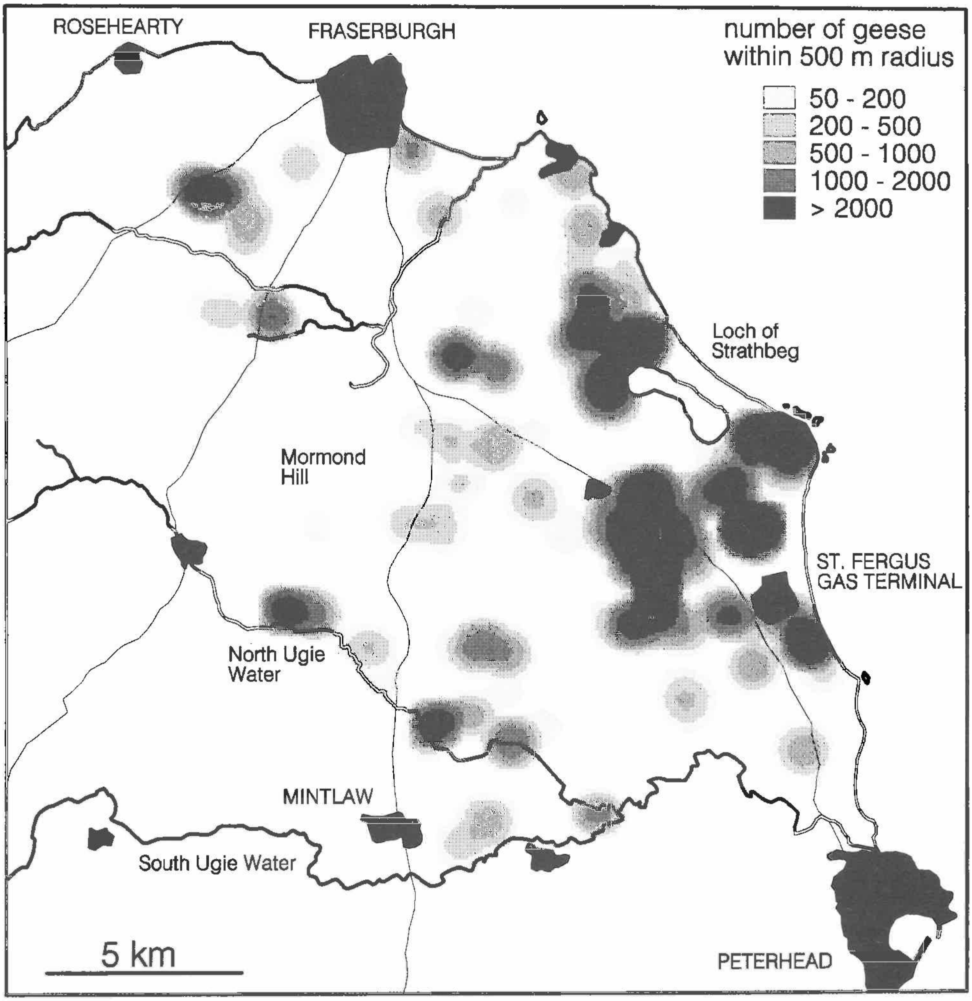

Figure 4. Feeding areas used by Pink-footed Geese in February to April 1990, from GRID analysis. Conventions as **Figure 3**.

Table 1: Distance of Pink-footed Goose flocks from the Loch of Strathbeg roost 1990. Kruskal-Wallis: H=19.43, $p<0.001$, April significantly different from both February and March.

Month	*n*	median	Interquartile range
February	118	4.6	3.6-8.0
March	243	4.3	3.2-6.8
April	235	3.8	2.3-5.0
Total	596	4.3	2.9-6.5

Table 2 a) The frequency of use by geese in 1989 of grass fields where geese were recorded once or repeatedly in March and April 1990 (14 fields in a feeding area in the far northwest not checked in 1989 have been excluded).

Use in1990	Total Number of fields (=100%)	Use in 1989(% of Fields)		
		No geese seen	geese seen once	geese seen more than once
Geese seen once	60	65.0	20.0	15.0
Geese seen more than once	94	41.5	20.1	38.3
Total	154	50.6	20.2	29.2

Table 2 b) The frequency of use by geese in March and April 1990 of grass fields where geese were recorded once or repeatedly in March and April 1989. Chi sq= 14.92,df=2, $p=0.001$.

Use in1989	Total Number of fields (=100%)	Use in 1990 (% of Fields)		
		No geese seen	geese seen once	geese seen more than once
Geese seen once	80	61.3	15.0	15.0
Geese seen more than once	67	32.8	13.4	38.3
Total	147	48.3	14.3	37.4

geese/ha) was 2,432 ha in 1989 and 3,232 ha in 1990, 70.2% of the grazing activity in 1989 and 83.5% in 1990 were thus concentrated on 28.6% (1989) and 32.8% (1990) of the area where geese were found. In February and March 1990, the geese were spread over a wider area than in April when they concentrated closer to the roost (**Table 1**) and were only rarely seen in the Ugie valley (Keller & Patterson unpublished).

Consistency in use of individual fields between years

Of all grass fields used by geese in March and April 1990, 49% had already been recorded as used in March and April 1989 (**Table 2a**). Conversely, 52% of the fields used in 1989 were again recorded as used in 1990 (**Table 2b**). Fields where geese had been seen more than once in one year were more likely to have been used in the other year than fields where geese were recorded only once (**Table 2**). Of the 71 grass fields used in 1989, but not in March and April 1990, 61 were checked for changes in crops that might have made them unsuitable for geese. On 16 fields (26%) the crops had changed, mainly to those not used by geese, while the remaining 45 fields (74%) were still grass fields. Possible changes in sward quality, presence of stock, disturbance and other factors which might have affected the geese, were not measured.

The amount of grazing in different parts of the feeding range

At the end of March 1990, there was no significant variation in the densities of goose droppings in core feeding areas at different distances from the roost (**Table 3**). In April, however, there was significant variation among these areas (**Table 3**). The highest mean density was found adjacent to the roost, followed by the area at an intermediate distance from the roost and the two areas near the roost. The two areas far from the roost had very low dropping densities.

Dropping densities were significantly higher in April than in March in the areas adjacent to the roost (**Table 3**, t-test, $p<0.01$) and at an intermediate distance (**Table 3**, $p<0.05$). Near

Table 3. Goose dropping density (droppings per m²) in areas at different distances from the roost in March and April 1990 (only fields where geese were seen during the four weeks prior to the count). ANOVA, between distance categories, March, $F(5,53) = 1.06, p>0.05$, April $F(3,43)=8.32$, $p<0.001$ (northwest and southeast areas in the same distance category combined).

Location	Number of Fields	Mean	SE	Min.	Max.
March					
Adjacent to roost	16	4.67	0.61	1.38	8.31
Near north-west	6	2.59	0.57	0.92	4.03
Near south-east	11	3.12	0.95	0.26	8.18
Intermediate	8	4.15	0.38	2.93	5.84
Far north-west	9	3.18	0.64	0.28	6.24
Far south-east	9	3.57	0.97	0.97	9.97
April					
Adjacent to roost	17	8.78	1.16	0.81	17.61
Near north-west	8	4.49	1.18	0.80	10.90
Near south-east	8	4.21	0.96	0.63	9.11
Intermediate	9	6.74	0.87	2.98	10.21
Far north-west	3	0.59	0.06	0.53	0.72
Far south-east	2	0.89	0.13	0.76	1.01

the roost there was no significant difference between months and far from the roost the density was significantly lower in April than in March ($p<0.001$).

For all three areas that were sampled in both 1989 and 1990, *ie* the area adjacent to the roost and the two areas near the roost, there were no differences in the densities of droppings between the two years (t-tests, $p>0.05$).

The use of feeding areas by individual radio-tagged geese

Radio-tagging

Seven geese were radio-tagged in February and March 1990, six in November and December 1990 and five in February and March 1991. Of these, one was not recorded after release and two disappeared after one to four days. The remaining 15 geese were all detected in feeding areas, although three were located only around

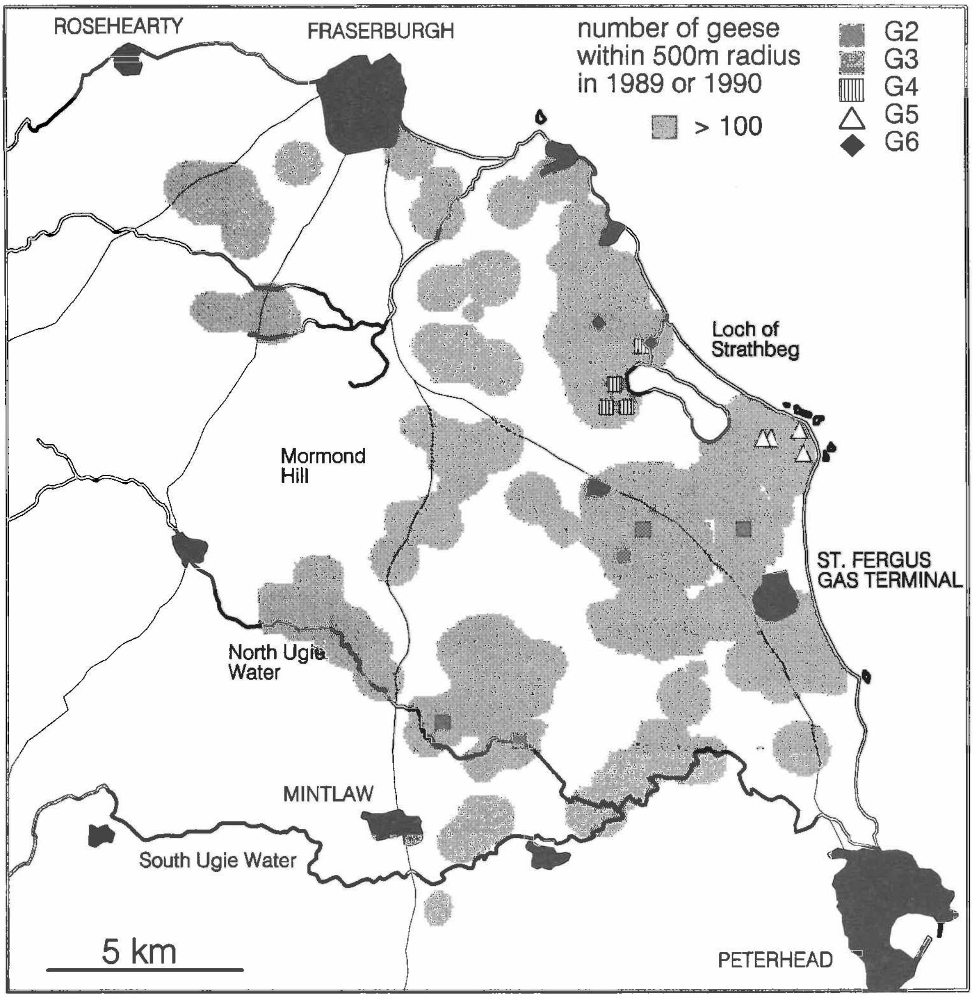

Figure 5. Radio-tracking locations of geese tracked in February to April 1990, in relation to the areas where goose flocks were seen in spring 1989 and spring 1990 (combined, shaded areas).

the Ythan estuary, 30 km south of Strathbeg and four others spent periods of up to several weeks there. One bird was also found at Montrose, 90 km south of Strathbeg, after having been seen at the Ythan. None of the tagged birds was observed in sufficient detail to determine whether it was paired or had a brood.

Feeding areas used by individuals

The distribution of fields where radio-tagged geese were located (**Figures 6 & 7**) varied considerably between birds. Many individuals were clearly not confined to one area within the feeding range and several were found in a number of widely separate parts of the area used by the roost population as a whole (**Figures 6 & 7**). Two birds (G9 and G15 in spring 1991) were found far out to the south-west, where geese had not been detected in the transect surveys in the preceding years (**Figures 4 & 7**).

In the course of a given whole day, most of the radio-tagged geese used only a restricted group of fields close together in one part of the feeding area. The mean distance travelled between consecutive fields was only 1.13 ±0.18 km (n=99 movements), with no significant difference between November to February (mean 0.94 + 0.20 km, n= 1) and March to April (1.21 ± 0.24 km, n=68, t=0.89, p=0.37). In the adjacent Ythan roost area, Giroux & Patterson (1995) found that radio-tagged geese moved a similar 0.8 ± 0.1 km between fields. Only eight of the 99 recorded movements took the Strathbeg geese from one core feeding area (**Figure 6**) to another (or into one from a little-used area), in these instances, the geese flew further (mean 4.71 ± 1.53 km, range 1.78-15.00 km). However, five of these flights were from the first fields used after leaving the roost at dawn and one was to the last field used before returning to the roost at dusk and so may have represented part of the journey between roost and feeding area, which had been interrupted by stopping in intermediate fields.

During a whole feeding day (mean tracking period, 17.9 ± 0.69 half-hourly fixes =9 hr) the tagged geese visited an average of 4.22 ± 0.39 different fields (n=24 days, excluding three of 4 hr or less). The mean length of stay on a field was 3.33 ± 0.31 half-hourly fixes (n=108 stay times), equivalent to 100 min if it is assumed that on average the birds moved half-way between two consecutive fixes. There was no significant difference between the mean staying time in November to February (3.83 ± 0.53 fixes, n=40) and that in March to April (3.04 ± 0.39, n=68, t=1.19, p=0.24).

Discussion

The two surveys of the feeding distribution of the geese identified the same activity centres in both years, apart from a new area in the far north-west, which had been missed in 1989 because it was beyond a gap in the birds' distribution and had not been covered by road transects. The extension of the study area in 1990 seemed to cover the whole feeding area of the geese, since the birds were hardly ever seen to fly beyond the limits of the study area. The very low dropping densities in the area to the west of the loch, where geese had been seen on only few occasions, showed, moreover, that the activity centres identified from road transects were indeed the main feeding areas of the geese. The results show that the geese were very concentrated within their feeding range and intensive grazing activity was restricted to a small proportion of the area.

The radio-tracking study was consistent with the earlier survey, in that most of the records of the tagged geese were within the core areas identified by the transect data. The main exception was an area far to the south-west of the roost, used by two tagged geese in April 1991. This site was outside the range surveyed by the transects, but was probably not used in 1989 and 1990, as geese were never seen to fly in that direction. The situation may, however, be a dynamic one, subject to periodic changes.

The median distances of goose flocks from the roost were similar to those found by Bell (1988) and to the mean maximum distance (4.8 ± 0.4 km) recorded by Giroux & Patterson (1995), but the birds were concentrated closer to the roost in April and stopped using the feeding areas along the river Ugie. This change

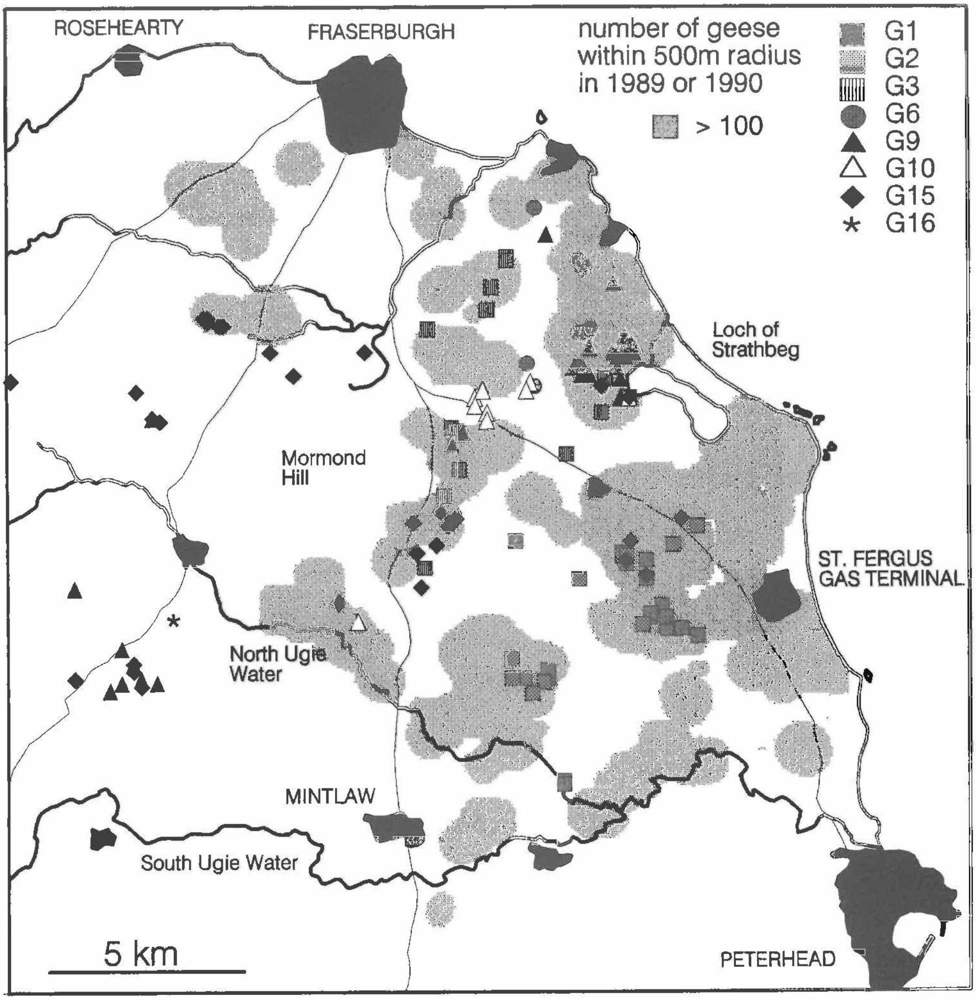

Figure 6. Radio-tracking locations of geese tracked between November 1990 and April 1991, in relation to areas where goose flocks were seen in spring 1989 or spring 1990 (combined, shaded areas).

corresponds with the difference in dropping densities between March and April, while in March the intensity of grazing did not differ between areas, in April the fields further away from the roost had clearly lower dropping densities than the areas closer to the roost. In April, the fields adjacent to the roost, most of which were within the RSPB reserve, were more intensively grazed than the areas surrounding the reserve. These findings, although based on only one year's data, suggest that new reserves close to the roost would be more effective than more distant ones in attracting a huge proportion of geese at a time when fields are most susceptible to damage (Patterson *et al.* 1989).

The similarity of the results from 1989 and 1990 suggests that the feeding distribution remains stable from year to year. However, the use of individual fields within these areas seems to be more variable, around half of the fields used in 1990 had not been used in 1989, and only about half of the fields used in 1989 were used again in 1990. Part of this change can be explained by crop rotation, but more subtle changes in the condition of the sward are also likely to change the attractiveness of grass fields from year to year. Other factors, like the intensity of scaring or the presence or absence of livestock are also likely to affect preferences for particular fields.

Radio-tracking showed that individual Pink-footed Geese were very mobile in that they moved readily between roosts (including rather surprising southward movements in spring, when the population was generally moving northwards). Giroux (1991) found similar shifts of roost site by radio-tagged Pink-footed Geese at the nearby Ythan area. Within the feeding range of the Strathbeg roost, most of the tagged birds used several different parts of the feeding area used by the local population. Giroux & Patterson (1995) similarly found radio-tagged Pink-footed Geese to have large ranges (21-69 km^2), although four out of the five birds with enough data for detailed analysis had significantly non-uniform distributions, indicating that they had centres of activity.

These results suggest that any new reserve sites would be encountered by a large proportion of the Pink-footed Geese from the nearest roost (and by new arrivals from other roost areas), rather than by only a restricted subset of them. Management techniques designed to attract geese to the reserves and to deter them from neighbouring crop areas should take this into account by relying on immediate impact on successive geese new to the area rather than on the gradual training of a stable local group.

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