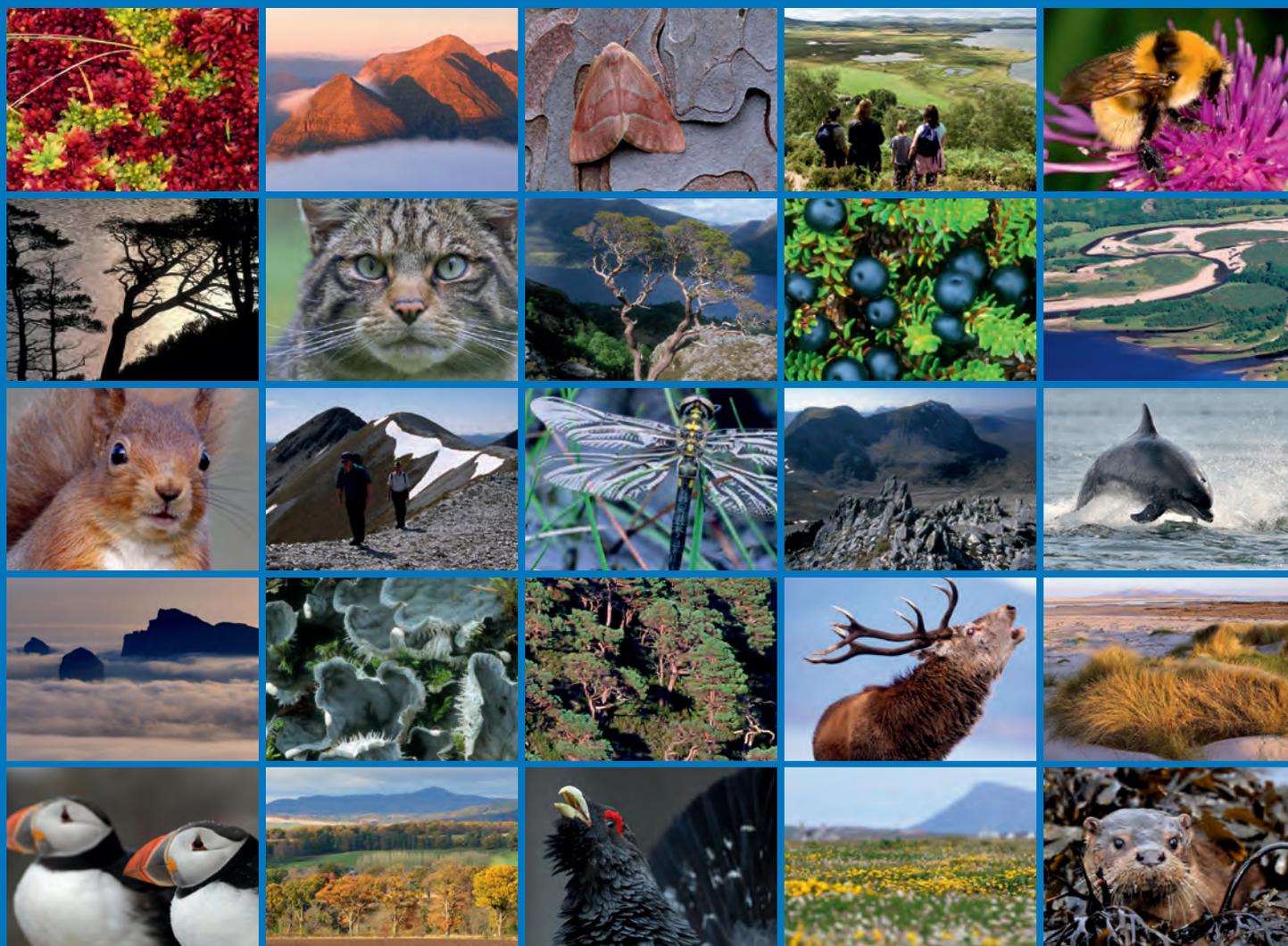


A survey of the feeding distribution of geese around the Loch of Strathbeg





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COMMISSIONED REPORT

Commissioned Report No. 937

A survey of the feeding distribution of geese around the Loch of Strathbeg

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COMMISSIONED REPORT

Summary

A survey of the feeding distribution of geese around the Loch of Strathbeg

Commissioned Report No. 937

Project No: 12696

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Keywords

Goose management scheme; Loch of Strathbeg; pink-footed goose.

Background

Based on fieldwork in March and April 2016, the survey aimed to assess to what extent the distribution of geese feeding in the vicinity of Loch of Strathbeg coincided with the current boundaries of the goose management scheme operating in the area. This was last assessed in 2004. The current survey repeated methods used in 2004, namely driving most of the roads in the survey area once per week for eight weeks and mapping the location of geese found.

A second part of this work was to provide a baseline measure of goose flight activity by which changes can be assessed under potential future changes to goose management scenarios in the area. The method employed involved weekly one hour counts from six vantage points during the same time frame as that in which the distribution survey was carried out.

Main findings

- Goose numbers, principally pink-footed geese, were high through March but fell rapidly through April with very few birds remaining by the last week of fieldwork.
- Goose distribution was similar to the reported during the previous survey in 2004, though with some exceptions including concentrations of geese identified beyond the current goose management scheme boundaries.
- Around a third of goose flocks comprising just over a quarter of goose numbers, were within the current goose management scheme boundaries.
- Most geese (93%) were in grass fields.
- Flight activity measured from the six vantage points at least partially reflected the distribution of feeding birds. The data presented provide a baseline against which changes can be assessed.

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1. INTRODUCTION

North-eastern Aberdeenshire is an important non-breeding area for geese, of which the overwhelming majority are pink-footed geese (*Anser brachyrhynchus*). These birds are part of the population that breeds in central Iceland and eastern Greenland and over-winter from late September to mid-April primarily in Scotland and England. Most geese using north-eastern Aberdeenshire roost overnight at the Loch of Strathbeg RSPB reserve and regular counts are carried out at this site of birds leaving the roost in the couple of hours from dawn. These show that numbers generally peak in early autumn before birds move further south to wintering areas elsewhere and rise a little in late winter/early spring as birds return north, en route to breeding grounds.

Geese roosting at Loch of Strathbeg feed during the day (and on moonlit nights) in surrounding fields. By this activity, they have the potential to cause loss of grass or crops on an economically significant scale. A goose management scheme has been in place in the vicinity of Loch of Strathbeg since 1994 although the boundaries of the scheme have not remained constant through this time. Farmers apply for individual fields to be part of this scheme, which provides financial compensation to offset losses caused by feeding geese. The boundaries of areas which are eligible to be considered for payments under the scheme were set following the surveys described by Keller *et al.* (1997). The survey was repeated in 2004 (Patterson & Thorpe, 2006), following which the scheme boundaries were refined and the area qualifying was reduced.

Given the interval since the last goose distribution survey, a resurvey was required. Furthermore, there is a possibility that the approach to goose management in the Loch of Strathbeg area might change from the current scheme, which provides undisturbed refuges, to an approach involving more disturbance. Such a change may result in an increase in the amount of flight activity by geese. The consequent increase in energy requirements and decrease in the time for undisturbed feeding could be harmful to geese in the period immediately prior to migration and breeding, when the birds need to accumulate fat reserves. Thus, to be able to detect any flight activity changes that do occur under a different management regime, a baseline level of flight activity under the present management scheme needed to be determined.

Hence, the requirements of the work described in this report were to:

1. Survey the feeding distribution of geese which roost at the Loch of Strathbeg in order to identify the areas most heavily used by the geese and to establish how far these areas coincide with the boundary of the existing management scheme.
2. Measure the amount of flight activity by geese in their feeding area around the Loch of Strathbeg.

2. METHODS

2.1 Timing

Fieldwork was carried out on 16 days (two days each calendar week) between 1 March and 22 April 2016. The survey area was separated into a north section and a south section. On each date, one section was covered for the distribution surveys along with the three corresponding flight vantage point counts within that section. Both sections were covered within each of the eight calendar weeks of fieldwork. These are subsequently referred to as weeks 1 to 8 (Table 1).

Table 1. Goose survey fieldwork dates in March and April 2016.

Week	South section	North section
1	1 March	7 March
2	11 March	13 March
3	14 March	18 March
4	25 March	27 March
5	31 March	2 April
6	5 April	7 April
7	12 April	14 April
8	21 April	22 April

Fieldwork was planned for days on which the weather was suitable for making observations and not likely to abnormally influence goose distribution around the site. This was regarded as being days when the wind was forecast to be no stronger than Beaufort force 5, with rain not exceeding short showers and with good visibility. In the event, rain was more sustained on some days than forecast, which may have reduced flight activity and bird detectability, but was not thought to have significantly impaired the distribution survey element of the work. Fieldwork was paused on two occasions during brief spells of heavy rain.

2.2 Distribution survey

The survey method followed that used by Patterson & Thorpe (2006) during the survey carried out in 2004 which in turn was based on Keller *et al.* (1997). This involves driving most of the roads within the survey area, noting the presence and size of goose flocks. Most pink-footed geese in North-East Scotland forage within 20 km of their roost site (Patterson, 2013) and the survey area is designed to encompass all likely areas where the majority of the geese that roost at Loch of Strathbeg may feed. A short section of track west of the A90 opposite St Fergus gas terminal which was driven in the 2004 survey was omitted in 2016 due to the very poor track condition. It is not thought that this resulted in failing to find any geese that would otherwise have been noted.

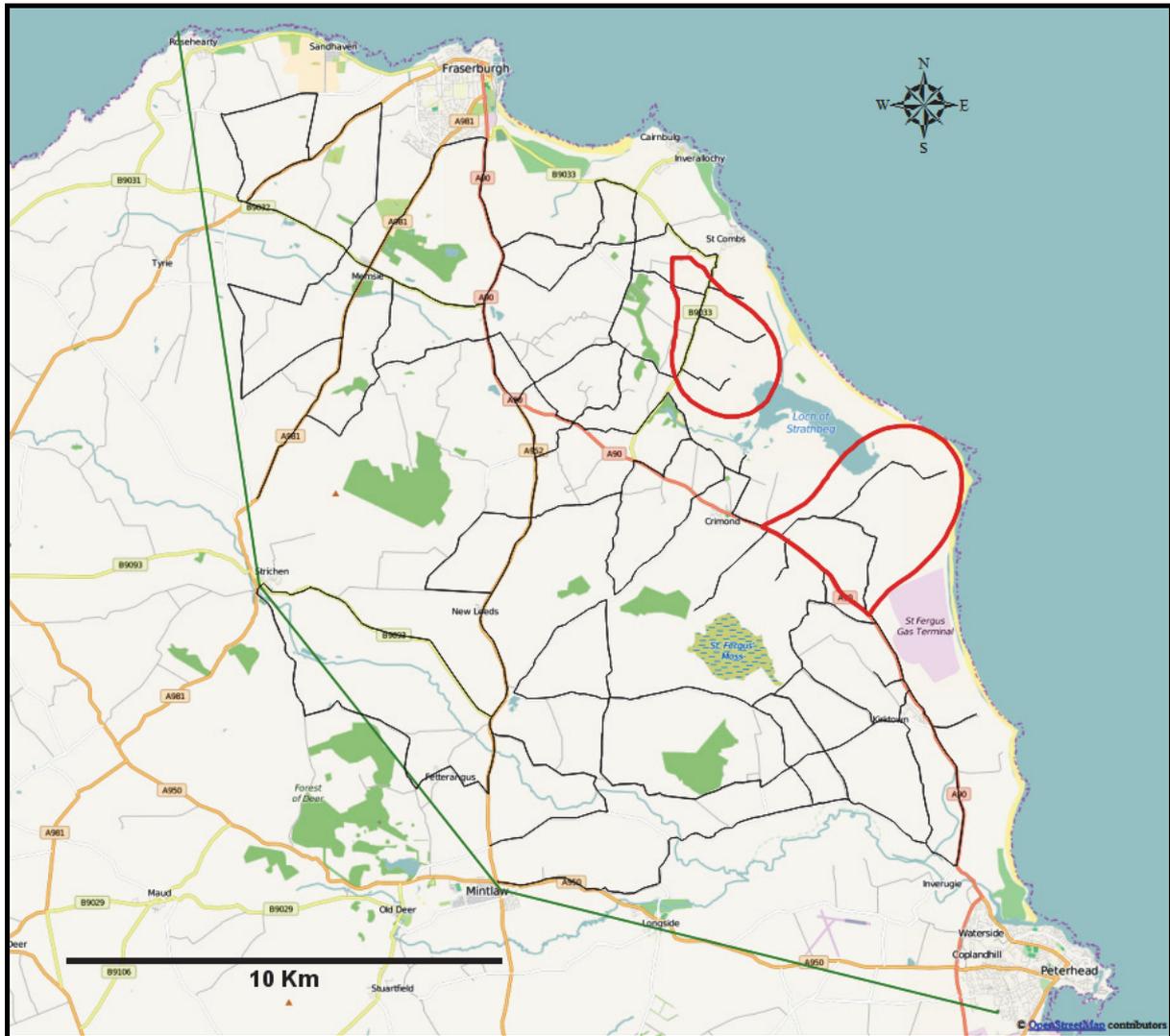


Figure 1. The study area showing, with black lines, the network of roads driven during the distribution survey. The roads north-west of the A98 (which is shown on the map as the road running south-west from Fraserburgh) at the north of the study area were driven just in weeks 3 to 8. The goose management scheme boundaries are shown with red outlines just the north-west and south-east of Loch of Strathbeg. The green line shows the outer boundary of the survey area as defined by Patterson & Thorpe (2006), though the route surveyed crossed over this boundary south of Strichen and geese noted along this section are included in the results presented.

Following Keller *et al.* (1997) the starting point and direction of the route was varied randomly for each survey visit, to reduce systematic bias relating to the time of day when each part of the area is visited. Fieldwork was timed to avoid the main times where geese were flying to and from roost and was thus planned to avoid the first and last two hours of daylight. At the beginning of March, this meant aiming to start at around 9am though fieldwork took longer than anticipated and some surveys early in the period did extend into the final two hours of daylight. However, no flights to roost were noted during this time suggesting that geese were still feeding in fields while the survey was being carried out. A recce day was spent prior to commencing data collection for familiarisation with the route.

Whilst driving the route, if geese were noted, these were observed from the roadside where safe to do so. Usually this was possible (sometimes involving a U-turn to find a safe place) though in a small number of cases along busy roads without convenient stopping places, a

rough “drive-by” estimate was made. Geese were not actively scanned for whilst driving, especially along busier roads, but instead frequent stops were made to look over fields. Positions that gave clear views across large areas were used to scan more distantly, with a telescope where appropriate. At two locations, short walks were taken each week to view areas of ground not easily viewed from roads. These were at Rattray Head (viewing south from NK10345766) and close to St Fergus Gas Terminal (viewing east and north-east from NK08485456). Additionally, fields to the north of Loch of Strathbeg were viewed from the field close to the RSPB visitor centre at NK05785810. Ordinarily, the visitor centre itself would provide a similar view of these fields but it was closed for renovation during this survey.

When geese on the ground were found, their identification was noted and the location of the centre of the flock was determined from a 1:25,000 map. Handheld GPS was occasionally used to assist with this but was of only limited value given the need to record the location of the birds rather than that of the observer. Most flocks were straightforward to define as a discrete unit. In a small number of cases they spanned across more than one field but if clearly acting as one flock, a single location was noted. Where there was ambiguity as to where one flock ended and another started, field boundaries were used to conveniently define each flock.

The number of geese of each species in each flock was counted or estimated. If there were areas within a flock that were not visible from the road, the geese were watched for a few minutes to make a judgement based on birds moving in and out of view.

The field type was noted in one of the following categories: grass, stubble, ploughed, winter cereal and other arable crop. Bird activity was not, however, noted within a field so although most birds were feeding when found, this was not necessarily the case for all flocks noted.

Birds seen in flight were watched to their landing position where possible and then noted for the survey. When geese were seen flying beyond the survey area boundary, their direction of flight was noted and an attempt made to locate their destination. This resulted in an additional loop being added to the road network covered in week 3, which was then included in the weekly survey and birds in this area were recorded and mapped in the same way as other feeding flocks. The location of this loop is referred to in the caption for Figure 1. Additionally a flock was noted in one location outside the survey area in weeks 3 and 4 whilst driving towards the survey area. These are included Appendix 1 but not included in any other totals given or mapping analysis.

Whilst carrying out the goose survey, swans seen on land were also noted as these may similarly cause economic damage to crops. The data are included in Annex 1, so that future changes can be assessed, but not otherwise analysed or referred to. Swans on water were not noted.

2.3 Flight activity survey

The requirement was to present a baseline level of flight activity under the present management scheme. Flight activity was assessed using vantage point watches. Six vantage points were selected during the pre-survey recce. These were one each within current goose management scheme boundaries, one south of the southern part of the scheme and one north of the northern part of the scheme and two more positions in the more western part of the survey area (Figure 2). The precise positions of vantage points were selected so as to allow clear views over as wide an area as possible and to permit convenient and safe parking at the location or close by (Table 2).

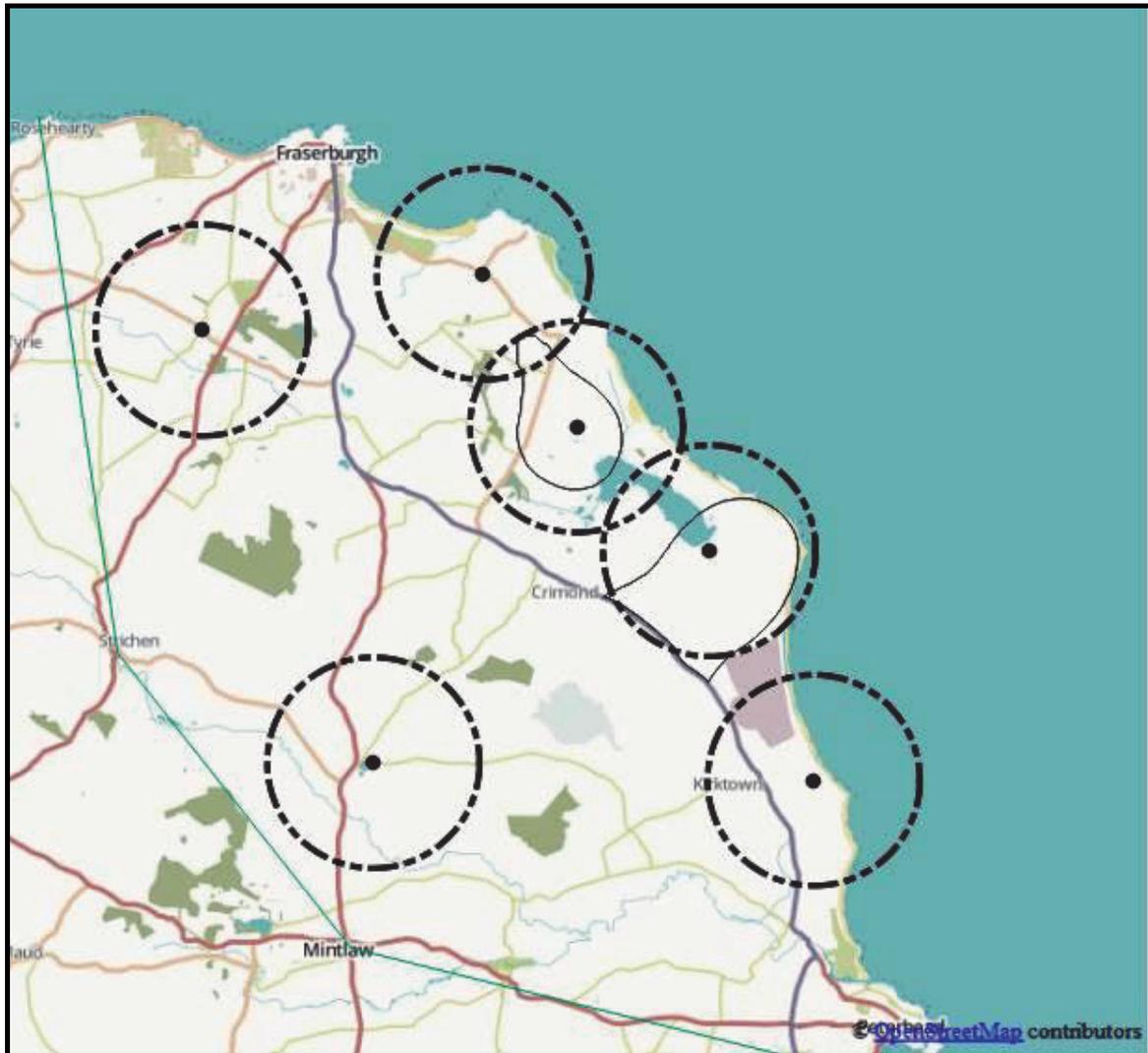


Figure 2. Location within the study area of the vantage points used for flight surveys. The 5 km radius survey area is shown in each case.

Table 2. Locations and parking details for vantage points (VP) used for goose flight surveys.

Section	Vantage point	Grid reference	Parking
South	Kirkhill	NK00625253	At VP
South	Rattray	NK08525756	At VP
South	St Fergus	NK10995213	At VP
North	Cairnbulg	NK03206410	By sub-station at NK03256425
North	Coralhill	NK05396049	At VP
North	Memsie	NJ96596277	At VP (or in Memsie village)

At each vantage point, a watch was conducted for one hour once during each week. All geese seen through 360° out to 5 km distance were noted. Geese were initially located either by sight or sound and a full scan of more distant parts of the watch area, using binoculars, was conducted at around five minute intervals. The order in which each of the three vantage point watches was conducted in a day was varied between weeks (Table 3).

Table 3. Time of start of vantage point watches for flying geese. Each watch lasted for one hour. Time for weeks 1 to 3 and the south section of week 4 are in G.M.T. The remainder are in B.S.T.

Week	Southern section			Northern section		
	Kirkhill	Ratray	St Fergus	Cairnbulg	Coralhill	Memsie
1	12.58	16.01	10.03	12.48	11.11	14.52
2	15.59	10.04	12.30	12.30	14.54	10.07
3	08.42	12.34	15.12	15.37	10.17	12.55
4	15.55	13.02	09.31	10.18	13.22	16.08
5	16.39	10.31	13.52	16.01	14.03	09.37
6	12.33	15.20	09.48	09.47	15.39	12.17
7	09.24	12.32	15.38	12.26	09.50	15.14
8	13.09	10.30	15.36	15.23	13.23	09.13

When geese were noted, the time, species, flock size (estimated if necessary), direction of flight and direction and distance from observer were noted. Flight height was also noted. For closer flocks (up to about 500 m distance) this was assessed when possible using a laser rangefinder, model Hawke LRF 900, set to measure vertical distance above the observation position. Measurements made with the laser rangefinder were used to guide estimates of flight height for other flocks. A note was made of whether the height was estimated or measured with the laser rangefinder.

Any disturbance events that caused birds to take flight, or had a reasonable potential to do so, were noted. Regular farming activities, such as tractor movements, were not noted if no goose disturbance was apparent.

At the vantage points at Coralhill, Ratray and St Fergus, feeding flocks of geese were usually visible close by. Geese taking off, flying short distances within a feeding flock and landing back in the same flock were not recorded but some flights involved relatively small scale movements between nearby feeding flocks, or turnover of birds in and out of these flocks, and these were noted.

The numbers of geese in flight per area per time period (e.g. similar to that described by Patterson, 2015) was the primary metric being assessed. The remaining data were collected in order that they would be available for future analysis of changes in flight behaviour. The survey was, by necessity, a sampling exercise, giving a quantified mean to allow future assessment of change, rather than a detailed assessment of goose movements across the whole area.

2.4 Analysis

For the distribution survey, the grid references of goose flocks (all species combined) were entered into QGIS software and this was used, along with open source background maps, to generate maps of goose abundance. Kernel analysis was carried out to determine which areas were most heavily occupied by geese using the Heatmap tool within QGIS. The radius for the analysis that was used was 500 m and the analysis was carried out by weighting the points based on the number of birds at each point. The data were analysed to display trends through the survey period. Data were also analysed to determine what proportion of birds were within the existing management scheme boundaries and to determine the proportion of birds recorded in each field type.

For the flight survey, goose flocks were assigned to a 1 km square based on the bearing from observer and estimated distance. Thus figures were calculated for geese seen in each 1 km square that was at least partly within a 5 km radius. Complete flight lines were not plotted so many of these birds would move across more than a single 1 km square. However, they were assigned solely to the square containing the position of the closest point to the observer that they were seen as this was typically the point at which height and direction of flight could most accurately be assessed. Most flocks were not watched for the full duration of their flight and, generally, most or all movement observed took place within the square in which the flock was initially detected. Goose detectability, particularly for smaller flocks, was greatest at the centre of the area surveyed, thus creating a centre-weighted bias. The survey was, though, designed to provide a repeatable metric by which to assess future change rather than an absolute statement of goose numbers moving through a particular area.

A further analysis was carried out to investigate the influence of goose distribution as defined during the distribution survey element of the work, especially those in line of sight of the vantage point, on the number seen from vantage points during the flight survey element. Viewshed analysis was carried out in ArcGIS (vers.10.0) to determine which areas of land should be visible from the vantage points, rather than obscured by topographical features. The results from this were used to determine which goose flocks found within 3 km of the vantage points (rather than 5 km, due to diminishing efficiency of detection of flying birds at a greater distance) would have been visible on the ground from the vantage point and which would not have been. As geese in flight would, in most cases, cross over both visible and non-visible ground, and given that distance from observer was estimated to an unknown degree of accuracy for more distant flocks, geese in flight were not directly related to “visible” or “non-visible” ground as defined by viewshed analysis. Instead, the analysis was simplified by categorising geese in the 3 km radius around each vantage point into four sectors, bounded by the cardinal directions. Simple regression analyses were used to determine correlation coefficients to examine whether the number of geese recorded in each sector during the flight survey was more related to the overall number of geese recorded during the distribution survey in that sector or number of geese visible as identified by the viewshed analysis.

3. RESULTS

3.1 Distribution survey

3.1.1 Goose numbers and species

The total number of geese recorded (all species combined) was 8,892 in week 1, rising to a peak of 17,314 in week 4 and 17,489 in week 5 and then declining to 574 in week 8 (Figure 3). Of the total number of all counts combined (83,610), 99.4% were pink-footed geese, with low numbers of other species recorded (Table 4). Full data are given in Annex 1.

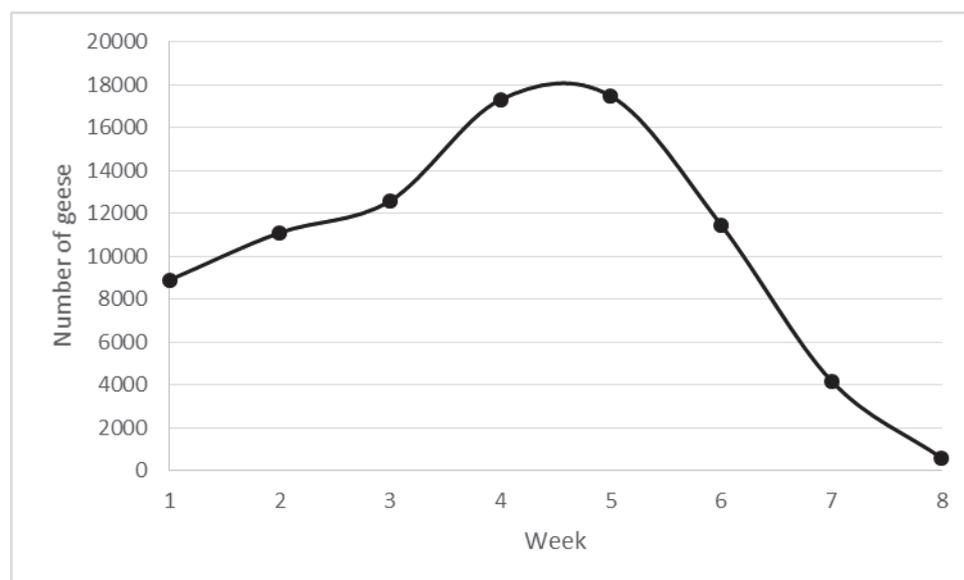


Figure 3. Weekly total counts of geese during distribution surveys in March and April 2016.

Table 4. Total summed counts of each goose species (or sub-species) recorded during the distribution survey.

Goose species	Total number	% of total number
barnacle goose	95	0.1
Canada goose	5	<0.1
European white-fronted goose	3	<0.1
greylag goose	407	0.5
Greenland white-fronted goose	16	<0.1
pale-bellied brent goose	1	<0.1
pink-footed goose	83083	99.4

3.1.2 Goose distribution

Although geese were recorded widely across the study area, a few parts consistently held sizable flocks (see weekly maps in Annex 2). During the first half of the survey, the largest concentrations were between Loch of Strathbeg and St Fergus gas terminal and to the north-west of the Loch of Strathbeg. In both cases, these were within the goose management scheme boundaries. There were further concentrations south and west of the goose management scheme area in the Crimond and St Fergus area and smaller numbers

elsewhere (Annex 2, Map 9). During the second half of the survey, the goose management scheme area south-east of Loch of Strathbeg remained heavily used, though fewer birds were noted in the scheme area to the north-west of the loch. The area south of St Fergus gas terminal remained well used whilst a further significant concentration was identified at the north-west extremity of the survey area west of Fraserburgh, this resulting from adding an extra loop to the road network surveyed from week 3 onwards (Annex 2, Map 10). It seems entirely likely that this area was also used during weeks 1 and 2 though it was not surveyed at that time. With data from all visits combined, these same areas showed concentrations of records. Overall, the majority of birds were recorded east of the A952 Mintlaw to Fraserburgh road, with the one additional concentration in the north-west of the survey area (Annex 2, Map 11).

Kernel analysis of the distribution of geese through the survey area showed much the same pattern. The goose management scheme areas contained significant concentrations of birds, especially that to the south-east of the Loch of Strathbeg. Further well-used areas were identified close to the scheme areas with the most important area more distally being that in the far north-west of the survey area (Annex 3).

Overall, 34% of goose flocks and 27.3% of individual geese recorded were within the current goose management scheme boundaries. There was no clear pattern of variation in these proportions during the survey period and the mean proportions were similar between the first half and second half of the survey period (Table 5).

Table 5. The percentages of flocks and of geese recorded on the distribution surveys, which were found within the boundary of the management scheme.

Week	Flocks	% within	Geese	% within
1	43	41.9	8892	27.4
2	34	32.4	11099	32.3
3	39	28.2	12587	24.4
4	48	31.3	17314	31.4
mean wks 1-4	41	33.5	12473	29.1
5	52	28.8	17489	23.4
6	42	31.0	11469	19.0
7	26	46.2	4182	37.6
8	7	57.1	574	85.5
mean wks 5-8	31.8	34.6	12614	26.3

3.1.3 Types of field used

The overwhelming majority of geese recorded (93.4%) were in fields of grass. No distinction was made in the recording of categories between improved and rough grasslands but both types were used. Birds recorded in winter cereals accounted for 3.3% of the total with less than 1% recorded in any other single field/substrate category (Figure 4).

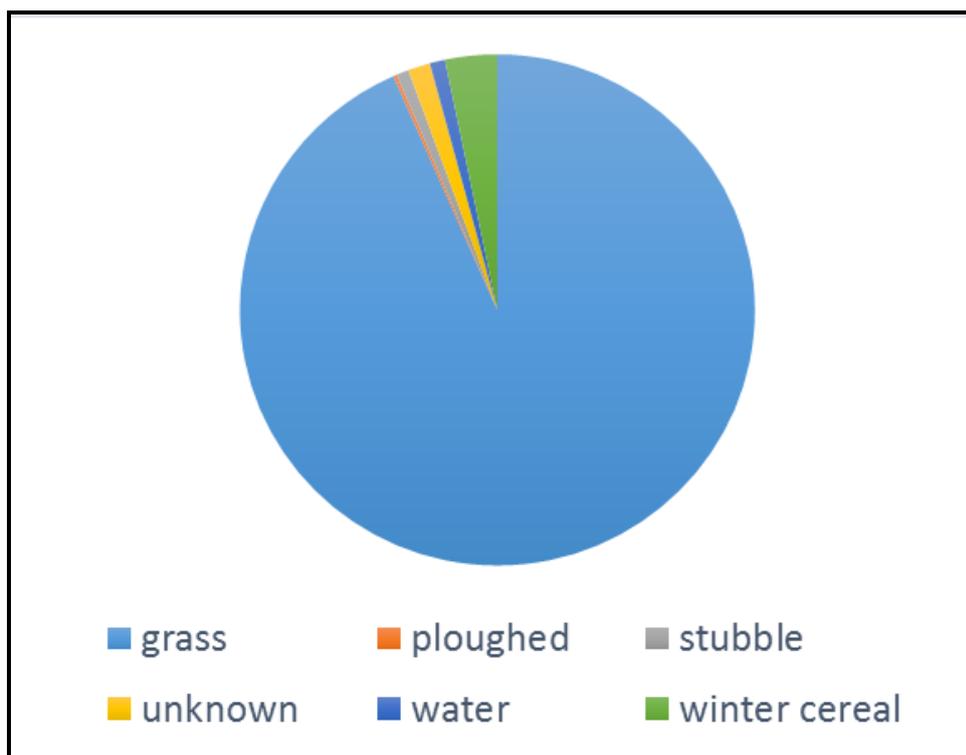


Figure 4. Goose distribution presented by field type or substrate on which geese were recorded.

3.2 Flight survey

A total of 201 goose flocks (including single birds) were noted during 48 hours of flight survey watches from the six vantage points. These totalled 19,323 birds. At vantage points close to regularly-used goose feeding areas (Coralhill, Rattray and St Fergus) many of the flights involved birds coming in and landing within a feeding flock or birds departing a feeding flock. These typically involved small numbers of birds on each occasion but could make up the majority of individual flocks noted during some flight surveys.

Goose flight numbers peaked in week 4 and were generally low during the final three weeks of fieldwork (Figure 5). When broken down by individual vantage point, the number of geese recorded during the flight survey varied considerably from week to week and showed no clear trends (Table 6). Numbers were low especially when the flight survey period coincided with precipitation (see Annex 5 for details of weather during the goose flight surveys).

The distribution of flight activity, as noted from each vantage point, is shown in a series of maps in Annex 4. These show patterns of activity that often reflect the distribution survey data. For example, the flight activity maps at Memsie show goose flocks between 3 and 5 km north-west of the vantage point. These are in the area where sizeable goose numbers were recorded when it was added to the distribution survey from week three onwards.

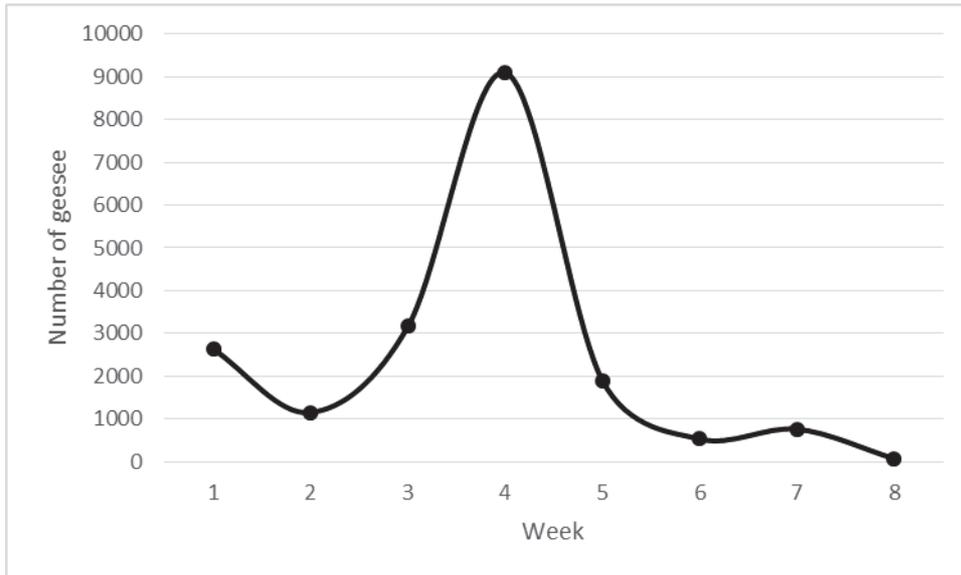


Figure 5. Weekly total counts of geese during flight surveys in March and April 2016.

Table 6. Sum of geese recorded in flight during a weekly one hour watch at each vantage point (number of flocks given in brackets).

Week	Cairnbulg	Coralhill	Kirkhill	Memsie	Ratray	St Fergus
1	0 (0)	62 (6)	0 (0)	563 (4)	1608 (9)	402 (2)
2	70 (2)	316 (9)	0 (0)	48 (2)	706 (13)	14 (2)
3	369 (14)	369 (7)	477 (7)	1736 (6)	209 (19)	3 (1)
4	342 (10)	4263 (25)	690 (3)	1472 (7)	1 (1)	2330 (3)
5	0 (0)	13 (2)	100 (1)	645 (5)	887 (8)	252 (16)
6	0 (0)	22 (5)	514 (3)	0 (0)	0 (0)	0 (0)
7	0 (0)	314 (5)	0 (0)	450 (1)	1 (1)	0 (0)
8	0 (0)	70 (1)	0 (0)	0 (0)	5 (1)	0 (0)

Flight height was assessed using the laser rangefinder for 33 flocks and estimated for the remaining 168 flocks. The overall mean height of flocks was 50.1 m. Flocks for which height was estimated by laser included a higher proportion taking off or landing in nearby fields than for flocks for which height was estimated and, hence, the mean height measured by laser was lower, at 41.4 m, compared with the 51.8 m mean height recorded when this was estimated.

Very few direct instances of goose flight in relation to disturbance events were noted, though unseen disturbances may have caused the initiation of flight of flocks that then appeared within the flight survey area. Bangs from shotguns or gas guns were heard regularly and though no goose flights were noted in connection with these, this could be because geese were already actively avoiding such areas. A list of disturbance events or potential disturbance events is given in Annex 6.

3.3 Viewshed analysis

Geese noted during the flight survey within 3 km of each vantage point were assigned to one of four sectors defined by cardinal directions and this revealed significant variation in the distribution of geese noted with respect to the vantage points (Table 7).

Table 7. Flocks and total number of geese recorded during flight surveys within a 3 km radius of each vantage point broken down by sector where sector 1 is north through to east, sector 2 is east to south, sector 3 is south to west and sector 4 is west to north. Bearings of 0°, 90°, 180° and 270° from the vantage point are assigned to sectors 1 to 4 respectively.

	sector 1		sector 2		sector 3		sector 4	
	flocks	geese	flocks	geese	flocks	geese	flocks	geese
Cairnbulg	1	1	14	288	6	166	6	131
Coralhill	13	720	38	4251	4	137	4	21
Kirkhill	6	899	2	100	1	160	5	622
Memsie	2	48	0	0	8	1102	5	554
Ratray	8	464	18	838	23	1960	1	125
St Fergus	0	0	2	420	16	235	3	16

The viewshed analysis identified which flocks of geese noted during the distribution survey that were within 3 km of a vantage point should be visible from that vantage point. There is likely to be some degree of error in this analysis given that flock locations were estimated to a six figure grid reference of the centre of the flock but the general pattern of areas in which flocks were assigned as being visible generally accords well with the impression gained during the surveys. Table 8 shows a breakdown of geese in each sector and those that viewshed analysis showed to be visible from the vantage points.

Table 8. Number of geese recorded during distribution surveys within a 3 km radius of each vantage point broken by sector where sector 1 is north through to east, sector 2 is east to south, sector 3 is south to west and sector 4 is west to north. The figures are further broken down into the number shown by viewshed analysis to be visible from the vantage point and the total number of geese noted in the sector.

	sector 1		sector 2		sector 3		sector 4	
	visible	total	visible	total	visible	total	visible	total
Cairnbulg	0	0	542	542	450	1567	0	2
Coralhill	1021	1141	4655	4655	2267	3069	0	1036
Kirkhill	0	3052	0	2257	56	886	1355	3455
Memsie	260	260	0	0	1773	1773	1859	1859
Ratray	1395	2499	3807	10362	3213	5946	358	438
St Fergus	0	0	700	700	2121	4701	2737	4437

There was a weak but significant relationship between the number of geese counted in the flight survey in each sector at each vantage point and the number of geese noted during the distribution surveys in the corresponding sectors ($r^2 = 0.19$, $p = 0.03$). However the relationship between the number of geese counted in the flight survey in each sector at each vantage point and the number of geese counted in the distribution survey, that viewshed analysis showed to be visible from the vantage point, was much greater ($r^2 = 0.50$, $p < 0.001$). A similar pattern, though with stronger relationships, existed between the number of flocks

counted in flight in each sector from each vantage point and the number of geese in the same sector noted in the distribution survey overall and also with those within the viewshed from the vantage point ($r^2 = 0.36$, $p = 0.002$ and $r^2 = 0.61$, $p < 0.001$ respectively).

4. DISCUSSION

4.1 Distribution survey

During the distribution survey, the peak count of geese recorded was 17,489. Monthly goose roost counts at Loch of Strathbeg RSPB reserve, contemporaneous with the distribution survey, were of 20,100 geese on 14 March and 3,720 on 11 April. The March roost count was 60% higher than the number recorded during the distribution survey in the same week whilst the April count was 11% lower. These variations may be because not all birds roosting at the reserve were feeding within the survey area and vice versa. They may also simply reflect daily differences in numbers present, given that the distribution surveys were carried out over two days which were not planned to correspond directly with roost surveys at Loch of Strathbeg. Nonetheless, the large fall in numbers between the two Loch of Strathbeg counts corresponds well with the trend in overall numbers found during the distribution survey.

The distribution survey identified several concentrations of feeding geese. The goose management scheme boundaries encompassed several of the areas that held the densest numbers of birds. The management scheme area to the south-east of Loch of Strathbeg was more heavily used than that to the north-west and, in particular, only the south-eastern side of the northern part of the scheme area was seen to be used by goose flocks.

Outside of the goose scheme boundaries, the area south of St Fergus gas terminal, along both sides of the minor road to Scotston, was consistently used by large number of geese as was the area immediately south of Crimond, along the minor road to Longhill. Goose concentrations were apparent in two other areas towards the centre of the survey area (Annex 3, Map 3) though appeared to be less substantial than those closer to Loch of Strathbeg. The remaining concentration identified, east of the hamlet of Peathill in the north-west of the survey area, held large goose numbers consistently from when it was first identified and added to the survey route in week 3 through to week 6, with numbers declining across the whole survey area thereafter. If this area had been included the survey in weeks 1 and 2, its apparent importance may have been even greater.

The overall pattern of records is similar to that identified in 2004 (Patterson & Thorpe, 2006). The main exceptions are concentrations described here in the north-west part of the survey area and south of the St Fergus gas terminal and the slightly wider spread of records in 2004 in the north section of the goose management scheme area. Two further areas of some importance were also identified in 2004, these being south-west of Fraserburgh and north of Mintlaw. Although both areas did hold some geese during the 2016 surveys, neither was identified as being of particular importance.

Although the goose management scheme areas did hold concentrations of geese, almost three quarters of geese recorded were outside the scheme boundaries. Patterson & Thorpe (2006) reported that 70% of geese in their survey were found within the boundaries of the management scheme that existed at that time. However, the scheme boundary then was substantially greater (88 km² compared to the present 16 km²) and encompassed all large concentrations identified in the current work with the exception of the concentration in the north-west part of the survey area. It is not known what proportion of birds from the 2004 survey were within the current smaller management scheme boundaries, although these boundaries were based largely on that survey.

In 2004, all goose flocks were in grass fields (Patterson & Thorpe, 2006). In 2016, the overwhelming majority were in grass fields but smaller numbers were noted in other field types, especially winter cereals (presumed to be mainly barley) which accounted for 3.3% of birds. Whilst winter cereals have generally increased as a proportion of land cover in recent

years, it is not known to what extent any such changes in the study area have affected the availability of such crops to geese between the 2004 and 2016 surveys. Field type should continue to be recorded in future surveys, though, to determine if winter cereals do become a more important food resource for feeding geese.

The distribution survey has a number of limitations as dictated by the topography of the area and limitations of fieldwork resources. These include that not all areas of land are visible from the road network. Previously, Keller *et al.* (1997) had estimated that this was so for under 10% of the study area. These hidden areas are scattered through the survey area so are not thought likely to bias the overall results from the distribution survey (Keller *et al.*, 1997; Patterson & Thorpe, 2006). The distribution survey does not take account of goose movements during the day so some flocks may be double counted and others not counted at all. Splitting the survey each week across two dates may have similar results. However, as the aim of the survey is to map the distribution of foraging geese rather than to count the total number of geese, this should not bias the primary findings. Furthermore, with the survey spread over eight weeks, regularly well-used areas should still be reliably identified. Some areas that occasionally hold large numbers of birds may be missed whilst large flocks may be seen in other areas that are only used periodically. However, the coincidence of the most regularly used areas identified in 2016 with those from 2004 gives some confidence that the survey method is appropriate and the results reliable.

4.2 Flight survey

The flight survey provides a baseline against which future surveys can be assessed. Flight activity varied considerably between visits so large changes in flight activity might be required in order to confidently detect significant changes. However, repeat surveys over time may help to provide information on the impacts of changes in goose management in the area. This may be assisted by assessment of whether flocks are engaged in long-distance movements, as might be expected in response to disturbance, or shorter movements between adjacent feeding areas. Goose flight heights may also change in response to changes in goose management and, to this end, use of a laser rangefinder to measure vertical distance helps to ensure accuracy of measurements for closer flocks and provides a benchmark by which to calibrate estimates for more distant flocks.

4.3 Viewshed analysis

Analysis of the viewshed from each vantage point showed that the number of geese counted in flight was more closely related to the number of geese counted in the distribution survey within the viewshed than the overall number noted in the distribution survey. This is not surprising given that areas that fell outside the viewsheds may, in some cases, represent “blind-spots” up to an altitude above that at which geese were flying. Nonetheless, there was also a significant relationship between geese noted in flight and the overall number noted in the distribution survey, suggesting that a high proportion of goose movements noted during the flight surveys were of local flock movements between feeding fields rather than birds passing through the area. If future goose management involves more active disturbance to flocks in fields, it is possible that this may result in longer goose flights and that analysis of the relationships examined here may show weaker correlations under such a scenario.

5. CONCLUSIONS

5.1 Distribution survey

The Loch of Strathbeg area remains important in spring for geese, especially pink-footed geese. The most heavily used areas by feeding birds remain similar to those identified in 2004 though with some differences. The most notable difference is the identification of an important concentration of birds in the north-west of the study area. This should be considered for inclusion in any future revision of goose management scheme boundaries.

5.2 Flight survey

Data were successfully collected as a baseline of goose flight activity from six vantage points within the study area. Numbers recorded were rather variable and large changes might be required to be able to detect significant differences during repeat surveys. However, addition of goose activity information (whether flying to or from adjacent feeding flocks) and flight height may assist with future analysis.

5.3 Viewshed analysis

Viewshed analysis provided a way of investigating biases in recording of geese during the flight survey due to topographical features of the land. It showed, as suspected, that there were differences in detectability of geese relating to how much land was directly visible from the vantage point. These biases are more likely to be an issue with geese flying at lower altitudes. Repeating such analysis during future surveys may provide some indication of whether the nature of flights with respect to proximity to feeding areas changes in response to different goose management approaches.

6. REFERENCES

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ANNEX 1: GOOSE DISTRIBUTION SURVEY DATA

In addition to geese, swans noted on land during the distribution survey are included in the table below though not included in the figures analysed elsewhere in this report. "Scheme" refers to whether or not the flock was inside the goose management scheme boundaries (1 = inside, 0 = outside).

Week	Date	Grid ref	Species	Count	Scheme	Field type
1	01/03/2016	NJ953536	mute swan	2	0	grass
1	01/03/2016	NJ953536	pink-footed goose	12	0	grass
1	01/03/2016	NJ958537	mute swan	17	0	winter cereal
1	01/03/2016	NJ962536	mute swan	4	0	winter cereal
1	01/03/2016	NJ983353	pink-footed goose	430	0	grass
1	01/03/2016	NK012542	pink-footed goose	200	0	grass
1	01/03/2016	NK032502	pink-footed goose	140	0	grass
1	01/03/2016	NK058529	pink-footed goose	340	0	grass
1	01/03/2016	NK072549	pink-footed goose	600	0	grass
1	01/03/2016	NK076490	pink-footed goose	7	0	grass
1	01/03/2016	NK080550	pink-footed goose	400	1	grass
1	01/03/2016	NK081529	pink-footed goose	110	0	grass
1	01/03/2016	NK081560	pink-footed goose	80	1	grass
1	01/03/2016	NK082562	pink-footed goose	20	1	grass
1	01/03/2016	NK082568	pink-footed goose	8	1	stubble
1	01/03/2016	NK087537	pale-bellied brent goose	1	0	grass
1	01/03/2016	NK087537	pink-footed goose	1700	0	grass
1	01/03/2016	NK088578	pink-footed goose	80	1	grass
1	01/03/2016	NK090575	pink-footed goose	91	1	grass
1	01/03/2016	NK093568	barnacle goose	1	1	grass
1	01/03/2016	NK093568	pink-footed goose	240	1	grass
1	01/03/2016	NK094554	pink-footed goose	25	1	grass
1	01/03/2016	NK095574	pink-footed goose	80	1	grass
1	01/03/2016	NK096559	pink-footed goose	15	1	grass
1	01/03/2016	NK097557	pink-footed goose	370	1	grass
1	01/03/2016	NK098571	barnacle goose	30	1	grass
1	01/03/2016	NK098571	pink-footed goose	20	1	grass
1	01/03/2016	NK103489	pink-footed goose	41	0	stubble
1	01/03/2016	NK105518	pink-footed goose	550	0	grass
1	01/03/2016	NK105524	whooper swan	8	0	grass
1	01/03/2016	NK108519	pink-footed goose	400	0	grass
1	07/03/2016	NJ950640	pink-footed goose	50	0	grass
1	07/03/2016	NJ952608	pink-footed goose	310	0	grass
1	07/03/2016	NJ953645	greylag goose	1	0	grass
1	07/03/2016	NJ953645	whooper swan	14	0	grass
1	07/03/2016	NJ954641	barnacle goose	3	0	grass
1	07/03/2016	NJ954641	pink-footed goose	500	0	grass
1	07/03/2016	NK037634	pink-footed goose	20	0	grass
1	07/03/2016	NK044583	pink-footed goose	92	0	grass

1	07/03/2016	NK050620	pink-footed goose	520	1	grass
1	07/03/2016	NK053561	barnacle goose	1	0	grass
1	07/03/2016	NK053561	Greenland white-fronted goose	7	0	grass
1	07/03/2016	NK053561	pink-footed goose	850	0	grass
1	07/03/2016	NK053617	pink-footed goose	16	1	grass
1	07/03/2016	NK054596	mute swan	5	1	grass
1	07/03/2016	NK054596	whooper swan	16	1	grass
1	07/03/2016	NK058609	pink-footed goose	350	1	stubble
1	07/03/2016	NK059562	barnacle goose	1	0	grass
1	07/03/2016	NK059562	pink-footed goose	90	0	grass
1	07/03/2016	NK060605	pink-footed goose	90	1	grass
2	11/03/2016	NJ952538	greylag goose	80	0	grass
2	11/03/2016	NJ952538	mute swan	2	0	grass
2	11/03/2016	NJ952538	pink-footed goose	20	0	grass
2	11/03/2016	NJ960537	mute swan	23	0	winter cereal
2	11/03/2016	NK003495	pink-footed goose	700	0	grass
2	11/03/2016	NK035502	pink-footed goose	240	0	grass
2	11/03/2016	NK054553	pink-footed goose	20	0	grass
2	11/03/2016	NK055551	pink-footed goose	800	0	grass
2	11/03/2016	NK056523	pink-footed goose	600	0	grass
2	11/03/2016	NK058558	pink-footed goose	40	0	grass
2	11/03/2016	NK067556	pink-footed goose	30	0	grass
2	11/03/2016	NK068548	barnacle goose	4	0	winter cereal
2	11/03/2016	NK068548	pink-footed goose	450	0	winter cereal
2	11/03/2016	NK068553	pink-footed goose	80	0	grass
2	11/03/2016	NK075528	pink-footed goose	110	0	grass
2	11/03/2016	NK077528	pink-footed goose	80	0	grass
2	11/03/2016	NK080560	pink-footed goose	600	1	grass
2	11/03/2016	NK081567	pink-footed goose	130	1	grass
2	11/03/2016	NK083526	pink-footed goose	80	0	stubble
2	11/03/2016	NK083565	pink-footed goose	400	1	grass
2	11/03/2016	NK083574	pink-footed goose	40	1	grass
2	11/03/2016	NK086577	pink-footed goose	55	1	grass
2	11/03/2016	NK087574	barnacle goose	1	1	grass
2	11/03/2016	NK087574	pink-footed goose	120	1	grass
2	11/03/2016	NK088544	pink-footed goose	90	0	grass
2	11/03/2016	NK092554	pink-footed goose	250	1	grass
2	11/03/2016	NK103489	pink-footed goose	43	0	stubble
2	11/03/2016	NK103580	whooper swan	13	1	water
2	11/03/2016	NK105522	mute swan	4	0	grass
2	11/03/2016	NK105522	pink-footed goose	950	0	grass
2	13/03/2016	NJ962625	pink-footed goose	400	0	grass
2	13/03/2016	NK004554	pink-footed goose	250	0	grass
2	13/03/2016	NK011514	pink-footed goose	1100	0	winter cereal
2	13/03/2016	NK022553	pink-footed goose	950	0	grass
2	13/03/2016	NK044585	pink-footed goose	400	0	grass

2	13/03/2016	NK054595	pink-footed goose	1300	1	grass
2	13/03/2016	NK055592	pink-footed goose	40	1	grass
2	13/03/2016	NK059602	pink-footed goose	650	1	grass
3	14/03/2016	NJ953537	greylag goose	50	0	grass
3	14/03/2016	NJ953537	mute swan	23	0	water
3	14/03/2016	NJ953537	pink-footed goose	250	0	grass
3	14/03/2016	NJ982537	pink-footed goose	105	0	grass
3	14/03/2016	NJ996411	pink-footed goose	500	0	grass
3	14/03/2016	NK006539	pink-footed goose	600	0	grass
3	14/03/2016	NK013544	pink-footed goose	400	0	grass
3	14/03/2016	NK028496	pink-footed goose	600	0	grass
3	14/03/2016	NK028519	pink-footed goose	710	0	grass
3	14/03/2016	NK049560	pink-footed goose	70	0	unknown
3	14/03/2016	NK055527	pink-footed goose	200	0	grass
3	14/03/2016	NK055555	pink-footed goose	250	0	grass
3	14/03/2016	NK057557	barnacle goose	1	0	grass
3	14/03/2016	NK057557	pink-footed goose	800	0	grass
3	14/03/2016	NK077529	pink-footed goose	350	0	grass
3	14/03/2016	NK087555	pink-footed goose	100	1	grass
3	14/03/2016	NK087575	pink-footed goose	1000	1	grass
3	14/03/2016	NK095555	pink-footed goose	700	1	grass
3	14/03/2016	NK097552	pink-footed goose	450	0	grass
3	14/03/2016	NK098580	pink-footed goose	200	1	grass
3	14/03/2016	NK099565	pink-footed goose	400	1	grass
3	14/03/2016	NK105522	pink-footed goose	900	0	grass
3	14/03/2016	NK108523	pink-footed goose	100	0	grass
3	18/03/2016	NJ948658	whooper swan	14	0	grass
3	18/03/2016	NJ949658	Canada goose	5	0	grass
3	18/03/2016	NJ950660	barnacle goose	1	0	grass
3	18/03/2016	NJ950660	pink-footed goose	600	0	grass
3	18/03/2016	NJ952605	pink-footed goose	50	0	grass
3	18/03/2016	NJ959624	greylag goose	3	0	grass
3	18/03/2016	NK002622	pink-footed goose	1400	0	grass
3	18/03/2016	NK022640	pink-footed goose	900	0	grass
3	18/03/2016	NK030597	pink-footed goose	2	0	grass
3	18/03/2016	NK032615	pink-footed goose	500	0	grass
3	18/03/2016	NK045582	pink-footed goose	120	0	winter cereal
3	18/03/2016	NK048594	pink-footed goose	100	1	stubble
3	18/03/2016	NK052597	pink-footed goose	80	1	grass
3	18/03/2016	NK053599	pink-footed goose	10	1	stubble
3	18/03/2016	NK054616	pink-footed goose	1	1	grass
3	18/03/2016	NK057618	pink-footed goose	18	0	stubble
3	18/03/2016	NK058582	pink-footed goose	80	0	grass
3	18/03/2016	NK060605	barnacle goose	1	1	grass
3	18/03/2016	NK060605	pink-footed goose	480	1	grass
4	25/03/2016	NJ952537	greylag goose	5	0	grass

4	25/03/2016	NJ952537	mute swan	1	0	grass
4	25/03/2016	NJ952537	pink-footed goose	17	0	grass
4	25/03/2016	NJ952537	whooper swan	1	0	grass
4	25/03/2016	NJ959536	mute swan	23	0	arable crop
4	25/03/2016	NK000544	pink-footed goose	550	0	grass
4	25/03/2016	NK013543	pink-footed goose	1000	0	grass
4	25/03/2016	NK014532	pink-footed goose	500	0	grass
4	25/03/2016	NK014544	pink-footed goose	300	0	winter cereal
4	25/03/2016	NK026498	pink-footed goose	900	0	grass
4	25/03/2016	NK042490	greylag goose	2	0	grass
4	25/03/2016	NK054557	pink-footed goose	2	0	grass
4	25/03/2016	NK059558	pink-footed goose	1300	0	grass
4	25/03/2016	NK073526	pink-footed goose	200	0	grass
4	25/03/2016	NK082562	pink-footed goose	900	1	grass
4	25/03/2016	NK084555	whooper swan	2	1	winter cereal
4	25/03/2016	NK085577	pink-footed goose	2	1	grass
4	25/03/2016	NK088545	pink-footed goose	25	0	grass
4	25/03/2016	NK088553	pink-footed goose	160	1	grass
4	25/03/2016	NK090557	whooper swan	1	1	grass
4	25/03/2016	NK090573	pink-footed goose	200	1	grass
4	25/03/2016	NK093574	barnacle goose	14	1	grass
4	25/03/2016	NK093574	pink-footed goose	1100	1	grass
4	25/03/2016	NK095554	pink-footed goose	250	0	grass
4	25/03/2016	NK099491	pink-footed goose	2	0	stubble
4	25/03/2016	NK100560	pink-footed goose	150	1	grass
4	25/03/2016	NK100573	barnacle goose	3	1	grass
4	25/03/2016	NK100573	pink-footed goose	750	1	grass
4	25/03/2016	NK105521	pink-footed goose	550	0	grass
4	25/03/2016	NK105524	pink-footed goose	100	0	grass
4	25/03/2016	NK107490	pink-footed goose	300	0	grass
4	25/03/2016	NK112502	pink-footed goose	400	0	winter cereal
4	27/03/2016	NJ933664	pink-footed goose	200	0	grass
4	27/03/2016	NJ939599	greylag goose	32	0	grass
4	27/03/2016	NJ945657	whooper swan	41	0	grass
4	27/03/2016	NJ948596	pink-footed goose	600	0	grass
4	27/03/2016	NJ952652	pink-footed goose	1100	0	unknown
4	27/03/2016	NJ952660	pink-footed goose	800	0	grass
4	27/03/2016	NJ953604	pink-footed goose	800	0	grass
4	27/03/2016	NJ978648	pink-footed goose	260	0	grass
4	27/03/2016	NJ997412	pink-footed goose	250	0	grass
4	27/03/2016	NK005626	pink-footed goose	200	0	grass
4	27/03/2016	NK008634	pink-footed goose	3	0	grass
4	27/03/2016	NK015568	pink-footed goose	650	0	grass
4	27/03/2016	NK029595	pink-footed goose	400	0	grass
4	27/03/2016	NK035633	pink-footed goose	2	0	grass
4	27/03/2016	NK044584	pink-footed goose	13	0	winter cereal

4	27/03/2016	NK053595	barnacle goose	1	1	grass
4	27/03/2016	NK053595	pink-footed goose	1300	1	grass
4	27/03/2016	NK059613	pink-footed goose	300	1	grass
4	27/03/2016	NK059616	pink-footed goose	100	0	grass
4	27/03/2016	NK060583	pink-footed goose	320	0	grass
4	27/03/2016	NK060606	pink-footed goose	100	1	grass
4	27/03/2016	NK062602	greylag goose	1	1	grass
4	27/03/2016	NK062602	pink-footed goose	450	1	grass
5	31/03/2016	NJ952537	greylag goose	15	0	grass
5	31/03/2016	NJ952537	mute swan	25	0	grass
5	31/03/2016	NJ952537	pink-footed goose	240	0	grass
5	31/03/2016	NJ952537	whooper swan	2	0	grass
5	31/03/2016	NJ958535	mute swan	2	0	winter cereal
5	31/03/2016	NJ984533	pink-footed goose	750	0	grass
5	31/03/2016	NK006494	pink-footed goose	300	0	grass
5	31/03/2016	NK012512	pink-footed goose	130	0	grass
5	31/03/2016	NK014542	pink-footed goose	4	0	grass
5	31/03/2016	NK020524	pink-footed goose	52	0	grass
5	31/03/2016	NK030514	pink-footed goose	700	0	grass
5	31/03/2016	NK031535	pink-footed goose	3	0	grass
5	31/03/2016	NK047542	pink-footed goose	40	0	grass
5	31/03/2016	NK053557	pink-footed goose	45	0	grass
5	31/03/2016	NK058529	pink-footed goose	175	0	grass
5	31/03/2016	NK060558	pink-footed goose	120	0	grass
5	31/03/2016	NK070525	pink-footed goose	600	0	grass
5	31/03/2016	NK071555	pink-footed goose	1700	0	grass
5	31/03/2016	NK072527	pink-footed goose	23	0	grass
5	31/03/2016	NK075524	pink-footed goose	12	0	grass
5	31/03/2016	NK079570	barnacle goose	1	1	grass
5	31/03/2016	NK079570	pink-footed goose	650	1	grass
5	31/03/2016	NK082561	pink-footed goose	300	1	grass
5	31/03/2016	NK084577	greylag goose	2	1	grass
5	31/03/2016	NK084577	pink-footed goose	4	1	grass
5	31/03/2016	NK086574	pink-footed goose	160	1	grass
5	31/03/2016	NK087547	pink-footed goose	65	0	grass
5	31/03/2016	NK089551	pink-footed goose	330	1	grass
5	31/03/2016	NK094566	pink-footed goose	100	1	grass
5	31/03/2016	NK095552	pink-footed goose	150	0	grass
5	31/03/2016	NK098565	pink-footed goose	350	1	grass
5	31/03/2016	NK098572	pink-footed goose	200	1	grass
5	31/03/2016	NK099579	barnacle goose	2	1	grass
5	31/03/2016	NK099579	Greenland white-fronted goose	2	1	grass
5	31/03/2016	NK099579	pink-footed goose	900	1	grass
5	31/03/2016	NK105516	whooper swan	1	0	grass
5	31/03/2016	NK105521	pink-footed goose	1200	0	grass
5	31/03/2016	NK107519	pink-footed goose	1300	0	grass

5	31/03/2016	NK110516	pink-footed goose	300	0	grass
5	02/04/2016	NJ938599	greylag goose	110	0	grass
5	02/04/2016	NJ948655	pink-footed goose	1900	0	grass
5	02/04/2016	NJ948655	whooper swan	10	0	grass
5	02/04/2016	NJ948660	pink-footed goose	250	0	grass
5	02/04/2016	NJ950658	pink-footed goose	300	0	grass
5	02/04/2016	NJ952607	pink-footed goose	210	0	grass
5	02/04/2016	NJ952661	pink-footed goose	250	0	grass
5	02/04/2016	NJ959639	pink-footed goose	80	0	grass
5	02/04/2016	NK015577	pink-footed goose	350	0	grass
5	02/04/2016	NK021641	pink-footed goose	2	0	grass
5	02/04/2016	NK022636	pink-footed goose	12	0	grass
5	02/04/2016	NK023635	pink-footed goose	450	0	grass
5	02/04/2016	NK030596	pink-footed goose	400	0	grass
5	02/04/2016	NK044582	pink-footed goose	150	0	winter cereal
5	02/04/2016	NK047567	pink-footed goose	200	0	grass
5	02/04/2016	NK055596	pink-footed goose	600	1	grass
5	02/04/2016	NK063602	pink-footed goose	500	1	grass
5	02/04/2016	NK064595	pink-footed goose	800	0	water
6	05/04/2016	NJ953537	mute swan	1	0	grass
6	05/04/2016	NJ954538	mute swan	28	0	winter cereal
6	05/04/2016	NJ996512	pink-footed goose	55	0	ploughed
6	05/04/2016	NK003494	greylag goose	1	0	grass
6	05/04/2016	NK003494	pink-footed goose	750	0	grass
6	05/04/2016	NK010516	pink-footed goose	90	0	grass
6	05/04/2016	NK014542	pink-footed goose	300	0	grass
6	05/04/2016	NK028515	pink-footed goose	400	0	grass
6	05/04/2016	NK032502	pink-footed goose	48	0	winter cereal
6	05/04/2016	NK047541	pink-footed goose	20	0	grass
6	05/04/2016	NK050525	pink-footed goose	1100	0	grass
6	05/04/2016	NK052557	pink-footed goose	350	0	grass
6	05/04/2016	NK061560	pink-footed goose	2	0	grass
6	05/04/2016	NK064487	swan sp.	2	0	winter cereal
6	05/04/2016	NK072521	pink-footed goose	67	0	grass
6	05/04/2016	NK073527	pink-footed goose	11	0	grass
6	05/04/2016	NK081561	pink-footed goose	80	1	grass
6	05/04/2016	NK084524	pink-footed goose	145	0	winter cereal
6	05/04/2016	NK089545	pink-footed goose	390	0	grass
6	05/04/2016	NK089549	pink-footed goose	12	1	grass
6	05/04/2016	NK090552	pink-footed goose	240	1	grass
6	05/04/2016	NK092575	barnacle goose	12	1	grass
6	05/04/2016	NK092575	European white-fronted goose	2	1	grass
6	05/04/2016	NK092575	Greenland white-fronted goose	1	1	grass
6	05/04/2016	NK092575	pink-footed goose	600	1	grass
6	05/04/2016	NK093576	pink-footed goose	550	1	grass
6	05/04/2016	NK098566	barnacle goose	5	1	grass

6	05/04/2016	NK098566	pink-footed goose	150	1	grass
6	05/04/2016	NK104521	European white-fronted goose	1	0	grass
6	05/04/2016	NK104521	pink-footed goose	300	0	grass
6	05/04/2016	NK106506	pink-footed goose	70	0	grass
6	07/04/2016	NJ938600	greylag goose	90	0	grass
6	07/04/2016	NJ941646	pink-footed goose	65	0	ploughed
6	07/04/2016	NJ946655	pink-footed goose	1300	0	grass
6	07/04/2016	NJ948657	pink-footed goose	1800	0	grass
6	07/04/2016	NJ954657	pink-footed goose	200	0	grass
6	07/04/2016	NJ957640	pink-footed goose	60	0	grass
6	07/04/2016	NJ998565	pink-footed goose	500	0	grass
6	07/04/2016	NK015564	pink-footed goose	70	0	grass
6	07/04/2016	NK029595	pink-footed goose	500	0	grass
6	07/04/2016	NK033552	pink-footed goose	210	0	grass
6	07/04/2016	NK060604	Greenland white-fronted goose	2	1	grass
6	07/04/2016	NK060604	pink-footed goose	440	1	grass
6	07/04/2016	NK060614	pink-footed goose	400	0	grass
6	07/04/2016	NK063604	pink-footed goose	80	1	grass
7	12/04/2016	NJ954536	mute swan	21	0	arable crop
7	12/04/2016	NJ959534	mute swan	2	0	arable crop
7	12/04/2016	NK000545	pink-footed goose	700	0	grass
7	12/04/2016	NK004497	pink-footed goose	130	0	grass
7	12/04/2016	NK010548	pink-footed goose	50	0	grass
7	12/04/2016	NK010575	pink-footed goose	10	0	grass
7	12/04/2016	NK064559	pink-footed goose	260	0	grass
7	12/04/2016	NK073520	pink-footed goose	55	0	grass
7	12/04/2016	NK074525	pink-footed goose	350	0	grass
7	12/04/2016	NK080571	pink-footed goose	4	1	grass
7	12/04/2016	NK088555	pink-footed goose	130	1	grass
7	12/04/2016	NK092576	barnacle goose	8	1	grass
7	12/04/2016	NK092576	Greenland white-fronted goose	2	1	grass
7	12/04/2016	NK092576	pink-footed goose	640	1	grass
7	12/04/2016	NK093577	pink-footed goose	60	1	ploughed
7	12/04/2016	NK095573	pink-footed goose	70	1	grass
7	12/04/2016	NK096554	pink-footed goose	310	0	grass
7	12/04/2016	NK098571	barnacle goose	5	1	grass
7	12/04/2016	NK098571	pink-footed goose	550	1	grass
7	12/04/2016	NK105522	Greenland white-fronted goose	2	0	grass
7	12/04/2016	NK105522	pink-footed goose	350	0	grass
7	12/04/2016	NK107517	pink-footed goose	330	0	grass
7	14/04/2016	NJ937600	greylag goose	11	0	grass
7	14/04/2016	NJ937600	pink-footed goose	2	0	grass
7	14/04/2016	NK012571	pink-footed goose	50	0	grass
7	14/04/2016	NK045564	mute swan	1	0	grass
7	14/04/2016	NK054602	greylag goose	2	1	grass
7	14/04/2016	NK057615	pink-footed goose	1	1	grass

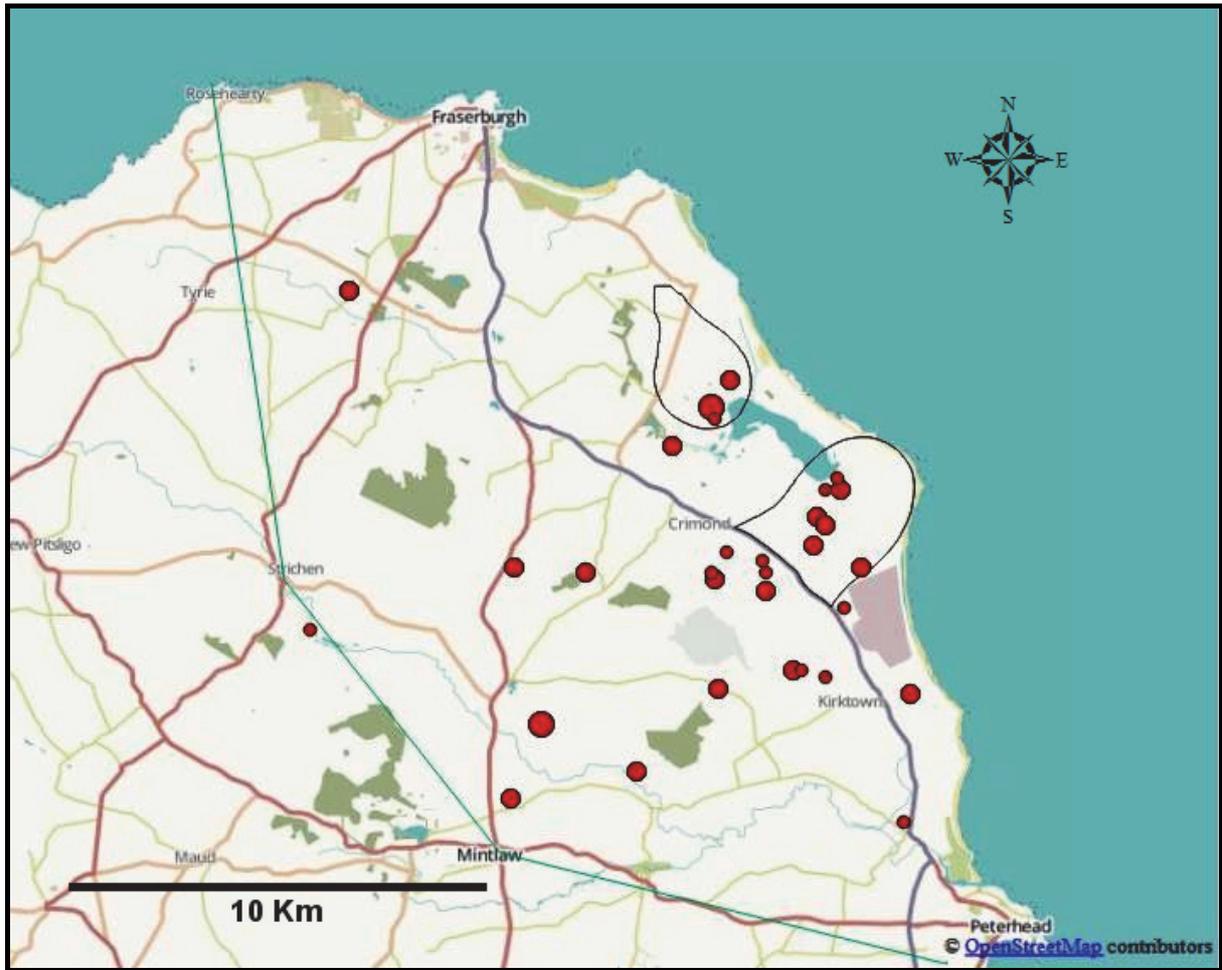
7	14/04/2016	NK060604	pink-footed goose	100	1	grass
8	21/04/2015	NJ955534	mute swan	9	0	winter cereal
8	21/04/2015	NJ955538	mute swan	11	0	winter cereal
8	21/04/2015	NK006515	pink-footed goose	1	0	winter cereal
8	21/04/2015	NK026493	pink-footed goose	80	0	grass
8	21/04/2015	NK097558	pink-footed goose	250	1	grass
8	21/04/2015	NK099564	pink-footed goose	150	1	grass
8	22/04/2015	NK021639	greylag goose	2	0	grass
8	22/04/2015	NK053594	pink-footed goose	1	1	grass
8	22/04/2015	NK055595	pink-footed goose	90	1	grass

ANNEX 2: MAPS OF WEEKLY GOOSE DISTRIBUTION DATA

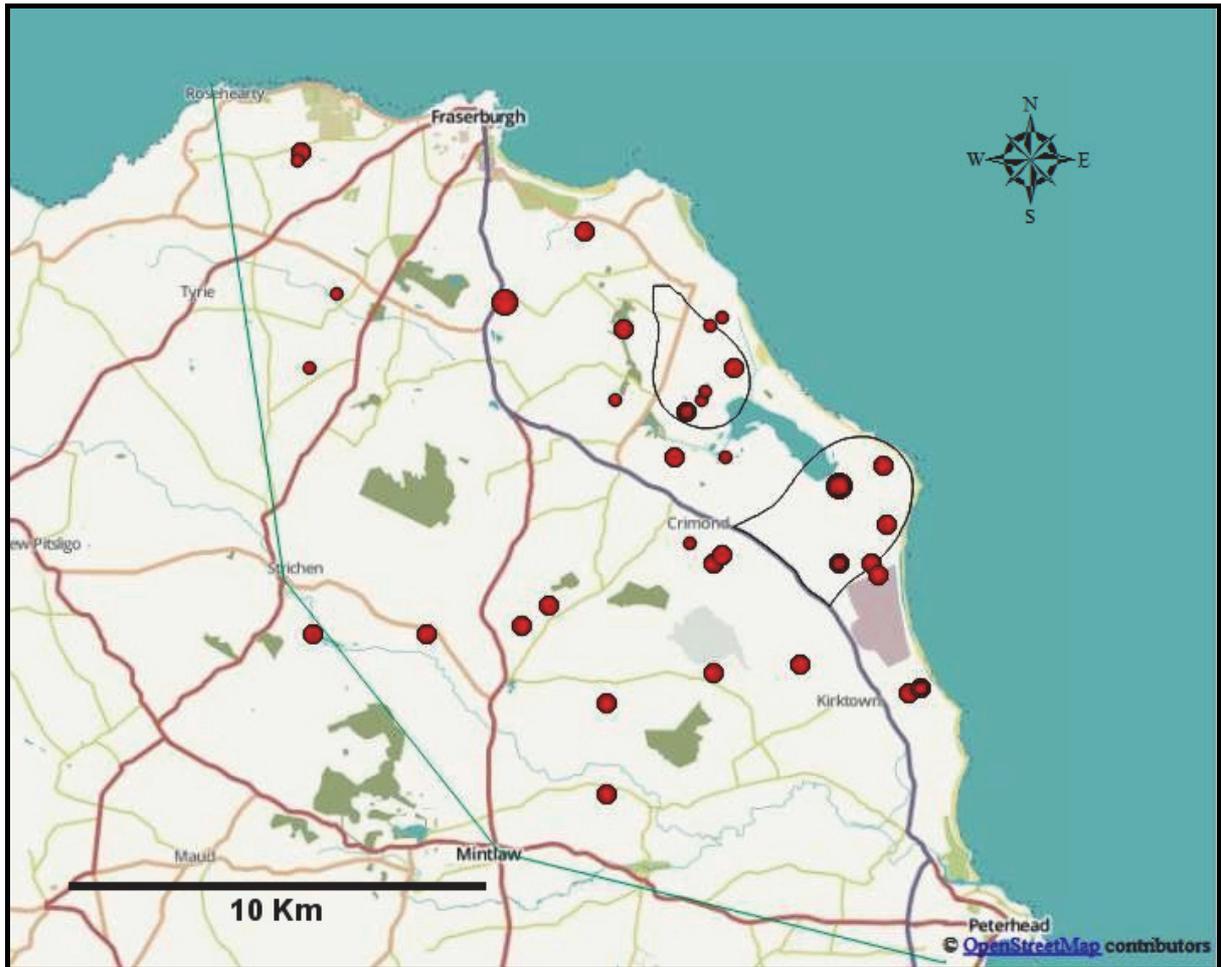
Distribution of goose flocks in weeks 1 to 8. Flocks are shown by red dots which are scaled such that small dots represents flocks of 1 to 100 birds, medium sized dots are flocks of 101 to 1000 birds and large dots are flocks of over 1000 birds.



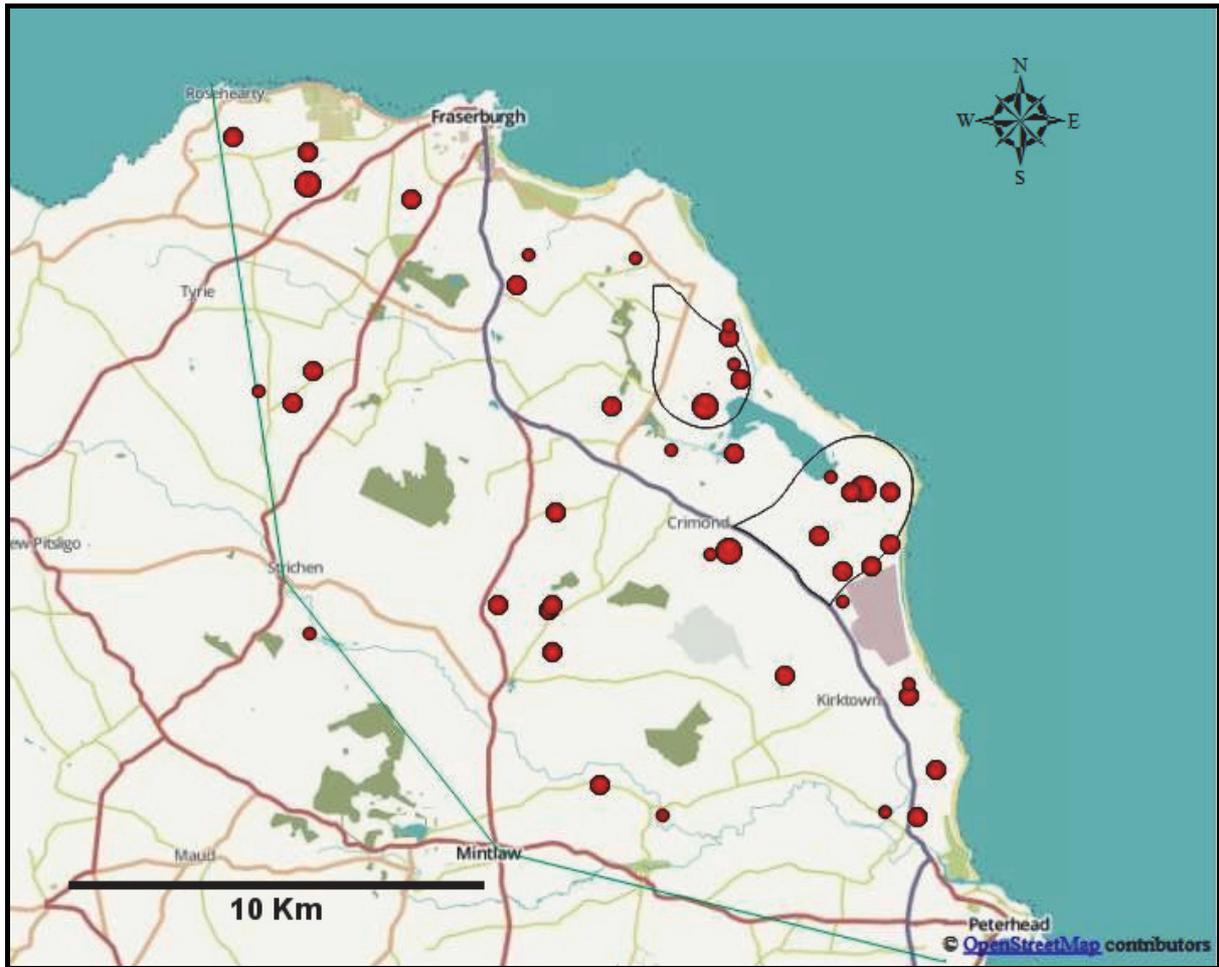
Annex 2, Map 1: Goose distribution in week 1.



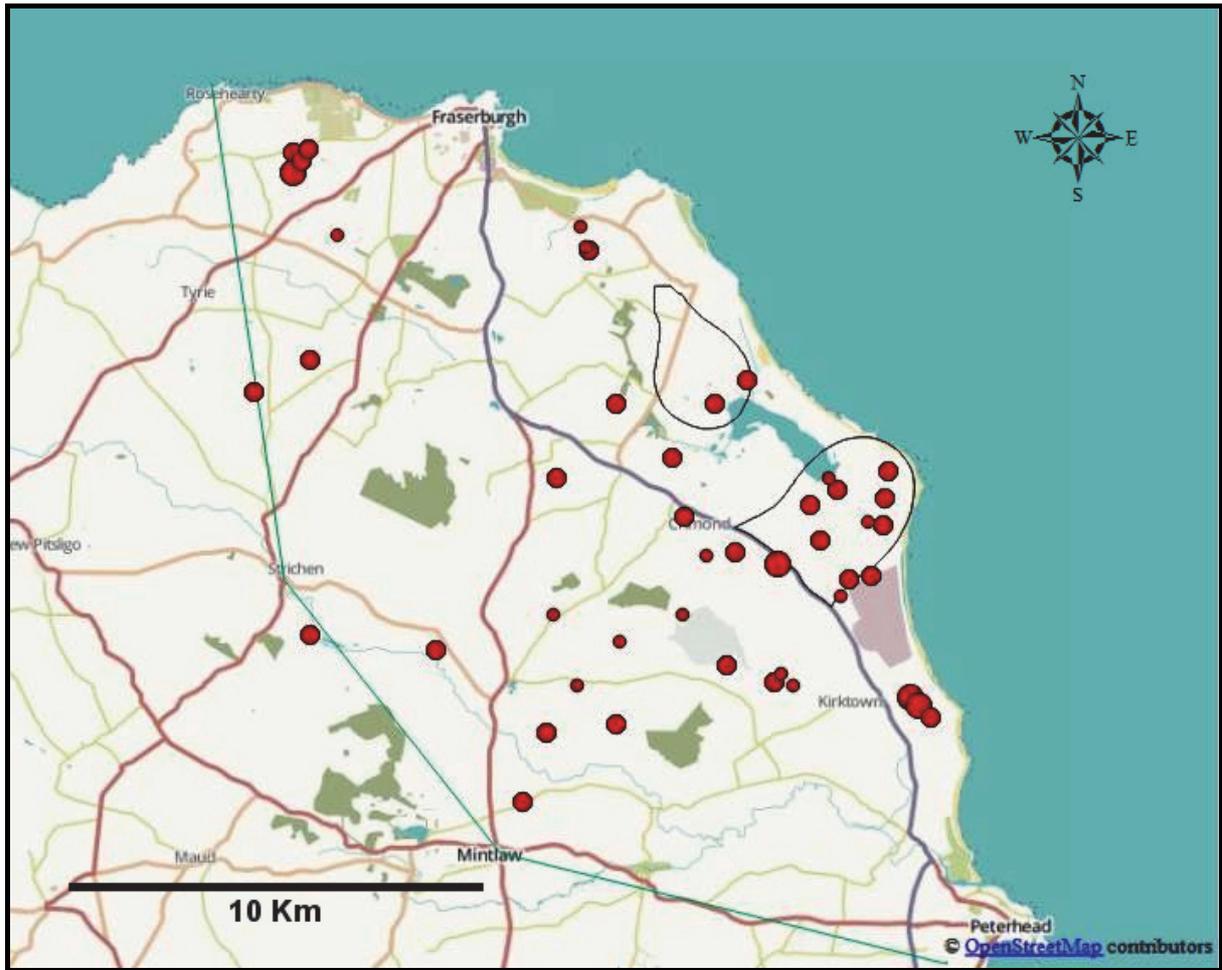
Annex 2, Map 2: Goose distribution in week 2.



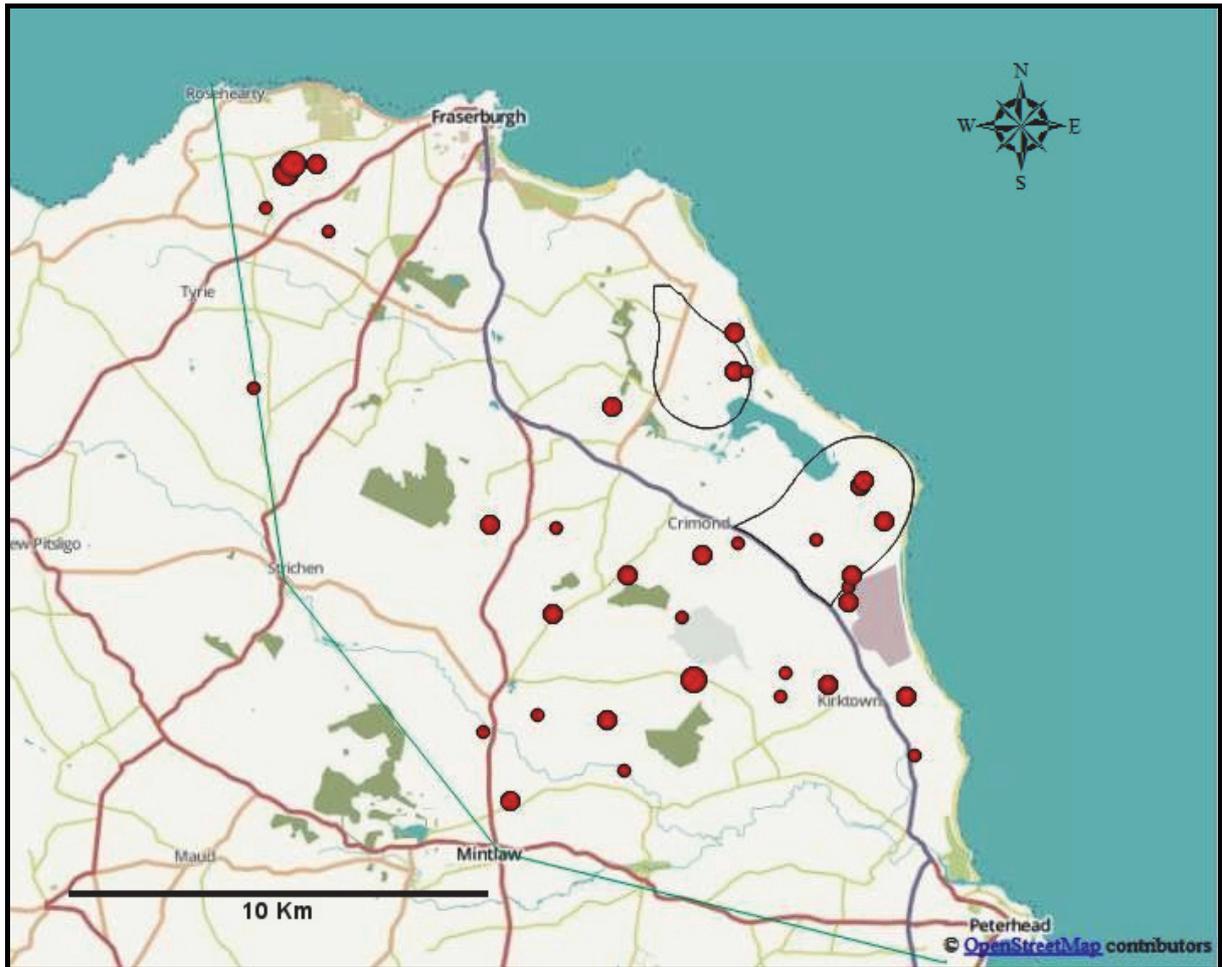
Annex 2, Map 3: Goose distribution in week 3.



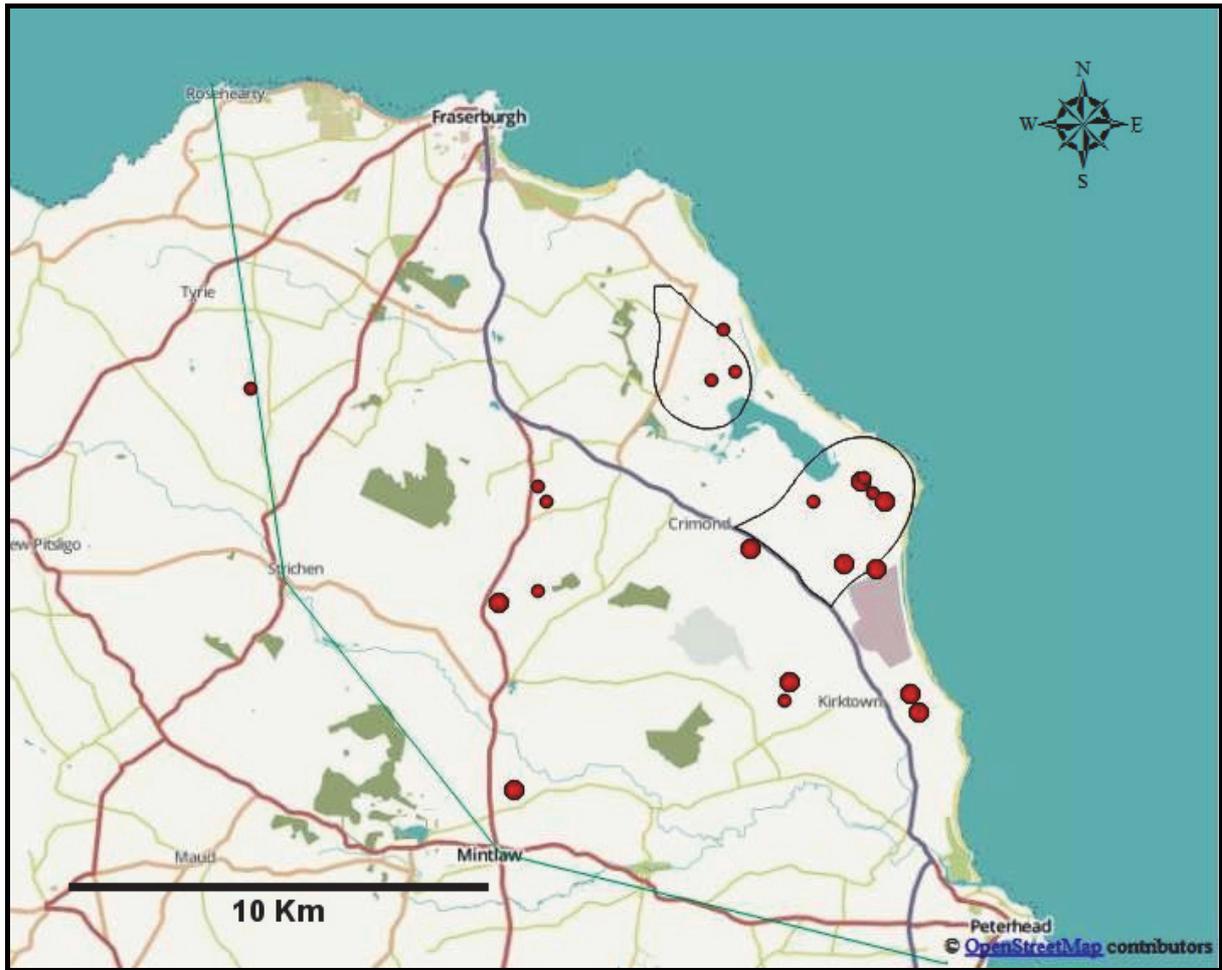
Annex 2, Map 4: Goose distribution in week 4.



Annex 2, Map 5: Goose distribution in week 5.



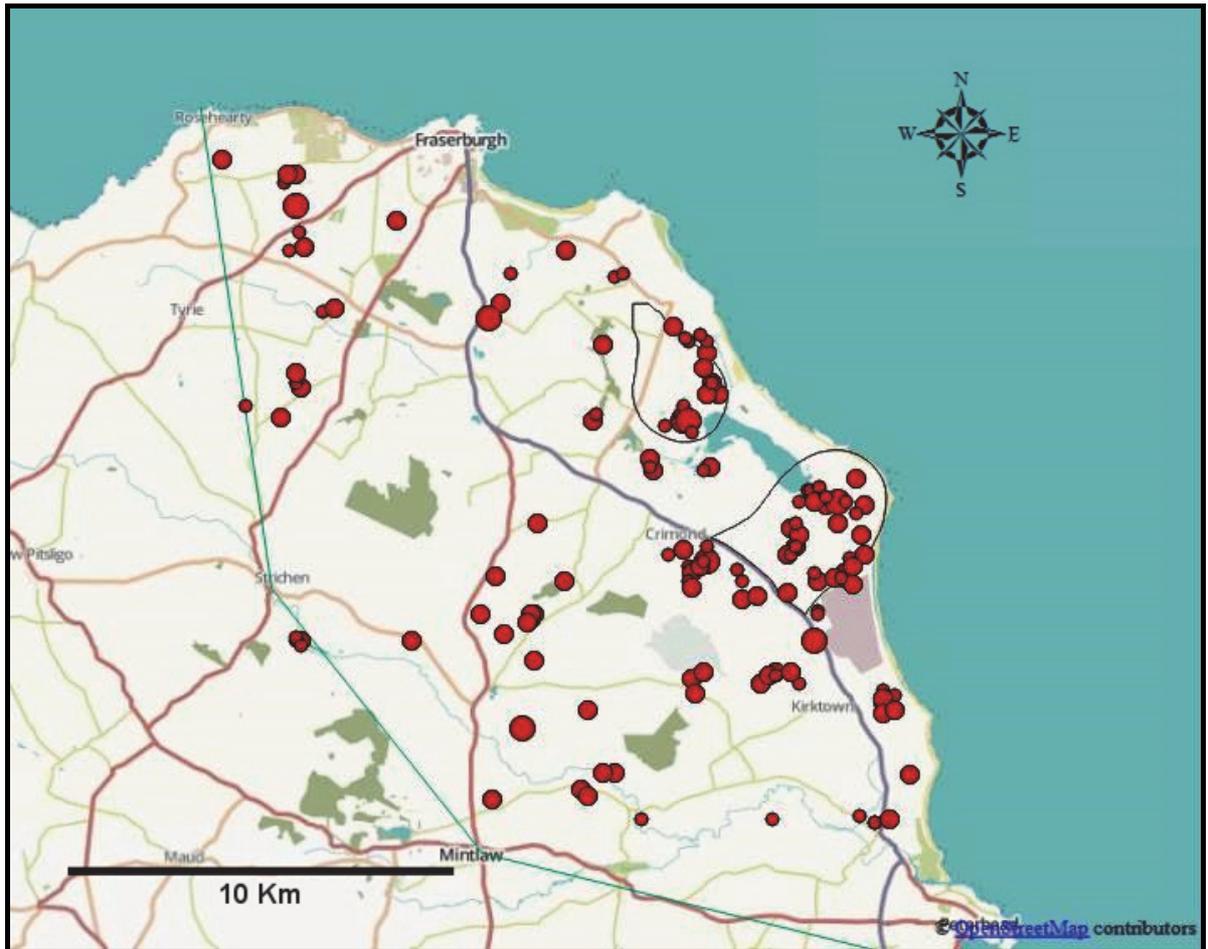
Annex 2, Map 6: Goose distribution in week 6.



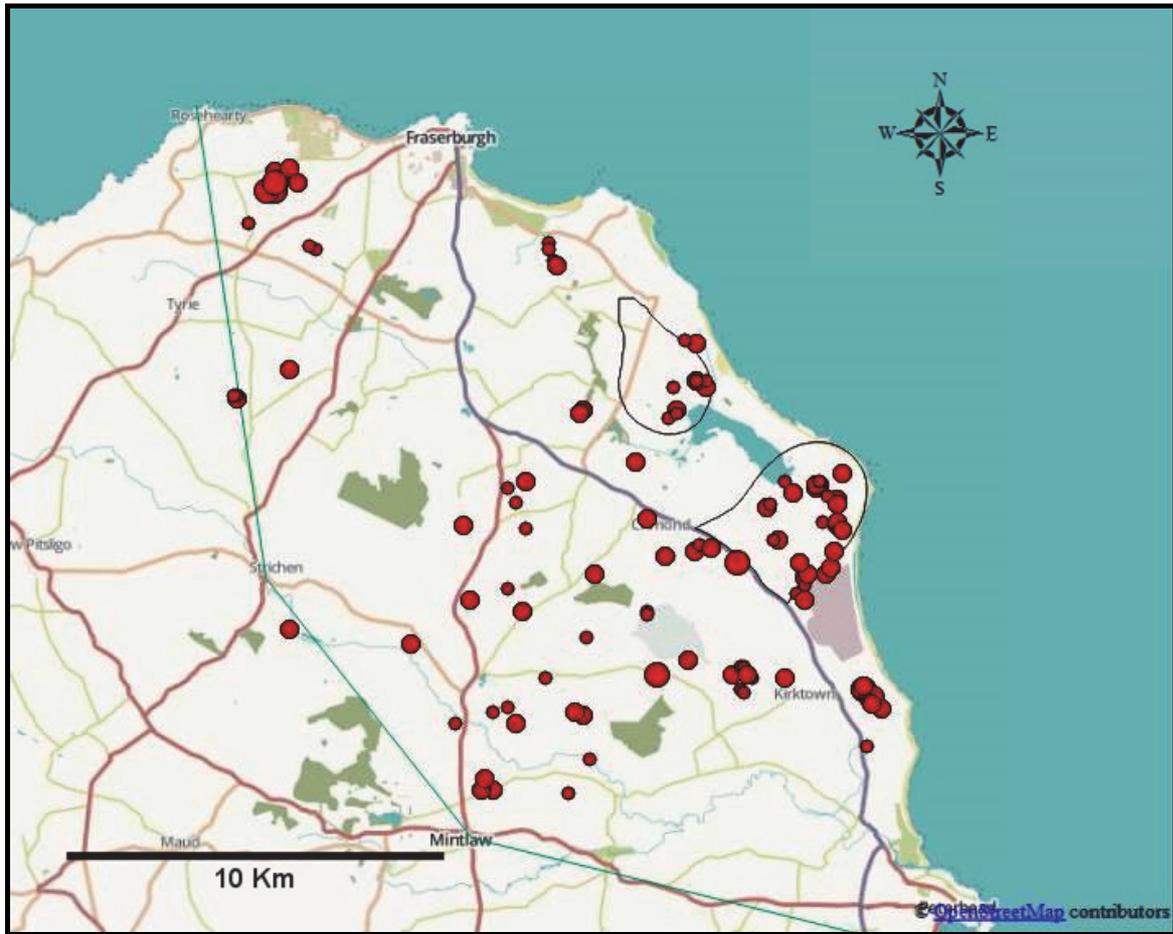
Annex 2, Map 7: Goose distribution in week 7.



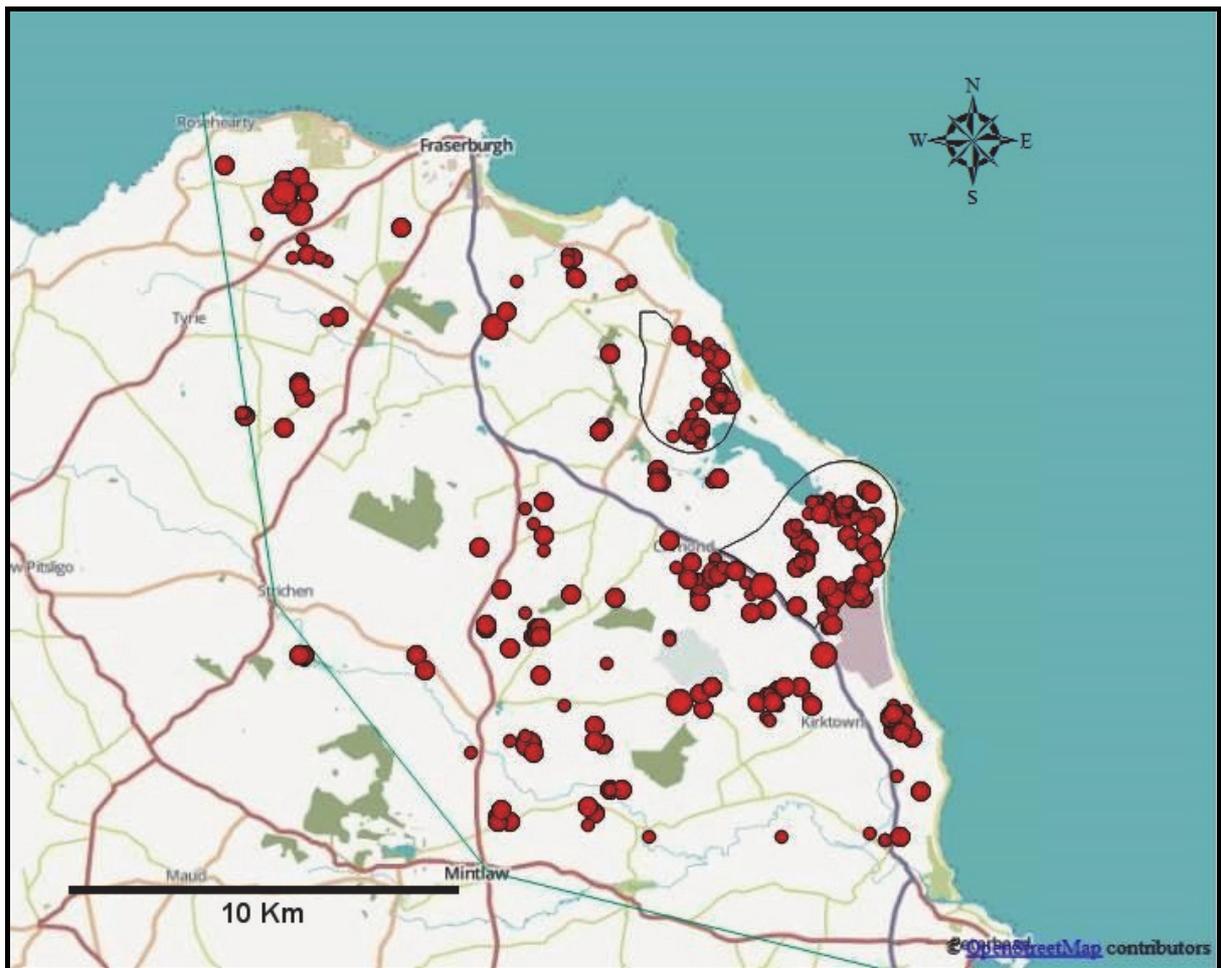
Annex 2, Map 8: Goose distribution in week 8.



Annex 2, Map 9: Goose distribution in weeks 1 to 4 combined.



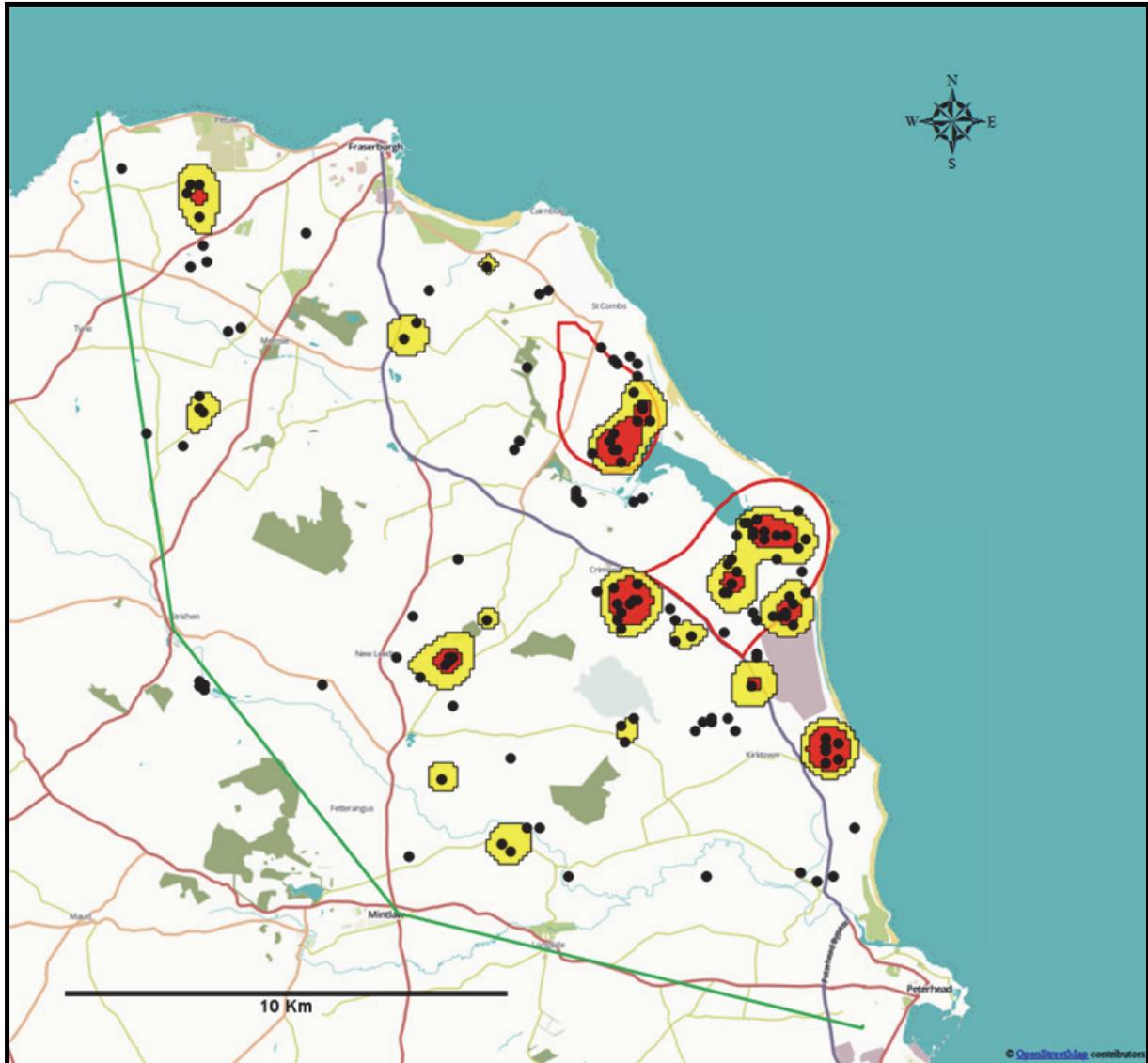
Annex 2, Map 10: Goose distribution in weeks 5 to 8 combined.



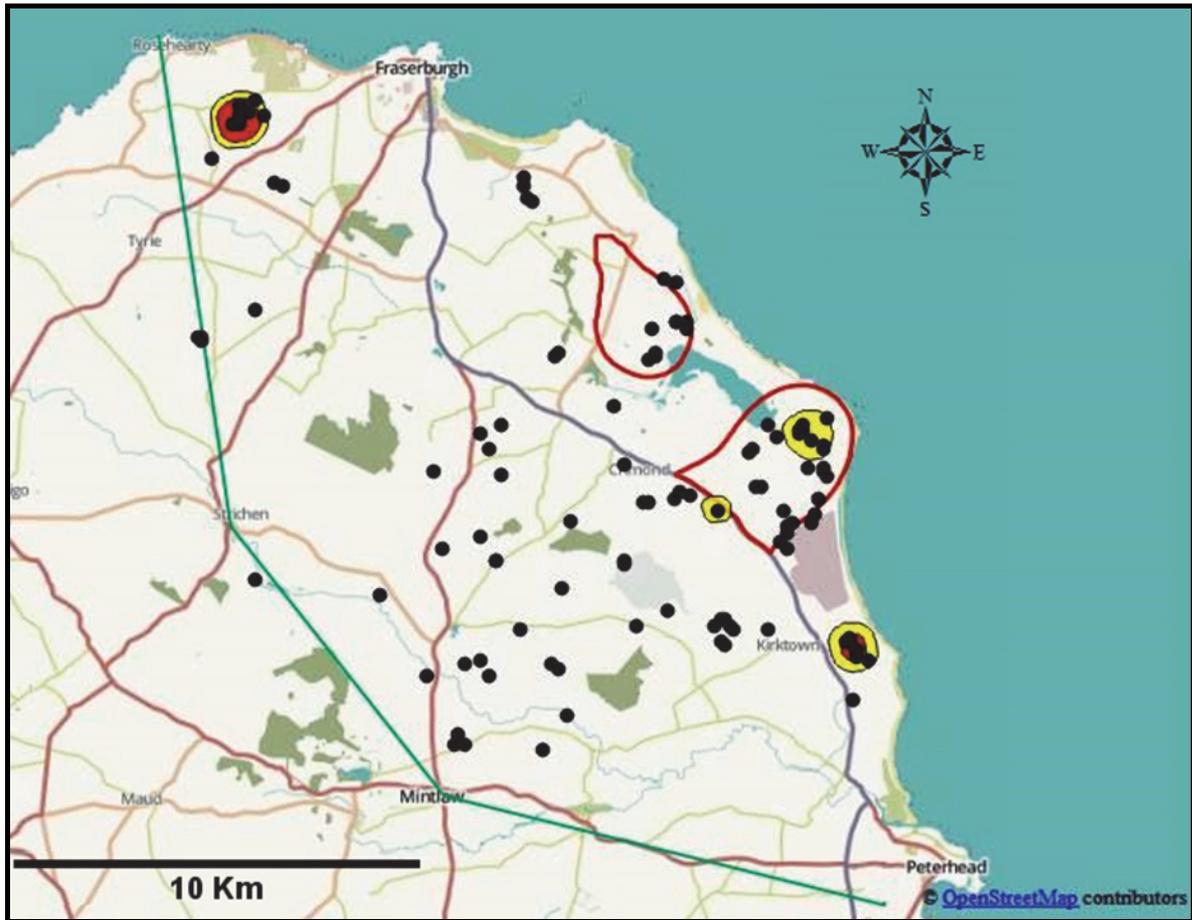
Annex 2, Map 11: Goose distribution in all weekly surveys combined.

ANNEX 3: KERNEL ANALYSIS OF GOOSE DISTRIBUTION DATA

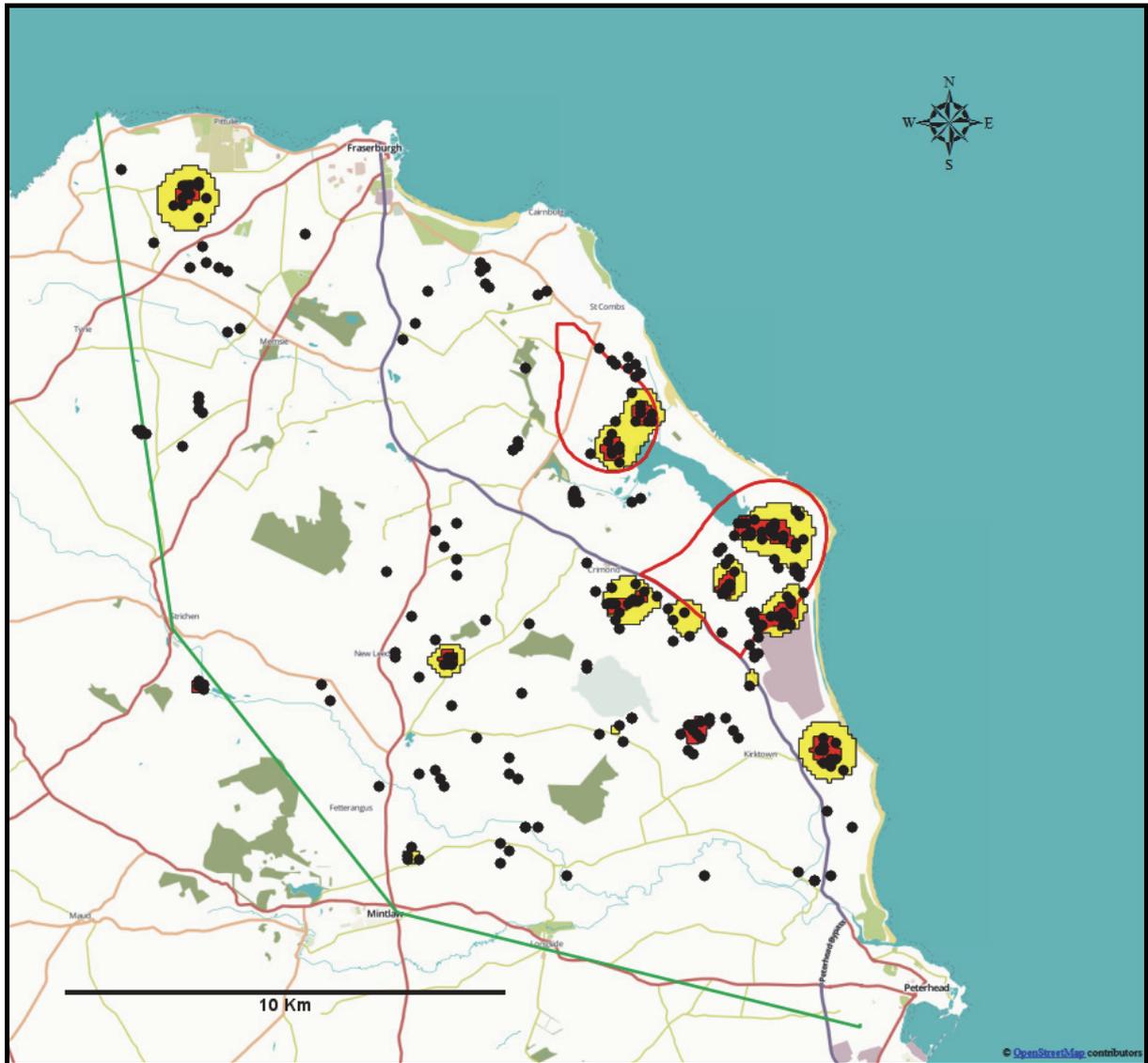
In the following maps, the dark red areas represent land occupied by 50% of the geese recorded whilst red and yellow areas combined cover land occupied by 75% of geese. Black dots show the locations of individual goose flocks and the goose management scheme boundaries are shown with red lines.



Annex 3, Map 1: Kernel analysis of goose distribution data from weeks 1 to 4.



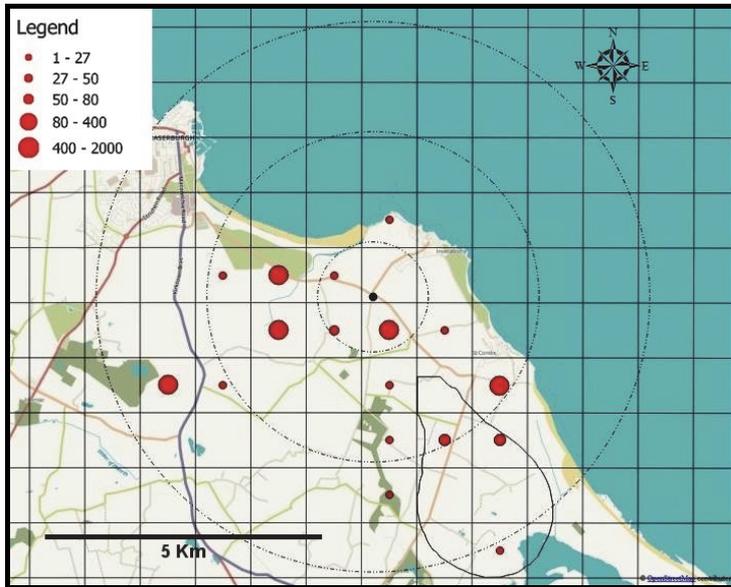
Annex 3, Map 2: Kernel analysis of goose distribution data from weeks 5 to 8.



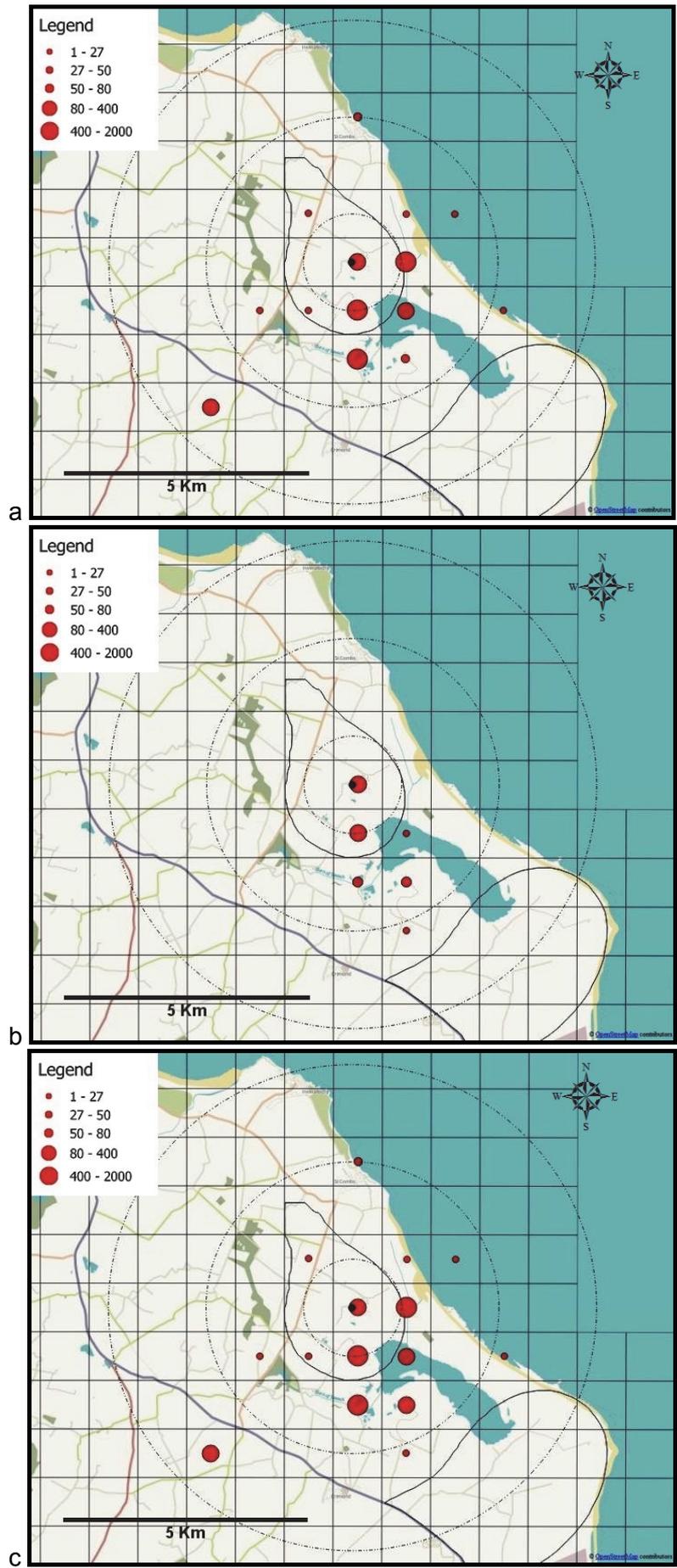
Annex 3, Map 3: Kernel analysis of goose distribution data from all weeks combined.

ANNEX 4: FLIGHT SURVEY MAPS

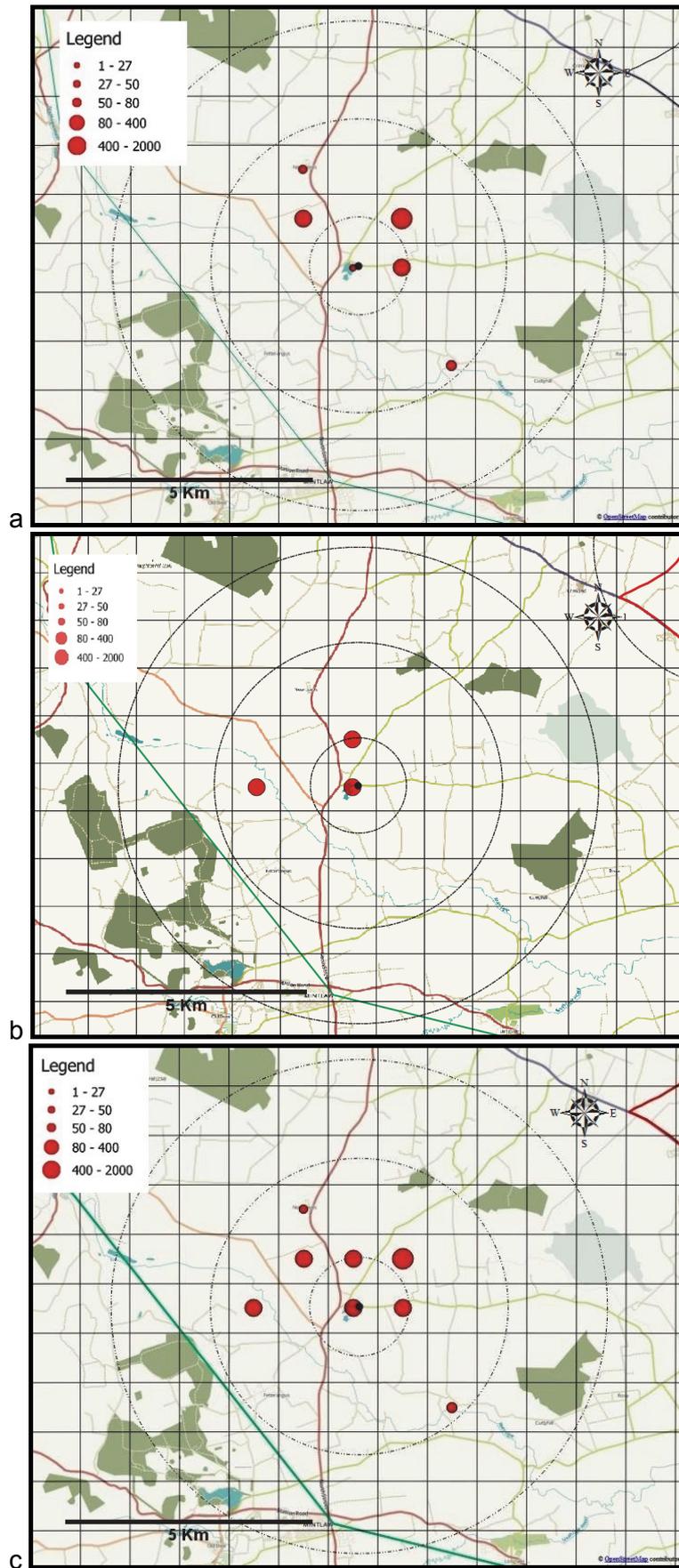
For each map, the symbols in each 1 km square are the sum across all eight visits of birds recorded in flight in that square. Each flock noted in flight was assigned to a single 1 km square, this being the closest to the observer over which the flock was observed to pass. This, along with declining detectability with increased distance, result in a centre-weighted bias to the maps. The circles show 1 km, 3 km and 5 km radii from the vantage point, shown at the centre with a black dot.



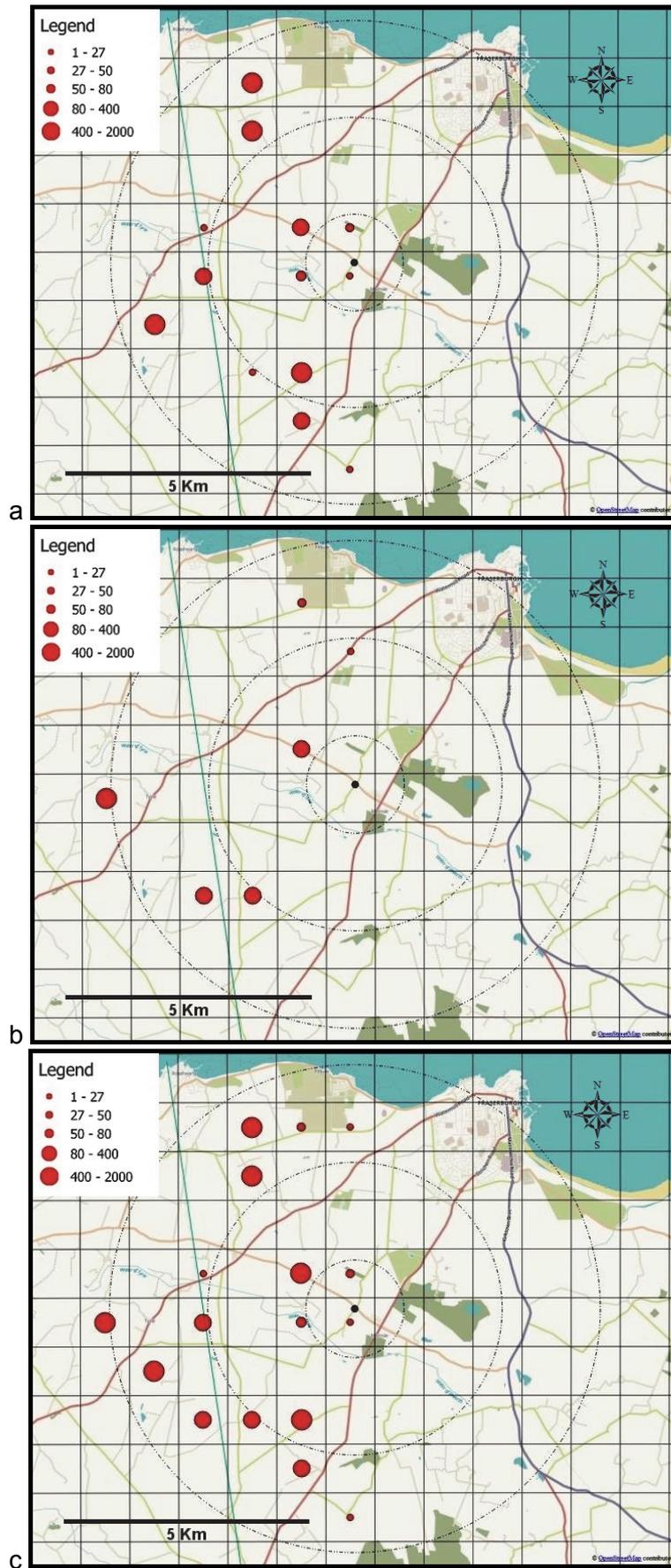
Annex 4, Map 1: Goose flight density recorded from the Cairnbulg vantage point. Note that no geese were noted in flight from this point during weeks 5 to 8 so the single map here shows both weeks 1 to 4 and all weeks combined.



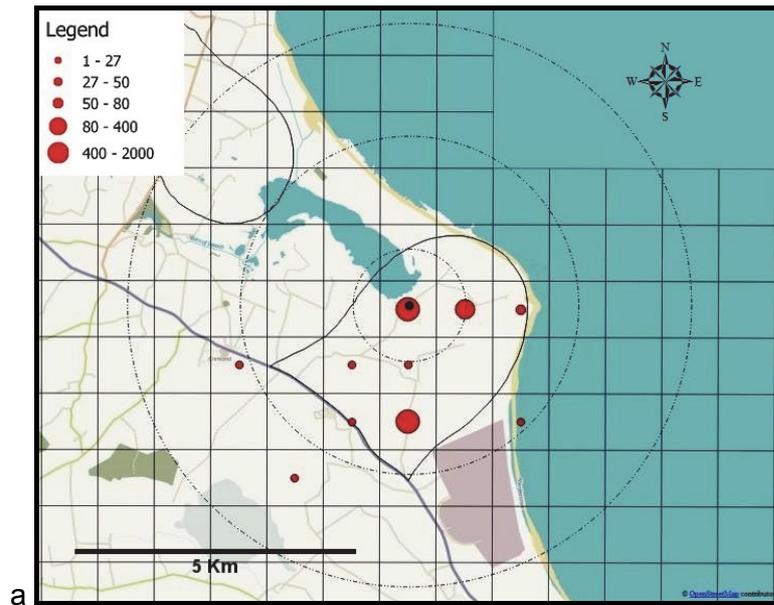
Annex 4, Map 2: Goose flight density recorded from the Coralhill vantage point displaying a, weeks 1 to 4, b, weeks 5 to 8 and c, all weeks combined.



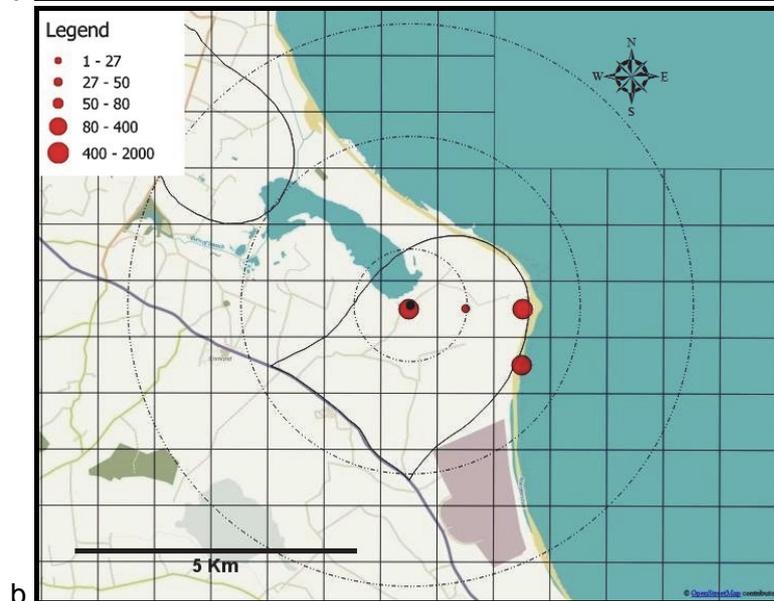
Annex 4, Map 3: Goose flight density recorded from the Kirkhill vantage point displaying a, weeks 1 to 4, b, weeks 5 to 8 and c, all weeks combined.



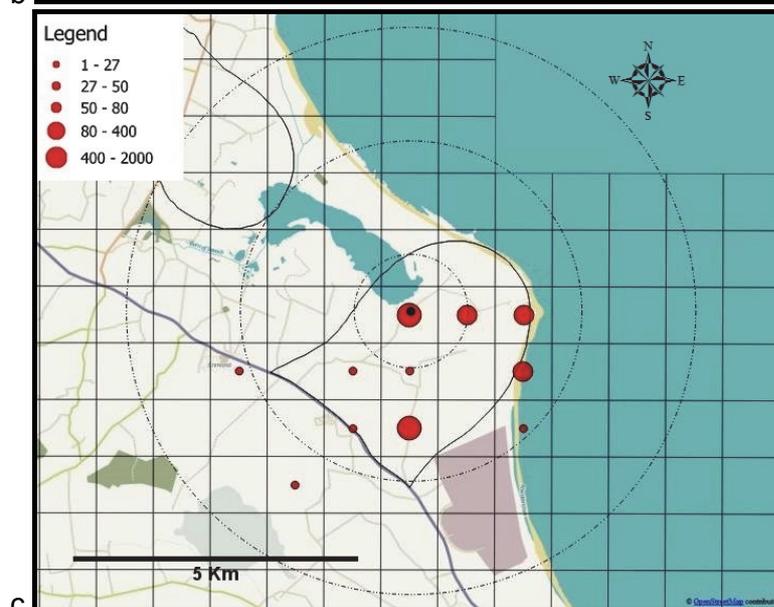
Annex 4, Map 4: Goose flight density recorded from the Memsie vantage point displaying a, weeks 1 to 4, b, weeks 5 to 8 and c, all weeks combined.



a



b



c

Annex 4, Map 5: Goose flight density recorded from the Rattray vantage point displaying a, weeks 1 to 4, b, weeks 5 to 8 and c, all weeks combined.



Annex 4, Map 6: Goose flight density recorded from the St Fergus vantage point displaying a, weeks 1 to 4, b, weeks 5 to 8 and c, all weeks combined.

ANNEX 5: VIEWSHED ANALYSIS MAPS

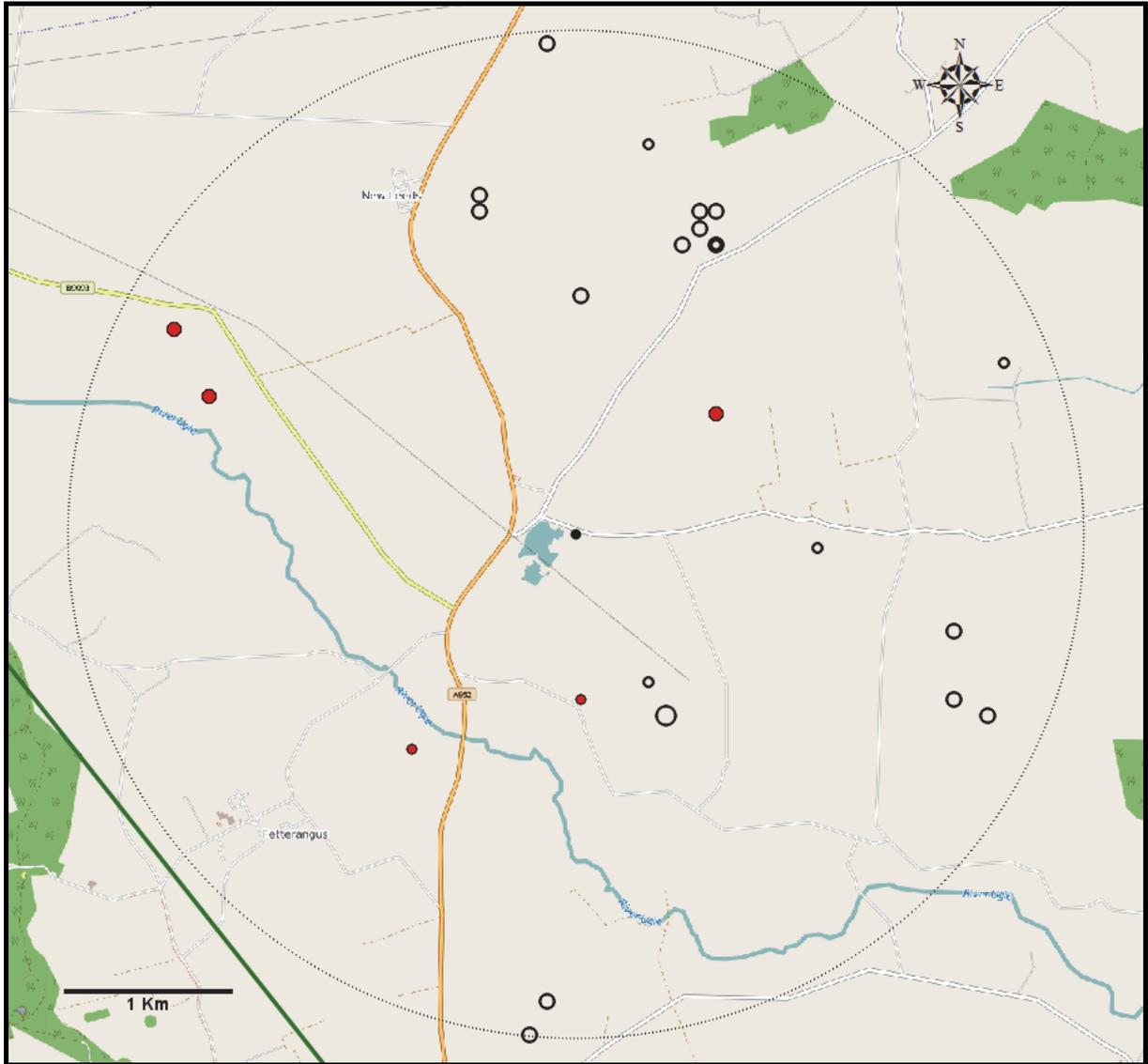
Each map shows goose flocks recorded during the distribution survey of geese in fields, within 3 km of the vantage points used for the flight survey. Symbols are shown with solid red circles if the viewshed analysis indicated that the flock would be visible on the ground from the vantage point used, and with open black circles if ground topography would mean that the flock would not be visible. Small symbols represent flocks of up to 100 birds, medium sized symbols are flocks of 101 to 1000 birds and large symbols are flocks of over 1000 birds. The vantage point itself is marked in the centre with a black dot and the large circle shows the 3 km radius. Dark red lines in maps 1, 2, 5 and 6 show the goose management scheme boundary. Straight green lines in maps 3 and 4 show the outer boundary of the survey area.



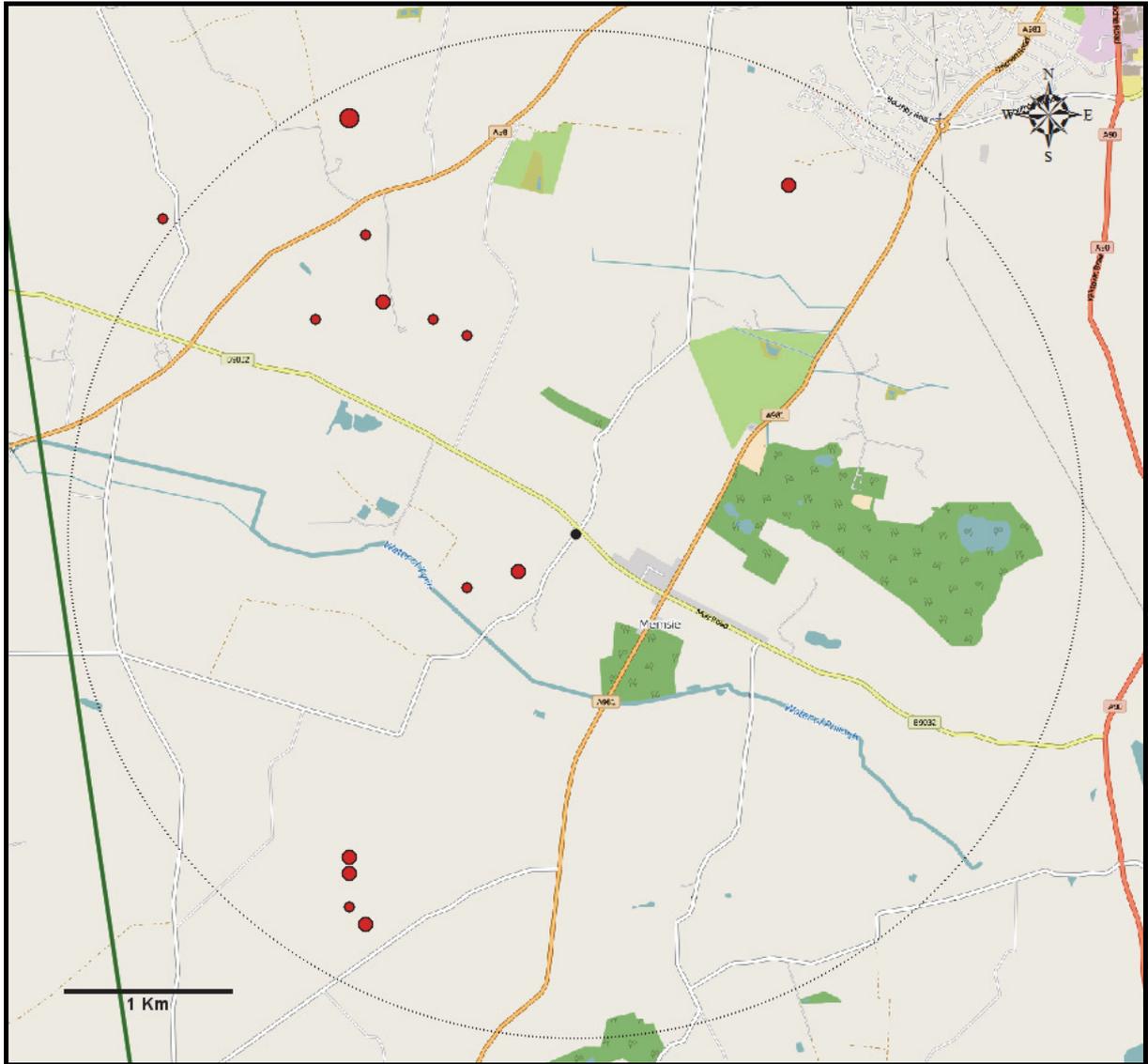
Annex 5, Map 1: Cairnbulg.



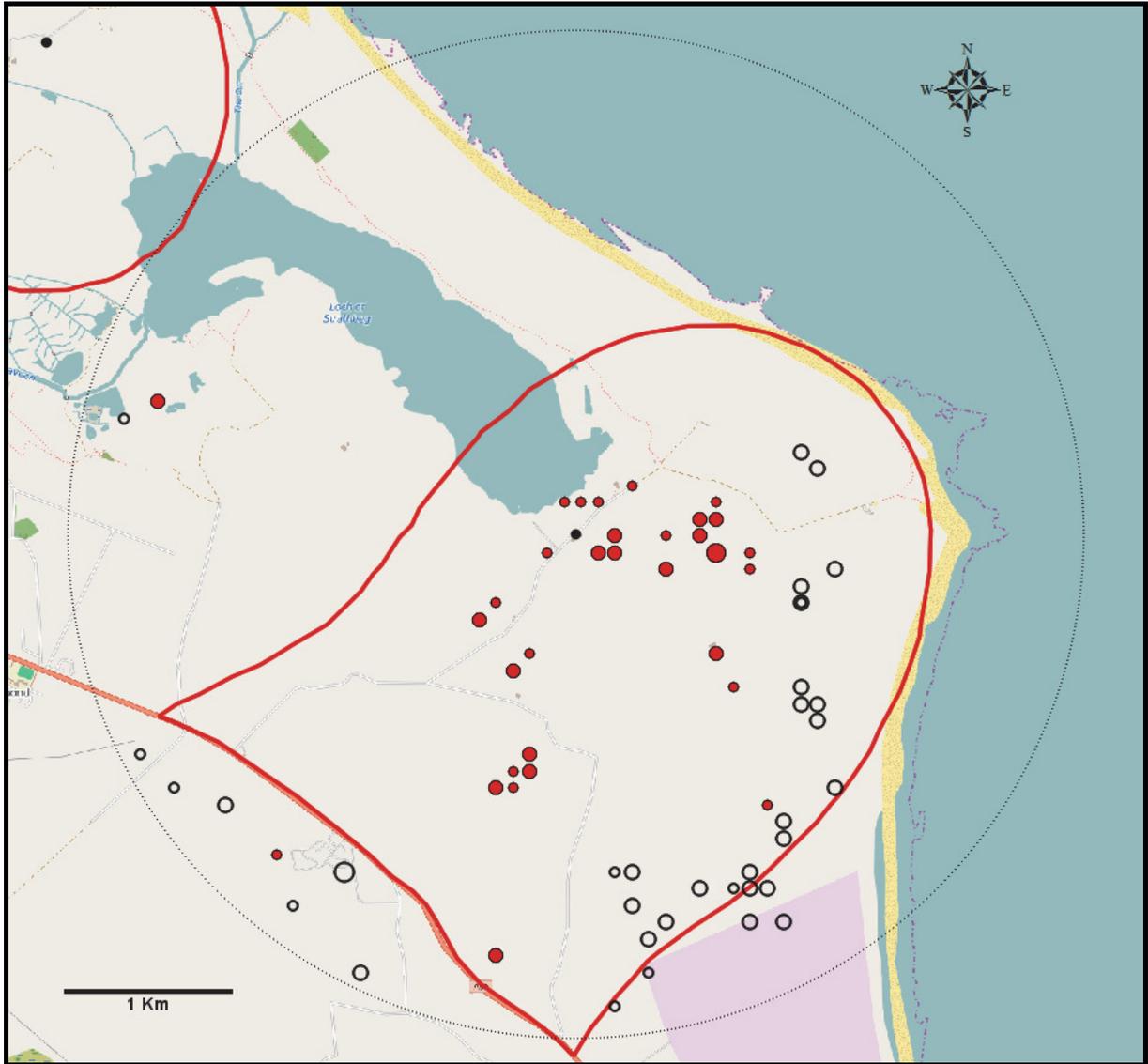
Annex 5, Map 2: Coralhill.



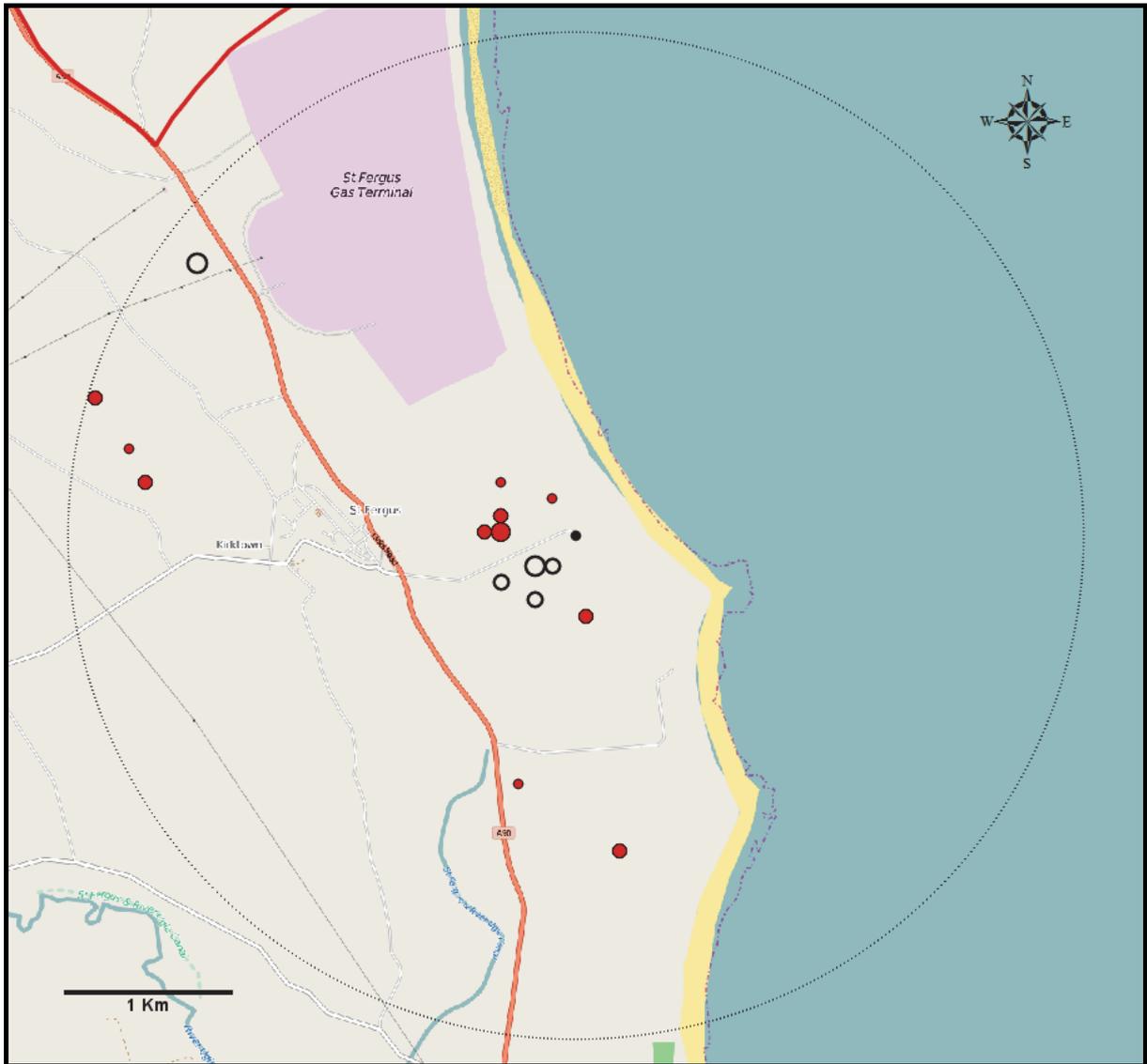
Annex 5, Map 3: Kirkhill.



Annex 5, Map 4: Memsie.



Annex 5, Map 5: Rattray.



Annex 5, Map 6: St Fergus.

ANNEX 6: FLIGHT SURVEY WEATHER

In all cases, visibility was good or excellent (at least 5 km).

vantage point	week	wind direction	wind speed (Beaufort)	cloud cover (eights)	precipitation
Cairnbulg	1	NNW	3	7	rain during 70%
	2	SSW	2	1	none
	3	NNW	3	8	none
	4	S	4	1	none
	5	ESE	1	4	none
	6	WNW	4	8	light rain during 70%
	7	NNW	3	7	none
	8	N	3	4	none
Coralhill	1	NNW	3	4	showers during 15%
	2	S	3	2	none
	3	NNW	2	8	none
	4	S	3	2	none
	5	SE	2	7	none
	6	N	4	4	none
	7	NNE	2	8	none
	8	NNE	3	6	none
Kirkhill	1	WSW	3	0	none
	2	S	4	8	steady light rain
	3	WNW	<1	1	none
	4	S	4	1	none
	5	S	3	1	none
	6	NW	3	8	occasional spots
	7	ENE	4	2	none
	8	NW	3	2	none
Memsie	1	NW	2	1	none
	2	SW	2	1	none
	3	NW	2	8	none
	4	S	1-3	6	none
	5	WSW	2	3	none
	6	NNW	2	5	none
	7	NW	2	7	none
	8	NW	3	5	none
Ratray	1	WSW	1	7	spots during 2nd half
	2	SSW	4	8	dry
	3	E	1-2	1	none
	4	SW	3	1	none

	5	S	2	2	none
	6	NW	4	8	none
	7	NE	4	7	none
	8	NW	4	7	light rain during 25%
St Fergus	1	WNW	4	7	none
	2	SSW	4	8	spots for 15 mins
	3	ENE	1	1	none
	4	SW	3	8	none
	5	S	2	2	none
	6	NW	2	8	light rain during 80%
	7	E	3	7	none
	8	NNW	3	5	none

ANNEX 7: DISTURBANCE EVENTS NOTED DURING FLIGHT SURVEY

All potential disturbance events noted during vantage point flight surveys are listed below along with associated goose movements if any. Regular agricultural activities, such as tractor movements, were not noted unless any disturbance to geese was seen to occur.

Week 2, Kirkhill: Bangs (possibly gas gun) twice each at 16.22, 16.26, 16.31 and 16.35, to the NW.

Week 2, Memsie: Several bangs (c.10) at 11.02 distantly to the south.

Week 2, Coralhill: Two bangs (probably shotgun) to the west at 15.47.

Week 3, Kirkhill: Bangs (shotgun or gas guns) heard occasionally (c. 5 minute intervals) from three directions.

Week 3, Rattray: Single bang heard at 13.17 to the south.

Week 3, Coralhill: Three bangs at 10.54 to the south-west.

Week 4, St Fergus: Tractor pulled into field and caused a flock of c.400 birds to take off, fly for c.200 m and land in different field (included in flight survey data). Also, two bangs heard distantly to the south.

Week 4, Coralhill: Two distant bangs at 13.50 to the west.

Week 5, St Fergus: Van turned in field entrance and caused small lift of birds that came straight back down in same flock (not included in flight survey data).

Week 7, Kirkhill: Four bangs to the north at 09.59.

Week 7, Coralhill: Light aircraft flying over caused c.180 birds to lift and then land in different field after short flight (included in flight survey data).

Week 7, Memsie: Bangs at 15.36, 15.42 and 16.01.

Week 8, Kirkhill: Five bangs at 13.38 to the north.

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