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Humber Gateway: Bird Detection Radar Pink-footed Goose Monitoring Autumn 2015

Commissioned by the Institute of Estuarine and Coastal Studies
on behalf of E.ON HGL

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Animal & Plant Health Agency

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Executive Summary

1. The Animal and Plant Health Agency (APHA) was commissioned by the Institute of Estuarine and Coastal Studies, on behalf of E.ON Humber Gateway Limited, to monitor the 2015 autumn passage and flight activity associated with migrating Pink-footed geese through the Humber Gateway Wind Farm and to compare this data with pre-construction data from a comparable 2012 study.

2. A bird detecting radar unit was sited near Southfield Farm along Spurn Road, Kilnsea (grid reference: TA416155) and the range was set to include the whole of the Humber Gateway Wind Farm development footprint.

3. Continuous radar surveys to cover the autumn migration period were carried out between 14 September and 20 November 2015 (68 days). The surveys were combined with visual observations undertaken by radar ornithologists for 7 hours each day, during daylight hours, providing a total of 476 observational hours.

4. Data was collected for Pink-footed geese exclusively. A total of 312 goose tracks were detected by radar, of which 117 were matched with visual observations (groundtruthed). Information on flight altitude was collected for 105 flocks.

5. The 117 goose tracks that were groundtruthed accounted for 5159 Pink-footed geese. The mean flock size was 45.1 birds (range 2-200).

6. Movements of Pink-footed geese occurred in two main peaks: 25-27 September (63 tracks) and 31 October – 21 November (230 tracks).

7. Pink-footed goose daily activity was fairly evenly distributed with peak movements between 10:00 and 20:00 GMT.

8. The majority of geese were recorded flying offshore (282 tracks), with only 30 tracks recorded inland.

9. There were fewer goose tracks within the wind farm footprint than in the pre-construction 2012 study (2.6% in 2015, compared to 11.2% in 2012). This could indicate avoidance of the wind farm.

10. Eight goose tracks occurred within the wind farm footprint. Of these, only one flock was recorded as having a flight altitude within the rotor-swept zone (24-136 m) and two flocks were visually observed to gain altitude on approaching the wind farm and to fly above the turbines. Altitude data was not obtainable for the remaining five of the goose tracks detected as occurring within the wind farm footprint.

11. Of the goose flocks with associated altitude data, 48.6% flew within the rotor-swept zone, but only one of these was within the wind farm footprint.

12. Compared with data from 2012, goose flocks flew significantly closer to the coast and further from the wind farm footprint, which could indicate avoidance behaviour. This is consistent with the results of other, similar radar studies of Pink-footed geese at other wind farms (Plonczkier & Simms, 2012a).

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1. Introduction

1.1 Pink-footed goose (*Anser brachyrhynchus*)

1.1.1 Species background information

The Pink-footed geese (*Anser brachyrhynchus*) that winter in the United Kingdom come predominantly from the Iceland and Greenland population. This population has undergone a long-term increase from ~50,000 in 1960 to a current population size of approximately 393,000 (Mitchell, 2015), of which 90% winter in the UK. A more recent survey has confirmed an 18% increase in the UK wintering population between 2001/2 and 2011/12 (RSPB, 2014). Although the species is known to suffer huge mortality in harsh weather (WWT, 2012), the relatively mild winters of 2012-2015 would not be expected to interrupt the pattern of steady growth.
Pink-footed goose autumn and spring migratory movements normally occur between three major feeding areas in the UK: the east coast of Scotland; the Lancashire mosses; and north Norfolk. The main flocks from Iceland arrive in Scotland first, followed by movements down the east and west coasts of England. There is also a major flight path across the Pennines between Lancashire and Norfolk, which converges with the east coast flight path at the mouth of the Wash. Geese make temporary use of sites on the Solway Firth and the Humber Estuary, with birds diverting from the usual east coast route to reach the latter site.

1.1.2 Migration pattern observed in autumn 2015

October 2015 produced the highest ever recorded counts of Pink-footed geese at several of the main UK wintering sites, including 93,700 in a co-ordinated count on the Lancashire mosses (WWT, 2015), and 85,632 at the Montrose Basin.

The 2015 autumn migration of Pink-footed geese was clearly later than previous years. First arrival dates usually fall on the first week of September or last few days of August, with birds arriving almost simultaneously around the UK. However, in 2015, most arrivals were notably later, for example at WWT Martin Mere, where the first record was on 11 September compared to 30 August in 2012 (WWT, 2015). This is supported by BTO's analysis of their own BirdTrack data collated from thousands of casual observers, which shows the reporting rate in 2015 to be delayed by roughly a week compared with historical data (BTO, 2015). It is also supported by first sightings at five regular visible migration watch points (Long Nab, Flamborough Head, Spurn Point and Oxenhope in Yorkshire, and Winter Hill in Lancashire) which were on average 11.2 days later in 2015 than 2012 (Trektellen, 2015).

The subsequent main arrival was also delayed. For example, on 20 September 2015, the flock at WWT Martin Mere numbered only 700, compared to 8000 on the same date in 2014 and 12,000 in 2012.

It appears that in autumn 2015 a higher number of Pink-footed geese took the Pennines route to the Humber Estuary, as evidenced by the record count of 18,000 roosting at Whitton Sands and Reads Island on 19 October (WWT, 2015). A comparison of visible migration data from regularly watched sites in different years shows that in 2012, during the main migration period September-November, a total of 1850 geese were recorded past Long Nab in Yorkshire compared with 7100 in a similar period in 2015. Further south at Flamborough, 2600 were recorded in 2012 but only 1600 in 2015. Even further south at Spurn Point, 15,600 were recorded in 2012 but only 7100 in 2015 (Trektellen, 2015). The counts suggest that although the east coast flight path has increased since 2012, in 2015 around half the birds arriving from Scotland diverted overland in the Scarborough area, heading towards the middle of the Humber Estuary rather than continuing to Norfolk. This is supported by anecdotal reports of larger-than-usual movements of geese over inland areas of east Yorkshire in 2015. It is likely that from the Humber Estuary most of these geese would have taken a direct route towards Norfolk, thus passing beyond the range of the radar. The exceptional numbers on the Humber may be in part a consequence of a delayed departure to Norfolk. Regular visible migration counts at Holme Bird Observatory in north-west Norfolk recorded first arrival dates of 6 September in 2012 and 27 August in 2014 but, in 2015 the first geese were seen on 20 September, and by 2 October a total of 1,260 geese had arrived compared to 2750 by the same date in 2012. However, by December numbers in Norfolk appeared to have reached normal levels, with numbers of 10,000 being reported (Penny Clarke, 2015).

Between September and November 2015, most goose movements were concentrated on particular dates when weather conditions were favourable. The 25 and 26 September were particularly busy days around the UK, with 14,000 geese counted heading south-west on the coast of Angus, Scotland and 3100 nearby at Lintrathen, plus 2800 recorded south past Long Nab, Yorkshire and 1800 past Spurn Point. Then on 26 and 27 September, a total of 734 geese headed north-west past Winter Hill, Lancashire. It seemed likely the latter were Humber geese which had decided to continue to the Lancashire mosses (Trektellen, 2015).

Another busy period was 8 - 9 October, with 3,000 geese observed heading south-west near Aberdeen, 540 heading south-east past Winter Hill (towards Norfolk), 570 south past Spurn Point, and 1300 arriving off the sea in north-west Norfolk.

This was followed by a very quiet few weeks with minimal movements, until the first days of November. On 1 and 2 November, 3900 geese were counted heading south-east past Winter Hill towards Norfolk and 2700 were counted heading south past Long Nab. On 5 November 300 geese arrived off the sea at Holme, Norfolk. These counts correspond with a significant drop in the roost at WWT Martin Mere from 16,000 to 10,000 between 29 October and 3 November, and a major decline in the roost on the Humber (RSPB, 2015).

Totals for the visible migration sites show that Pink-footed goose migration was delayed in 2015. At Spurn Point, the monthly goose totals for September - November 2012 were fairly even: 5,212, 4,529 and 5,941. In 2015 the distribution was later: 2437, 1199, and 3456 and numbers were also lower.

Changes to normal flight path patterns are not entirely unexpected. Although Pink-footed geese demonstrate site fidelity, it has also been noted that they will adopt a flexible strategy in choosing feeding and roosting areas (Fox, 1994). One historic instance of changing flight path patterns occurred in 1955, when postponed ploughing in Lancashire (due to bad weather), combined with greater barley stubble availability in Scotland caused the geese to delay their departure for Norfolk. This does not seem to have been the case in 2015, when harvests and ploughing reportedly occurred at typical times. There is no obvious reason for the change, but the milder weather might have given the geese less incentive to migrate.

1.2 Background to the study

This species-specific radar monitoring was focussed on recording the flight activity of Pink-footed geese during autumn migration in 2015 as they passed through the area in the vicinity of the now fully energised Humber Gateway Wind Farm. A similar study was carried out during pre-construction in 2012 (Plonczkier & Simms, 2012b), and this report provides a comparison of the 2012 and 2015 findings.

1.3 Aims and objectives

The primary aim of this study was to track the movement and behaviour of migrating Pink-footed geese within the Humber Gateway Wind Farm site and its vicinity. The main objectives of the study were to:

- Tag Pink-footed goose tracks on the radar; record the number of birds in each flock, and estimate flight altitude;
- Provide information on how the numbers passing through or over the wind farm compare to the number of birds passing between the Humber Gateway site and the coast (near-shore area) and areas further west;
- Provide information on the flight altitudes of flocks and the proportion of these flying within the rotor-swept zone (24-136m);
- Provide information on the proportions of geese recorded in different months and at different times of the day/night; and
- Compare this data with the pre-construction data from 2012 and so analyse differences in flight patterns, if any.
- Establish whether a similar proportion of birds continue to fly through the wind farm during operation, or whether the birds demonstrate avoidance behaviour.

2. Methodology

2.1 Overview

The study used a Bird Detection Radar (BDR), combined with ornithological observations, to survey to movements of Pink-footed geese on autumn migration in and around the area of the Humber Gateway Wind Farm development. The study ran for ten weeks (68 days) between 14 September 2015 and 21 November 2015 and was timed to cover the peak migration period for Pink-footed geese migrating south along the north-east coast of England.

The survey area covered by the BDR was 12 nautical miles (22.2 km) across and included the whole of the Humber Gateway Wind Farm footprint and most of the Humber Estuary. The radar recorded the accurate locations of goose movements, while ornithological observers confirmed species, flock size, and flight altitude.

The survey methods and equipment used in this survey have previously been deployed to monitor Pink-footed goose migration along the English east coast (Simms et al., 2008, 2009, 2010, 2011), including at the Humber Gateway in 2012 (Plonczkier & Simms, 2012b). This work has been peer-reviewed and published (Plonczkier & Simms, 2012a) and is accepted by the Marine Management Organisation and Natural England as an appropriate survey methodology for monitoring offshore goose migration.

2.2 Bird Detection Radar unit

In its standard setup, the APHA Bird Detection Radar system (BDR) detects bird movements and other radar signal returns across for 24 hours per day as required. Radar data on bird movements can be collected during periods of darkness and low visibility and at distances beyond those at which visual observations are possible. The APHA BDR uses two JRC marine radars: the S-band radar antenna is set to detect birds in the horizontal plane, and the X-band radar antenna is set to detect birds in the vertical plane.

Radar returns are generated by potential targets, landscape features ('clutter') and randomly generated returns ('noise'). BDR returns are filtered using specially developed algorithms (MERLIN software developed by Detect Inc., Panama City, Florida, USA) that differentiate between potential bird targets and other returns, such as other flying objects, noise or clutter. Data on bird targets are automatically recorded to Microsoft Access databases. In addition, information provided by visual observations (e.g. on species and number of birds) can be added to the radar-recorded data (groundtruthing).

Recorded data on targets detected by the S-band radar provides information on the horizontal locations of those targets. The S-band surveillance radar usually covers an area with a radius of 11.1 km (6 nm). However, in 2010, APHA (then FERA) conducted a successful trial during which an offsetting technique was used to extend the range of goose detection offshore to approximately 14.8km (8 nm)(Simms et al., 2011). During this study, this offset was used to extend the range to 14.8 km to the east in order to include the whole of the Humber Gateway Wind Farm footprint, which extends between 8 and 14 km. The total are covered was 12 nm across (22.2 km).

The X-band radar scans above the unit through a narrow beam in an arc to 1.4 km (0.75 nautical miles, nm). Recorded data on targets detected by the X-band radar provides information on the altitudes of those targets.

The ranges used in this study are based upon the known radar performance characteristics and the radar cross-sections of individual birds (Eastwood, 1967; Rinehart 2004).

2.3 Study area

The BDR unit was situated in the same position as in the 2012 pre-construction study; on a slightly elevated point along the sea bank opposite Southfield Farm along Spurn road, Kilnsea (grid reference: TA 416155). The unit was positioned such that both radar antennae were at a height of approximately 4 m above ground level (approximately 8 m above sea level).

The lack of potential obstructions to the radar signal meant that this site gave the S-band radar a good location for detecting bird movements over the sea around the site of the Humber Gateway Wind Farm. The S-band radar was able to scan 360° around the BDR unit, with an offset range of 14.8km (8nm) to the east and 7.4 km (4nm) to the west. This meant that the entire footprint of the Humber Gateway Wind Farm was included within the S-band radar's range, as well as most of the Humber Estuary to the west, Spurn Point to the south, and over 14 km of coastline to the north. The S-band radar range also covered several nautical miles to the north and south of the wind farm (see Fig.1).

2.4 Radar data collection

Both S-band and X-band data were recorded 24 hours a day throughout the duration of the study. Information on targets detected by both radars was automatically stored to Microsoft Access databases.

The settings within the MERLIN software programme allow various parameters to be adjusted, depending on the study requirements. For this study, the same settings were used as in the 2012 pre-construction study (Plonczkier & Simms, 2012b). These included a strong filtering system to allow for long-distance tracking of relatively large targets. Although this aggressive screening filter does not record smaller targets, e.g. individual or small flocks of passerines, it does allow a high level of detection and continuous tracking of larger targets (notably waterfowl flocks). When tracks were groundtruthed, this data was added to the radar databases (see section 2.4.1).

In addition to the automated data acquisition by MERLIN software, real-time video of the S-band and X-band radar display screens were recorded throughout the study period. This allowed detailed analysis of the radar data once fieldwork had been completed, and the identification of goose tracks that were not observed (e.g. that occurred outside of field observation hours).

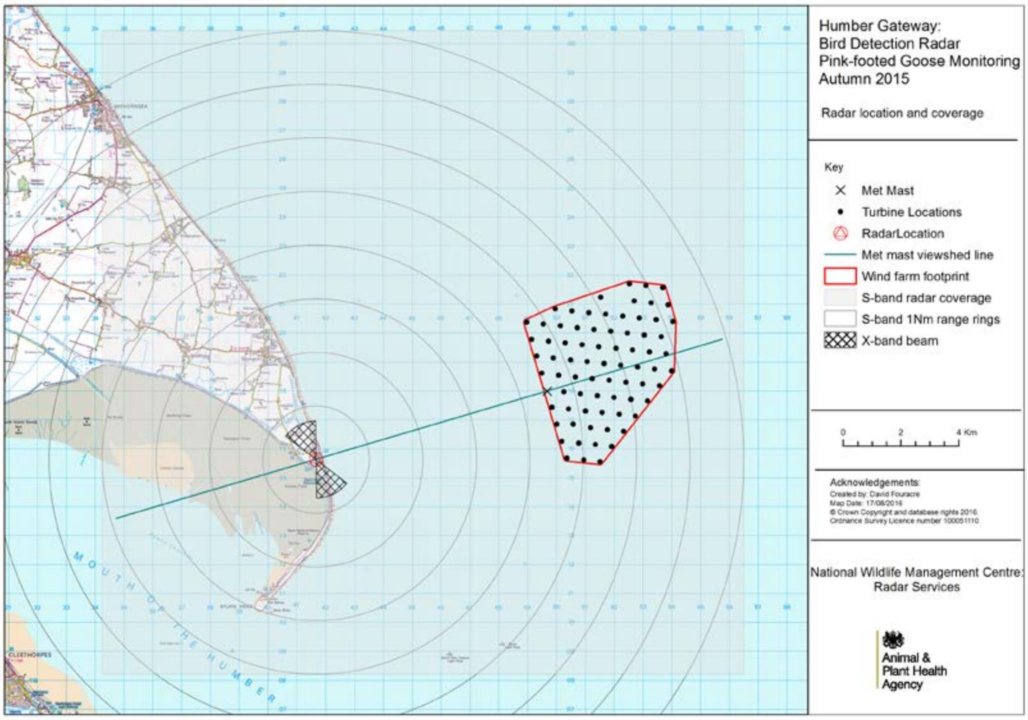

Figure 1. Map of the study area, including radar and wind farm locations and extent of radar coverage.

2.5 Ornithological field observations

2.4.1 Groundtruthing

Field observations were undertaken for seven hours each day by two APHA radar ornithologists: one manning and monitoring the live radar screens, and one carrying out detailed vantage point field monitoring synchronised with the radar deployment. The optical equipment used throughout the observation period included Leica 8x42 binoculars and a tripod-mounted Swarovski ATM65 HD telescope with 30x wide-angle eyepiece. Radar workers monitored radar display screens, looking for bird tracks, while field observers recorded species, flock size, estimated flight altitude and avoidance behaviour of the flocks responsible for the tracks initially detected by radar. Radar ornithologists swapped between the roles of radar monitoring and visual observations approximately every 3 hours in order to minimise observer fatigue. Radar workers and field observers were in constant communication with each other throughout observation periods. This allowed radar workers to inform field observers of the location of likely goose flocks before they came into view, and field observers to relay information on species and flock size to radar workers so that this information could be 'tagged' on the system. The process of associating field observation data (e.g. on species and flock size) with radar-recorded data on tracks is called groundtruthing.

Field observers were positioned with a view perpendicular to the coastline that included the whole of the Humber Gateway Wind Farm. Confirmed visual observations of Pink-footed geese were recorded, along with number of birds, estimated flight altitude, estimated distance from the observer, direction of flight, and any observed avoidance behaviour. This information was relayed to the radar worker, and any Pink-footed goose flocks that were recognised by MERLIN software were 'tagged' on the radar system. This 'tagging' associates all observed data with radar-recorded flight paths. Pink-footed goose flocks that were observed by ornithologists but not recognised by MERLIN software were still recorded, and these were identified later through analysis of the radar display videos based on noted locations, directions, and timings.

2.4.2 Estimation of flight altitude

Flight altitude of goose flocks were estimated by the observer as the geese crossed a transect line running from the radar to the meteorological mast (see Fig. 1). Altitude was assessed visually with reference to the wind turbine closest to the mast and recorded in multiples of turbine height. The exact distance of the flock from the radar at this point, as recorded by the radar, was then used to estimate actual flight altitude in metres, using the following formula:

$$B = ((M \times d) + o) \times e$$

Where:

B = the actual flight altitude of the bird

M = the slope of the line between the observer and the top of the reference turbine (i.e. the height of the top of the reference turbine/distance between the observer and the reference turbine)

d = the distance between the observer and the bird, as recorded by the S-band radar

o = the height of the observer's eye above sea level

e = the estimated flight altitude of the bird by the observer, in turbine heights

Figure 2 is a diagram to show how this formula was used, and Figure 3 shows a worked example. Because the field observer was always stood beside the radar unit, the distance between the radar and the bird, as recorded by the S-band radar, is equivalent to the distance between the observer and the bird. The distance between the observer and the reference turbine is also a constant (8km), as is the height of the top of the reference turbine (136m). M is therefore a constant for this study (136/8000 = 0.017). An average value for o (altitude of the observer's eye above sea level) of 5.1 m was used throughout. When a goose flock did not fly past the reference turbine (e.g. flocks that flew to the west of the radar location), altitude was estimated by the observer in metres.

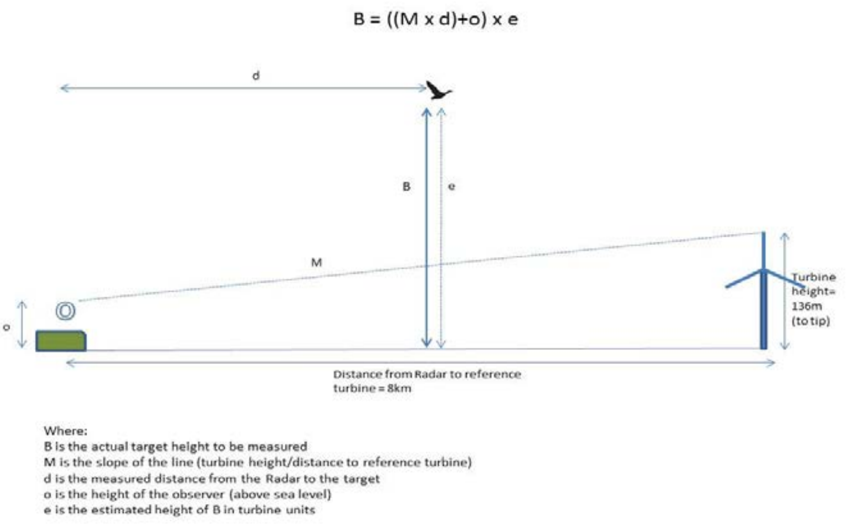

Figure 2. Diagram to show how the flight altitude calculation formula was used

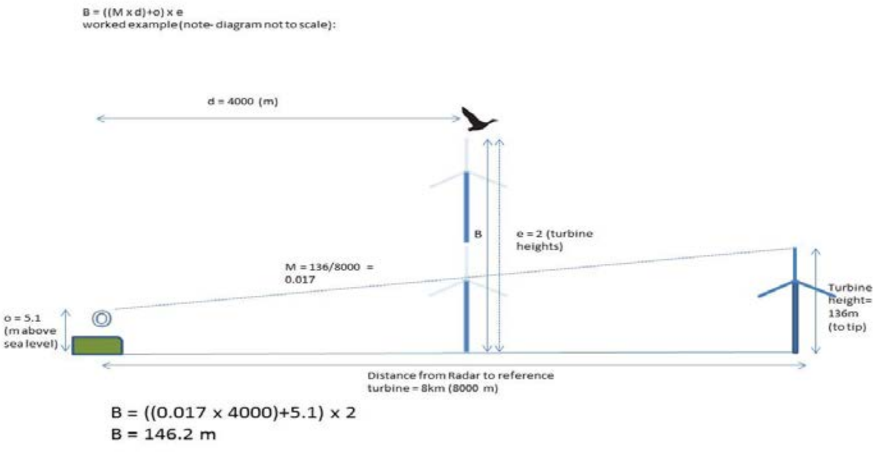

Figure 3. Diagram showing a worked example of the flight altitude calculation formula

2.6 Weather recording

Weather conditions were recorded continuously throughout the study period using an AIRMAR PB150 weather station (AIRMAR Technology Corporation, Milford, New Hampshire, USA) mounted on the radar trailer at 3 m above ground level. Parameters recorded included wind speed (metres per second) and direction, temperature (°C), and barometric pressure (bar). In addition, cloud cover (oktas), sea state (Beaufort scale), visibility (nm) and precipitation (presence/absence) were recorded visually by fieldworkers every 2 hours during the observation period.

2.7 Radar data analysis

Groundtruthed goose tracks were automatically recorded to S-band radar databases, along with associated observations. These could then be easily extracted and displayed in ArcGIS. In addition, the real-time videos of the S-band radar display screen that were recorded throughout the study period were used to identify goose tracks that occurred outside observation periods (e.g. at night). All identified goose tracks were then transcribed into a GIS platform using ArcGIS. Only radar tracks that were groundtruthed by observers were used to describe flight altitude and flock size.

2.7.1 Visual analysis of S-band data

The radar tracks produced by migrating goose flocks have a distinctive shape, speed, and flight pattern. Familiarity with the characteristics of these tracks and with those created by other species groups allows experienced radar ornithologists to identify likely goose tracks on the radar display screen. Goose tracks can therefore be identified both in the field before birds come into view and through retrospective visual analysis of recorded radar display screens. This therefore allows likely goose tracks to be identified for times that were outside of field observation hours (e.g. at night).

The real-time video recordings of the S-band radar display screen were reviewed for the entire study period by experienced ornithologists. Recordings were analysed using active video playback and any potential goose tracks were paused and examined frame by frame to enable positive identification. This process also allowed for the identification of tracks that were occasionally lost to the MERLIN software but still detected by the radar. The trajectories of these tracks and the fact that no other goose species were observed migrating in the same way during the study period means that these subsequently identified goose tracks can be assumed to have been made by Pink-footed geese, although there is a small chance that some may have been caused by other species.

2.7.2 X-band radar data

X-band data was recorded throughout the study period, as radar databases and real-time video recordings of the radar display screen. However, very few Pink-footed geese flew above the radar within the narrow X-band beam, so this data was not analysed for the report. Instead, visual estimates of flight altitude were used (see section 2.4.2).

2.8 Definitions of terms used

The following definitions apply throughout the report.

'Flock': A physical group of birds. In this report, all flocks discussed are flocks of flying Pink-footed geese.

'Track': A track is the visual representation of the data collected on the movements of a flying flock of birds by the radar. Tracks can be seen on the S-band radar display screen and data on tracks is automatically recorded to radar databases.

'Groundtruthing': The process by which ornithological field observers visually identify the birds that have been detected by the radar and then associate this data with radar-recorded data.

'Groundtruthed track': A radar track for which associated field observer data (e.g. on species, number of birds, and flight altitude) has been collected. Only tracks made by Pink-footed geese were groundtruthed for this study.

'Non-groundtruthed track': A radar track for which no associated field observer data has been collected, for example because it occurred outside of observation periods. In this report, the only non-groundtruthed tracks discussed are those that have been identified through analysis of radar data as likely Pink-footed goose tracks.

3. Results

3.1 Survey effort

Field surveys were carried out between 14 September and 21 November (see Table 1). Field observations took place during daylight between 08:00 and 15:00 hours (GMT) every day during the study period, providing a total of 476 hours of observation over 68 days. Radar data was collected from 09:00 on 14 September until 09:00 on 21 November, providing a total of 1483 hours of data collection over 68 days. Variation in the number of operational hours per week is a result of the radar being switched off to undertake necessary maintenance.

Table 1. Total hours survey effort for recording period 14 September – 21 November 2015

Period	Dates	Radar data	Visual observations
Week 1	14/09/15 - 21/09/15	122	49
Week 2	22/09/15 - 28/09/15	151.75	49
Week 3	29/09/15 - 05/10/15	144.25	49
Week 4	06/10/15 - 12/10/15	131.5	49
Week 5	13/10/15 - 19/10/15	137	49
Week 6	20/10/15 - 26/10/15	168	49
Week 7	27/10/15 – 02/11/15	168	49
Week 8	03/11/15 – 09/11/15	165.5	49
Week 9	10/11/15 – 16/11/15	166	49
Week 10	17/11/15 – 20/11/15	129	35
Total (hours)		1483	476

3.2 Weather

Temperatures remained relatively high throughout the study period, with an average daily temperature of 11.3°C and a maximum temperature of 23.5°C on 19 September (compared to an average of 9.5°C and a maximum of 18.4°C in 2012). The minimum temperature of 2.8°C was recorded on the night of 20 November.

The prevailing wind direction for each day of the study period was determined (to 8 pts). The prevailing wind directions for the study period were south-westerly and westerly (15 days each). There were 9 days when the prevailing wind was from the north-east, 4 days when the prevailing wind was from the south-east, and 3 days when the prevailing wind was from the east. Only one day (19 September) was recorded as having a prevailing wind from the north-west.

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Maximum wind speed was 24.6 m/s on 18 November and the minimum wind speed of 0 m/s occurred on several days, corresponding with a period of fog. Figures 4 - 6 show the daily mean temperature, wind speed and barometric pressure for the study period. Table 8 (in the Appendix) summarises the weather conditions for each day of the study period.

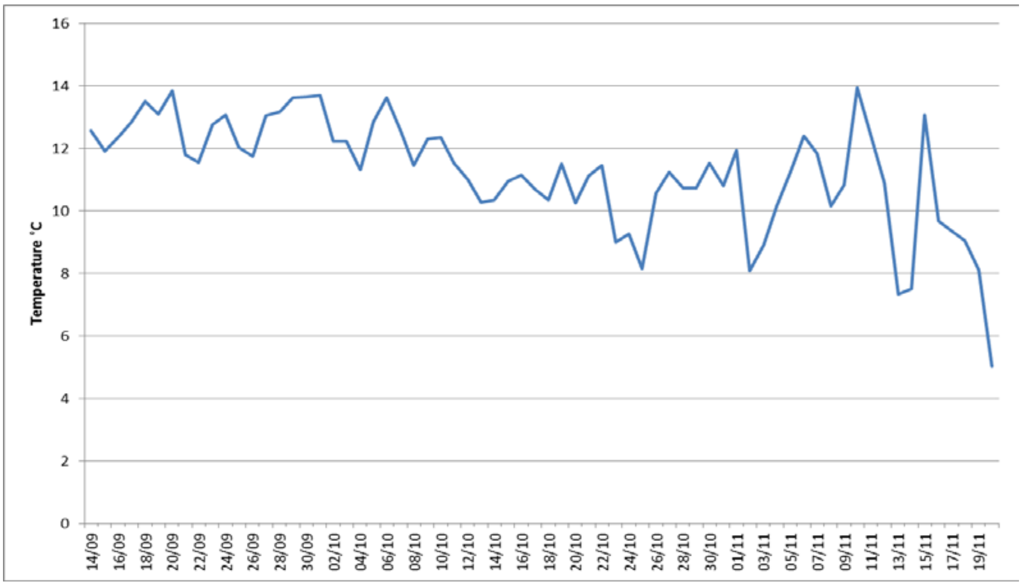

Figure 4. Mean daily temperature (14 September – 20 November)

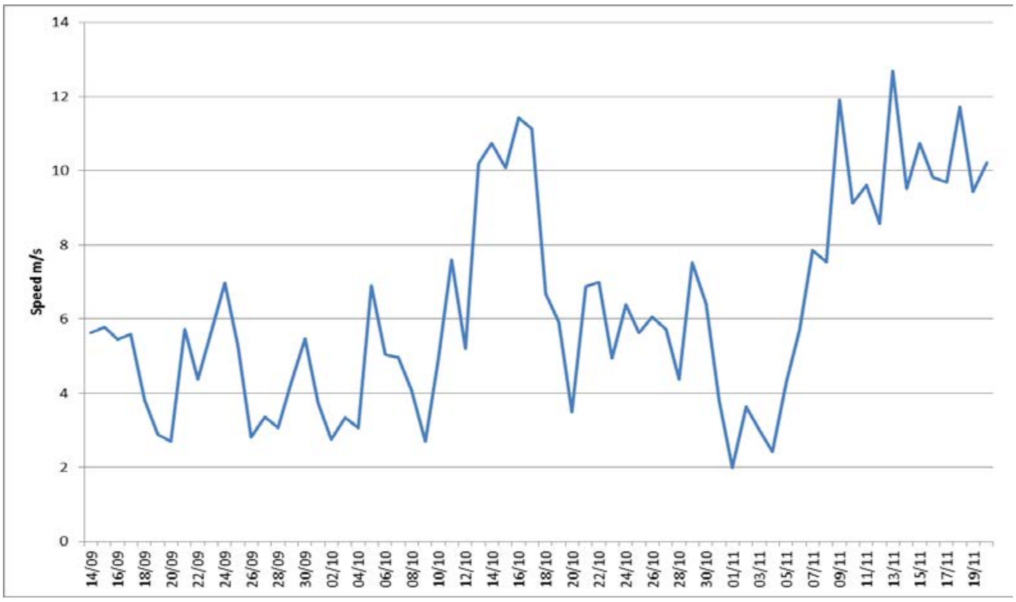

Figure 5. Mean daily wind speed (14 September – 20 November)

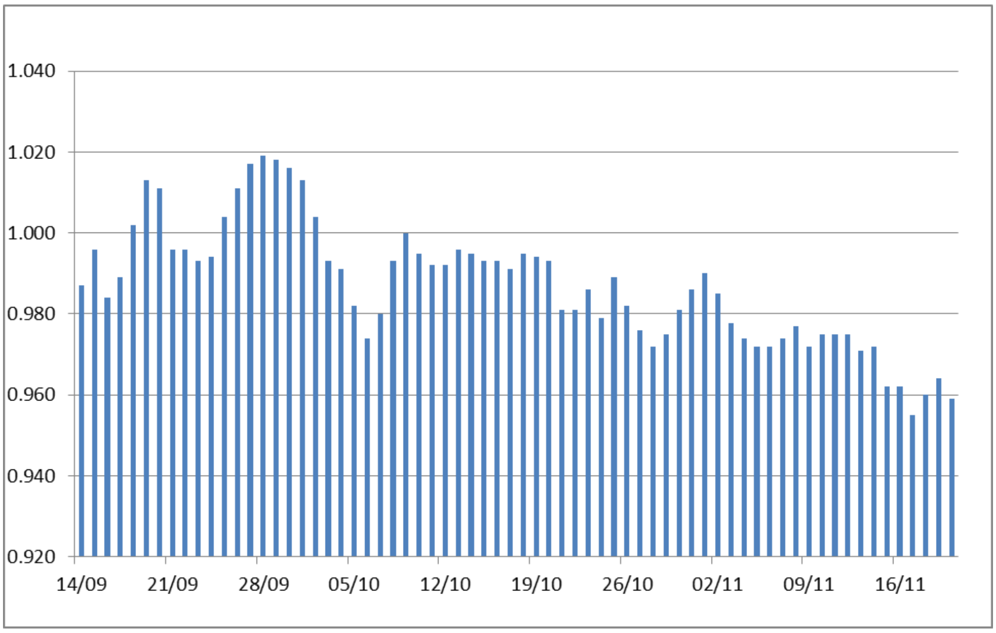

Figure 6. Mean daily pressure in bar (14 September – 20 November)

The average cloud cover across all field observation time periods was 5.4 oktas (i.e. 67.5% cloud cover), as shown in Figure 7. Visibility remained above 6 nm for 77.2% of the time and above 3 nm for 89% of the time. There was a period of reduced visibility between 2 and 4 November when fog reduced visibility to less than 1 nm (see Fig. 8).

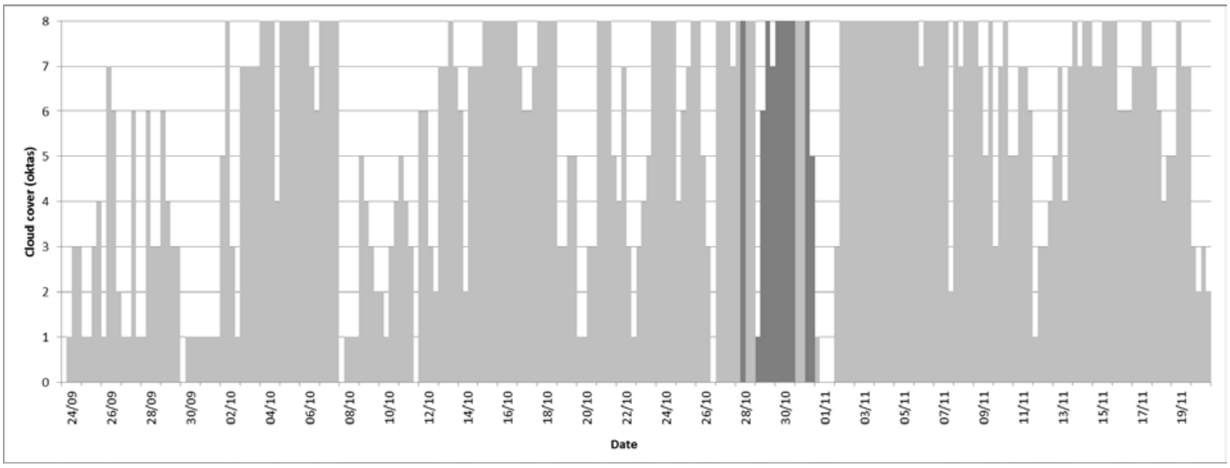

Figure 7. Cloud cover recorded by observers (four daily recordings at 08:00, 10:00, 12:00 and 14:00 hours). Dark grey are periods of reduced visibility (less than 1 nm).

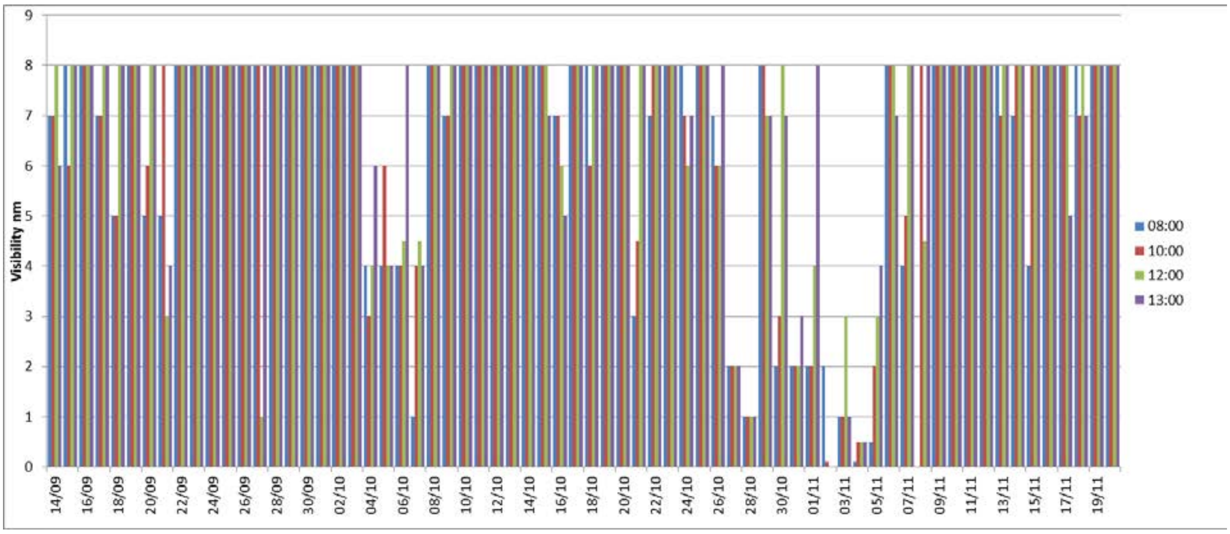

Figure 8. Visibility recorded by observers (four daily recordings at 08:00, 10:00, 12:00 and 14:00 hours).

A calm to moderate sea state (0-4 Beaufort scale) prevailed through the majority of the field observation periods (77.9% of the time), with rough conditions (sea state 5 or above) recorded for a time on 27 September, 5, 13, 14, 16 and 17 October, and 7, 9, 13 and 18 November.

Table 2 shows a summary of weather conditions during the 2015 study period.

Table 2. Summary of weather conditions recorded during the 2015 study

	14 Sept – 21 Nov 2015
Average temperature for study period	11.3°C
Maximum temperature for study period	23.5°C (19 Sept)
Minimum temperature for study period	2.8 °C (20 Nov)
Prevailing wind direction	SW
Maximum wind speed	24.6 m/s (18 Nov)
Minimum wind speed	0 m/s
Average pressure	0.987 bar
Maximum pressure	1.019 bar (28 Sept)
Minimum pressure	0.955 bar (17 Nov)
Average cloud cover during observation time	67.5%
Percentage of observation time when visibility was below 3nm	11%

3.3 Bird movements detected by the S-band radar

Table 3 shows a summary of all goose tracks detected by the S-band radar during the 2015 study. A total of 312 goose tracks were recorded in 2015 over the 68-day study period. Of these, 117 were groundtruthed as Pink-footed geese. A further 195 tracks were identified as likely goose tracks through radar video analysis. Of the groundtruthed tracks, 105 had associated estimated flight altitude data that allowed their flight altitude to be calculated (see section 2.4).

Figure 9 is a map showing all goose tracks recorded by the radar during the 2015 study period, including tracks that were groundtruthed and tracks that were identified through visual analysis of S-band radar data (non-groundtruthed). Figure 10 shows groundtruthed tracks only, and Figure 11 shows only non-groundtruthed goose tracks.

Table 3. Summary of the numbers of goose tracks detected by the S-Band radar during the 2015 study

	No of tracks (% of total no of tracks)
Total no of tracks	312
Total groundtruthed	117 (37.5%)
Groundtruthed at time of observation	84 (26.9%)
Observed but groundtruthed retrospectively	33 (10.6%)
Identified through radar video analysis	195 (62.5%)
With altitude data	105 (33.6%)
In daylight	175 (56.1%)
At night	137 (43.9%)
Within the wind farm footprint	8 (2.6%)
Within rotor-swept zone	51 (16.3%, 48.6% of tracks with altitude data)
Within footprint and rotor-swept zone	1 (0.3%, 0.9% of tracks with altitude data)

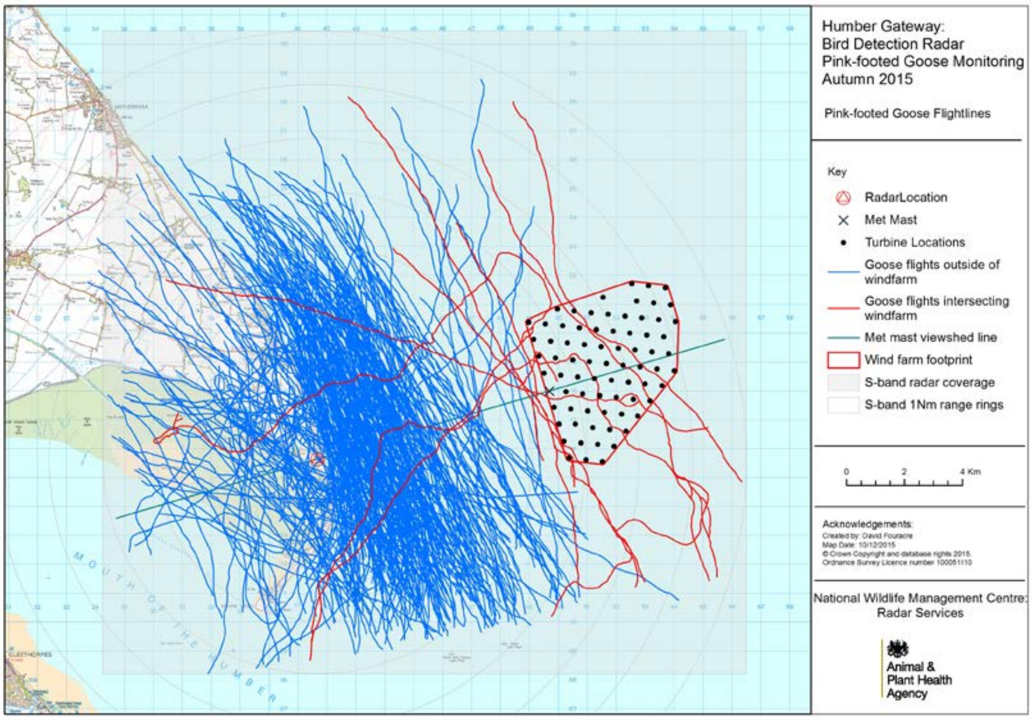

Figure 9. Map showing all goose tracks recorded by the S-band radar during the 2015 study period.

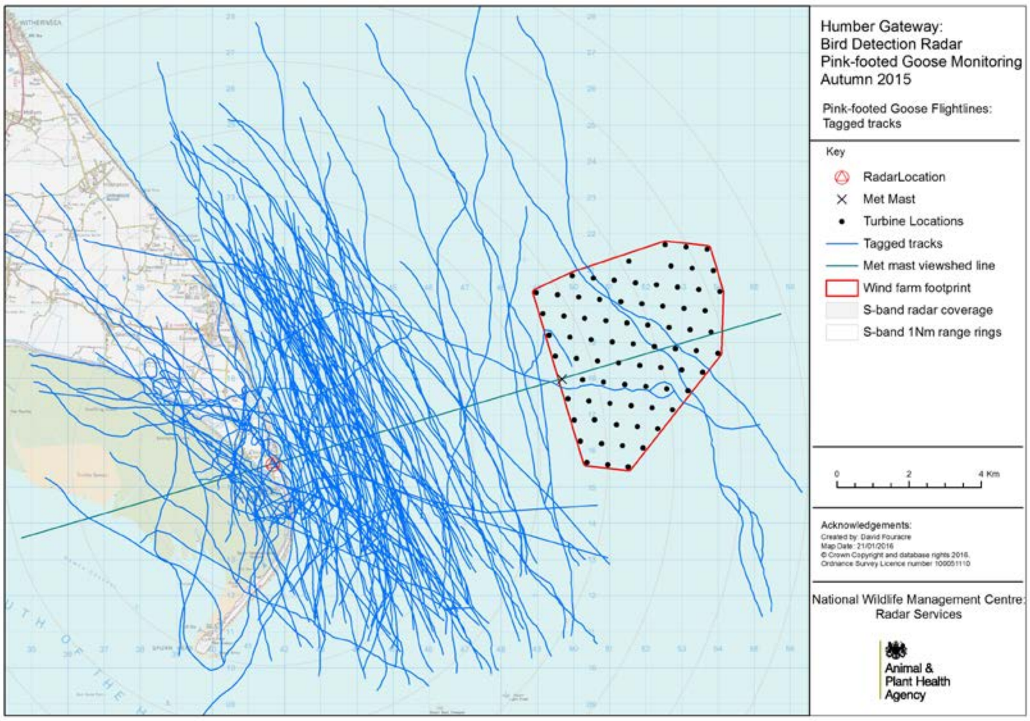

Figure 10. Map showing all groundtruthed tracks recorded by the S-band radar during the 2015 study period.

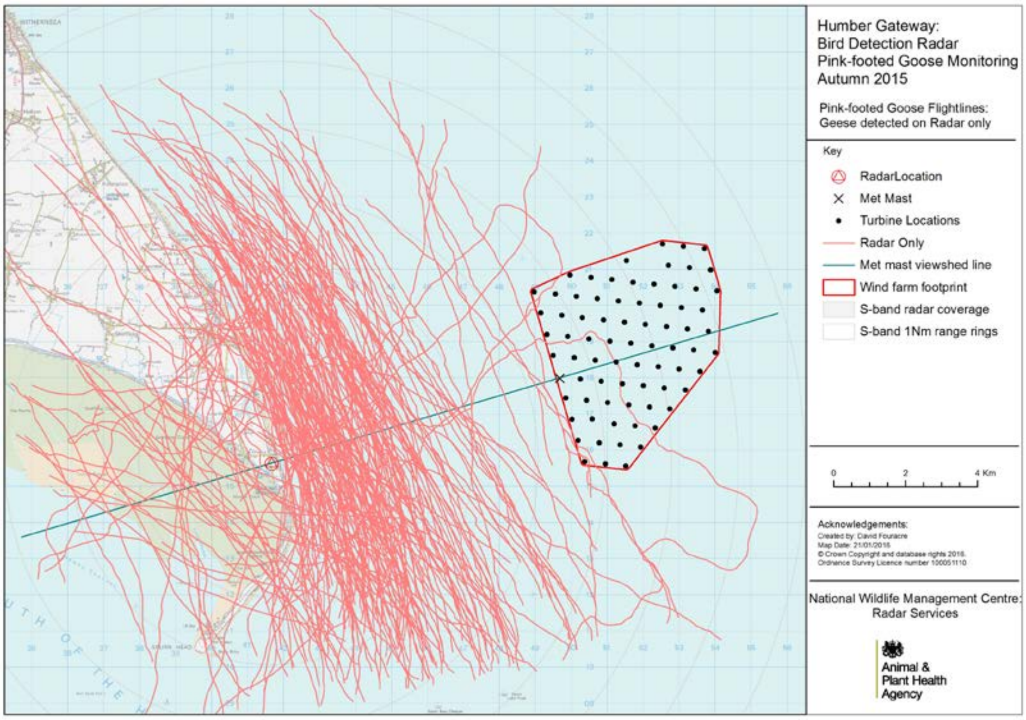

Figure 11. Map showing all non-groundtruthed tracks recorded by the S-band radar during the 2015 study period.

3.3.1 Temporal distribution of radar tracks

Movements of Pink-footed geese, as detected by the radar, occurred during two peak periods of passage in 2015: 25-27 September and 31 October - 21 November (see Fig. 12). There were also small numbers of tracks recorded between 8 and 25 October. The highest number of tracks recorded was on 20 November.

Figure 13 shows the numbers of tracks along with the numbers of individual Pink-footed geese counted by field observers for the study period. Note that tracks detected by the radar outside of the observation periods will not have associated counts of individual birds.

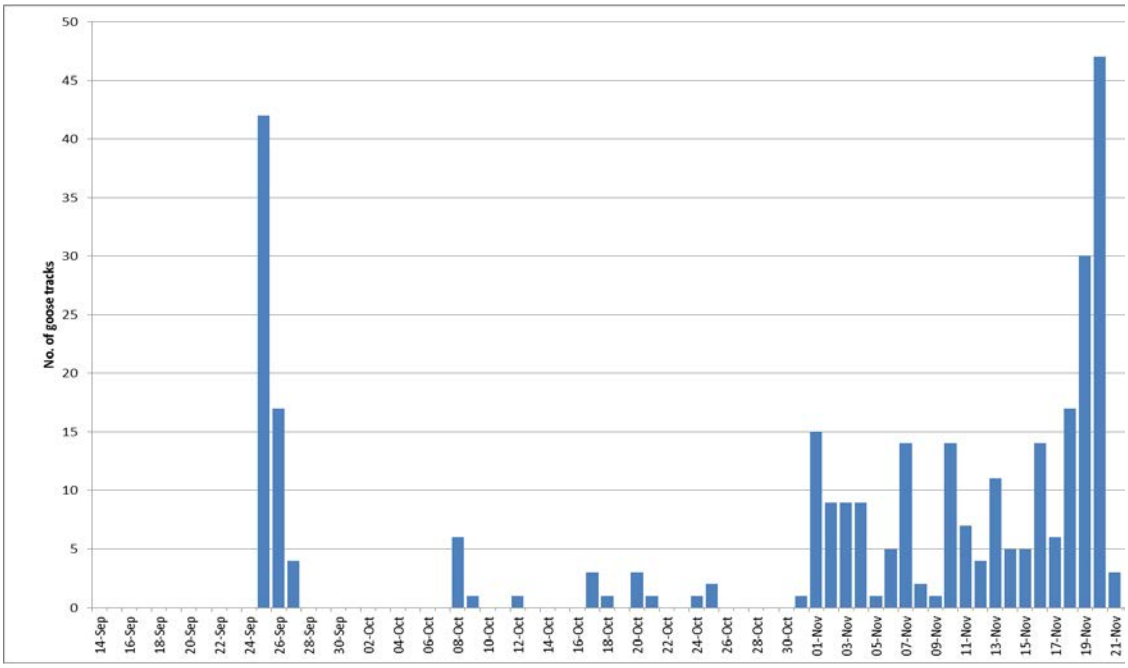

Figure 12. Total numbers of goose tracks detected by the radar between 14 September and 21 November 2015.

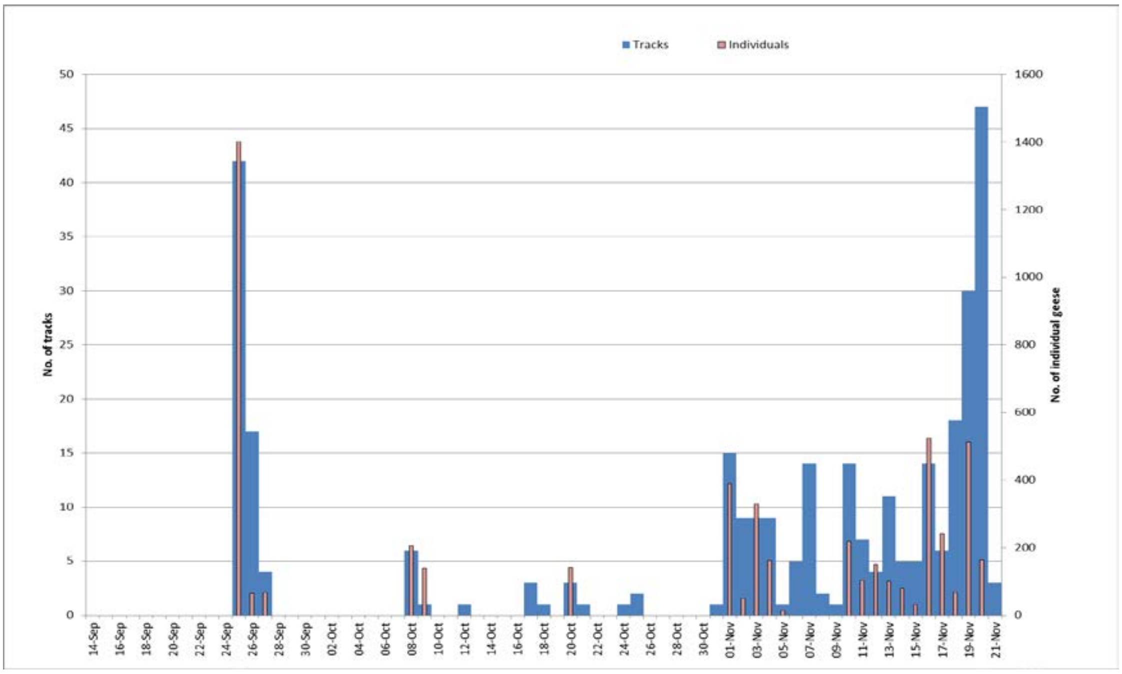

Figure 13. Total numbers of goose tracks detected by the radar, with total numbers of individual Pink-footed geese counted by field observers (during observation periods only) between 14 September and 21 November 2015.

Figure 12 shows there were two main peaks of migration between 14 September and 21 November. There was a brief peak between 25 and 27 September, with 42 tracks recorded on 25 September. Of these, 29 were groundtruthed and comprised a total of 1401 birds. There were 17 tracks recorded on 26 September. Of these, 4 were groundtruthed and comprised a total of 65 birds. There were 4 tracks recorded on 27 September, of which 2 were groundtruthed and these comprised a total of 68 birds.

A small number of tracks were recorded during October, but the largest numbers of tracks occurred between 31 October and the end of the study on 21 November, with a clear peak between 18 and 20 November. There were 18 tracks recorded on 18 November, of which 3 were groundtruthed. These comprised a total of 68 birds. There were 30 tracks recorded on 19 November, of which 15 were groundtruthed. These comprised a total of 513 birds. There were 47 tracks recorded on 20 November, of which 6 were groundtruthed, comprising a total of 164 birds.

Out of a total of 312 Pink-footed goose tracks, 117 (37.5%) were groundtruthed. Figure 14 shows the numbers of groundtruthed and non-groundtruthed tracks over the 10-week period. A large proportion of the non-groundtruthed tracks occurred at night, as can be seen in Figure 15. Figure 15 shows the proportion of goose tracks recorded within observation periods, in daylight but outside of observation periods, and at night.

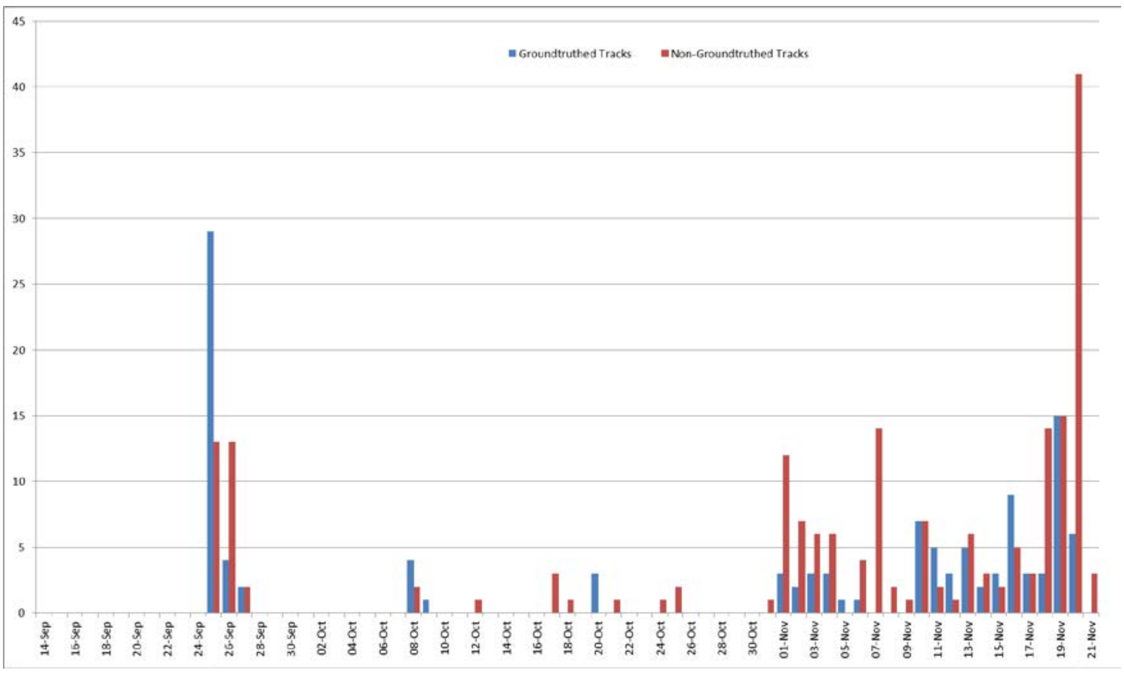

Figure 14. Number of groundtruthed and non-groundtruthed tracks detected by the radar between 14 September and 21 November 2015.

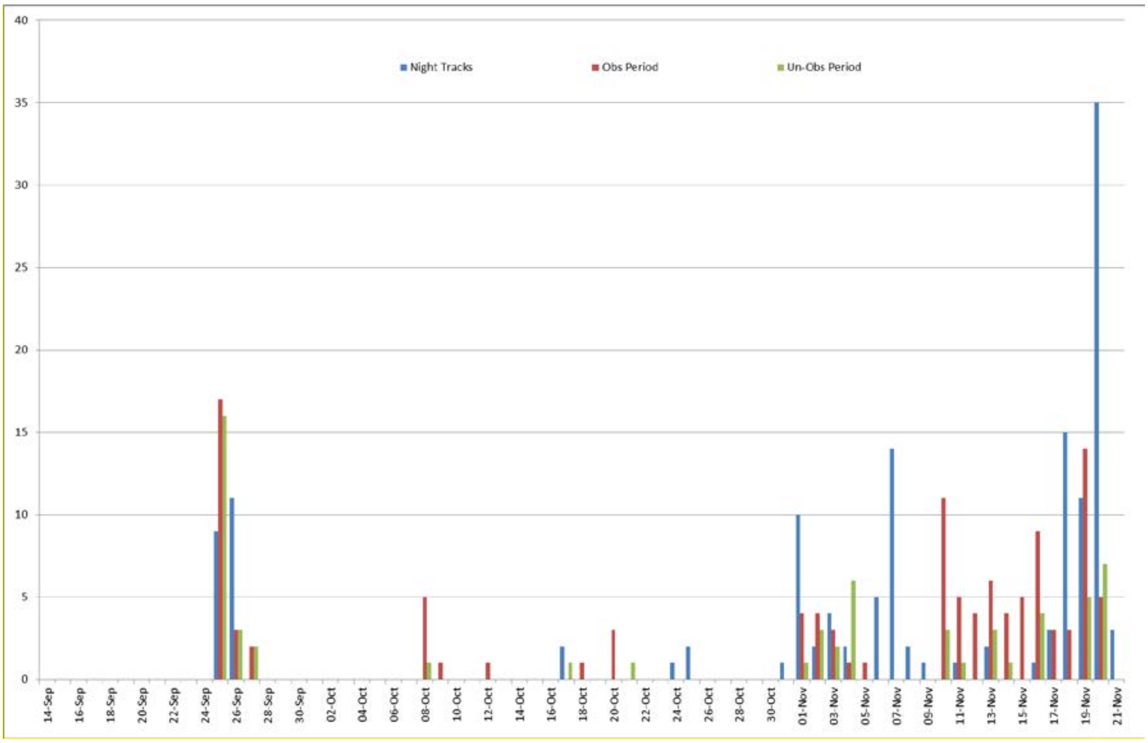

Figure 15. Temporal distribution of goose tracks divided into three time periods. Observation period: 08:00-15:00; Night: hours of darkness (between half an hour after sunset and half an hour before sunrise); Un-obs period: in daylight but outside of observation period.

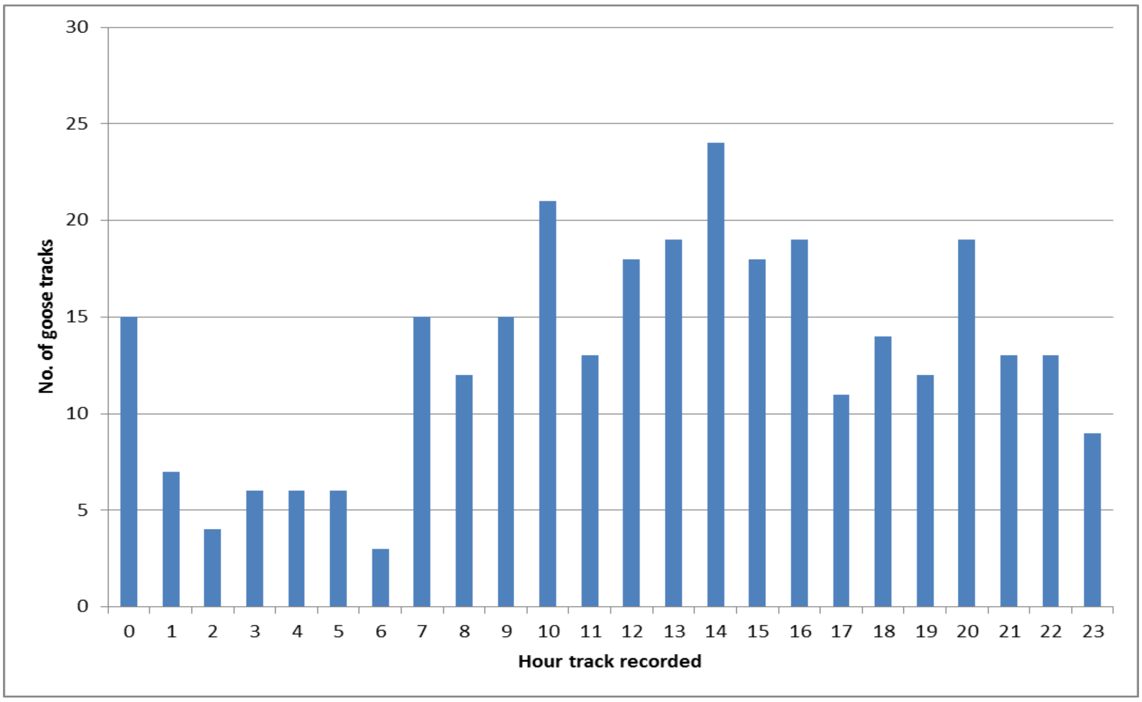

Figure 16. Number of goose tracks per hour interval (14 September – 21 November 2015). Time was recorded as GMT.

Of the 312 goose tracks detected by the radar, 60 tracks (19% of all tracks) occurred during the observation periods. In total, 175 tracks (56% of all tracks) occurred during daylight. Of these, 115 tracks (37% of all tracks) occurred during daylight but outside of observation periods. A further 137 tracks (44% of all tracks) occurred during the hours of darkness. Nocturnal activity occurred on 19 nights; whilst diurnal activity occurred on 27 days (175 tracks) (see section 3.3.3).

Figure 13 shows the numbers of individual Pink-footed geese counted by field observers during observation periods. A total of 5159 Pink-footed geese were observed, in 117 flocks The mean flock size was 45.1 birds (range 2-200). The maximum number of flocks observed and groundtruthed by field workers occurred on 25 September. The maximum number of individual birds was therefore recorded on 25 September. It is possible that more individual birds moved through the area on the night of 20 November, when the highest number of tracks were detected by the radar, however because the majority of these occurred at night, they were no groundtruthed, and no count data is available.

Figure 16 shows the distribution of tracks for each hour of the day for the entire study period. While there appears to be a peak in movement at around 14:00, goose movement was detected at some point for every hour of the day, with considerable numbers at night.

3.3.2 Overall movement of Pink-footed geese in 2015

Figure 17 shows all goose tracks detected by the radar during the autumn 2015 survey period (14 September to 21 November). The red tracks are those that passed through the wind farm footprint and the blue tracks are those that did not pass through the wind farm at any point in their trajectory. A total of 312 tracks were recorded, 8 of which passed through the wind farm footprint (see Table 4).

Table 4. Total number of goose tracks detected by the radar in relation to the wind farm footprint (2015)

Area	Number of Tracks	Percentage of total
Outside the wind farm	304	97.4
Within the wind farm footprint	8	2.6

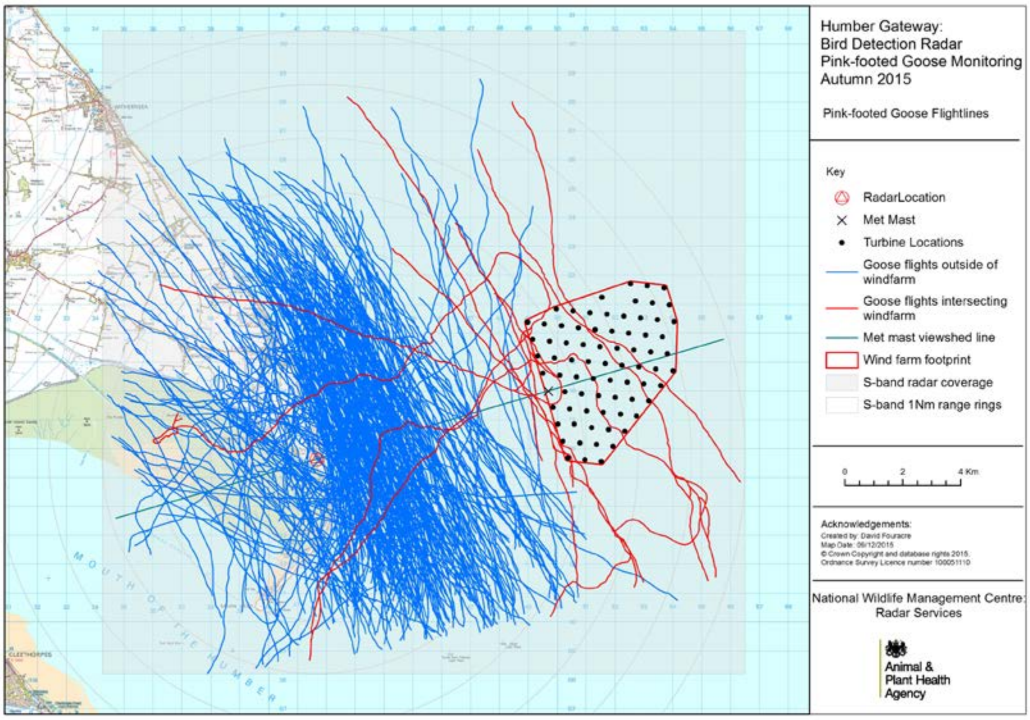

Figure 17. Map showing the location of goose tracks recorded by the radar in 2015 relative to the Humber Gateway Wind Farm footprint.

Figure 18 shows tracks recorded in 2015 that appear to exhibit avoidance behaviour with respect to the wind farm. Although most tracks recorded in 2015 were already closer to the coastline by the time they were initially detected than those recorded in 2012, the tracks shown in Figure 18 were further out to sea on first detection than most and appear to have taken evasive action with respect to the wind farm by turning towards the coast. This was not seen in 2012, which is to be expected, as the wind farm was still in pre-construction at that time and there was therefore no need for geese to avoid it.

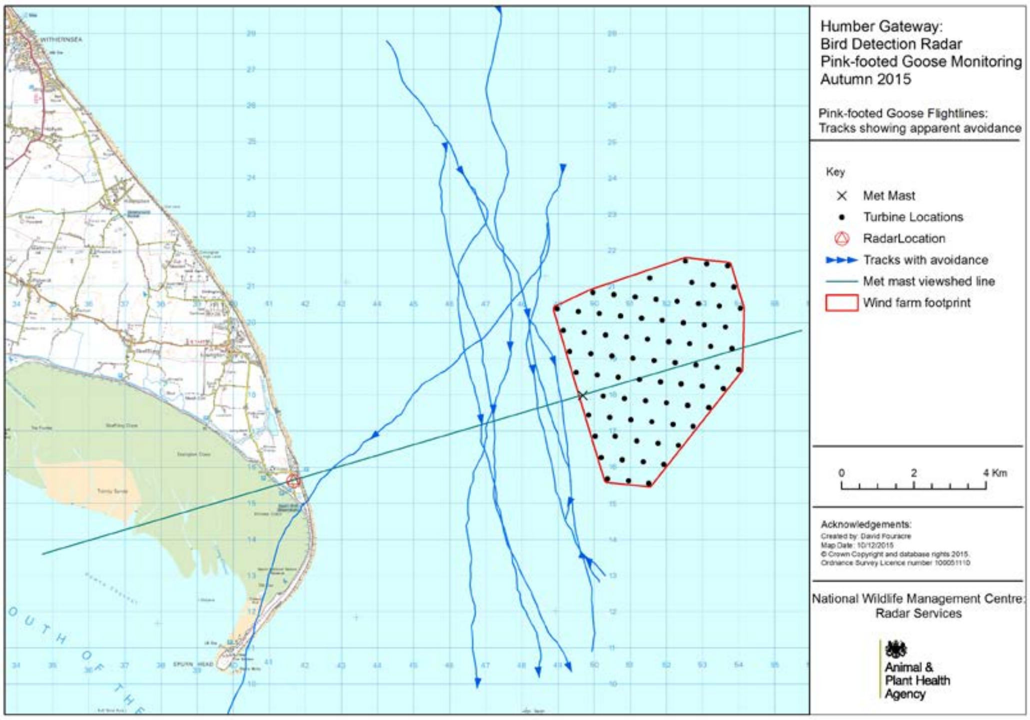

Figure 18. Map showing tracks that appear to change trajectory to avoid the wind farm area

3.3.3 Diurnal and nocturnal tracks

Daylight was defined as from 30 minutes before sunrise until 30 minutes after sunset for each day. Tracks recorded in daylight were separated from those recorded during the hours of darkness and are shown in Figure 19 and Figure 20, respectively.

Diurnal tracks occurred on 27 days and nocturnal tracks occurred on 19 days. There were 175 tracks (56% of all tracks) recorded during daylight, and 137 tracks (44% of all tracks) recorded at night.

During the September peak (25, 26, and 27 September), 32% of the tracks recorded were at night, while during the November peak (18, 19, and 20 November), 64% of tracks recorded were at night.

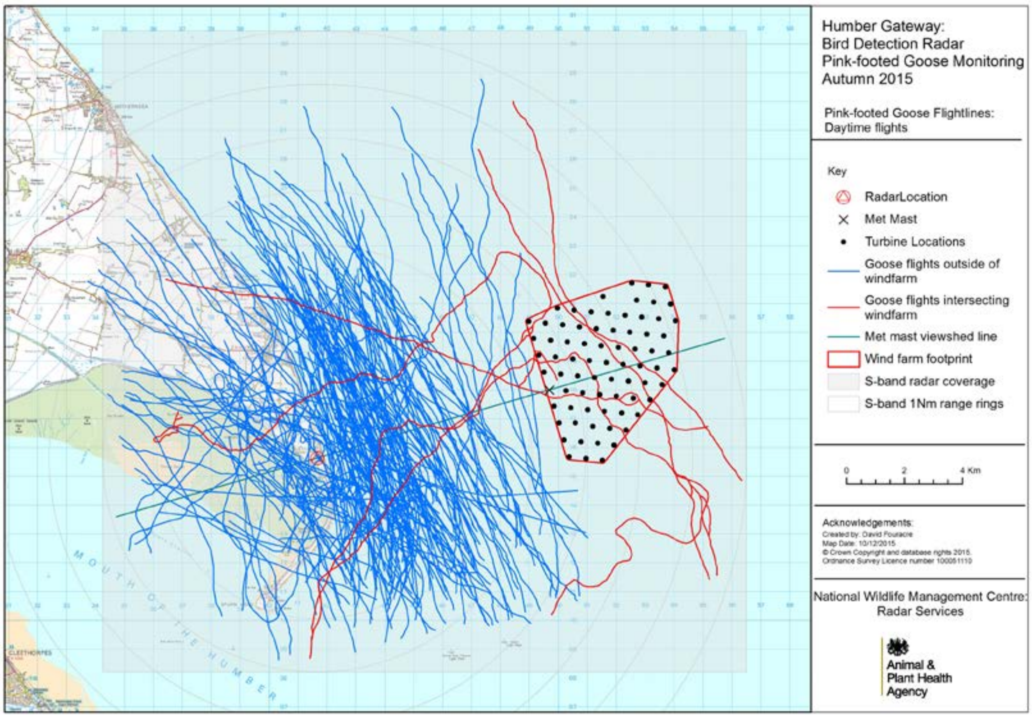

Figure 19. Map showing all tracks recorded during daylight hours in 2015

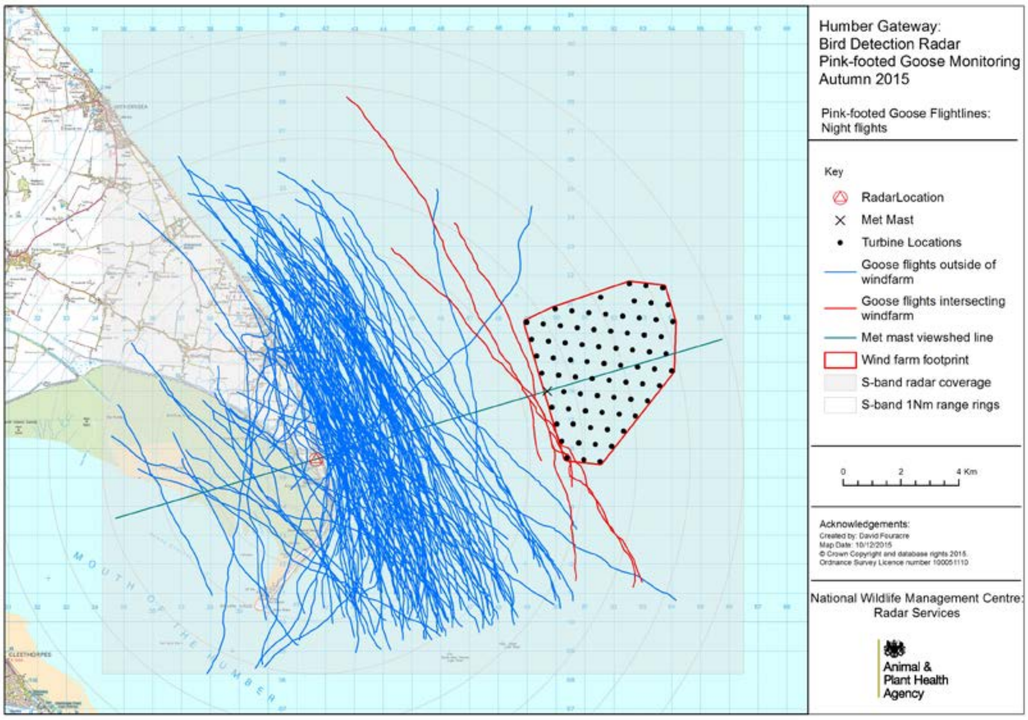

Figure 20. Map showing all tracks recorded during hours of darkness (time between half an hour after sunset and half an hour before sunrise) in 2015

3.3.4 Flight altitude

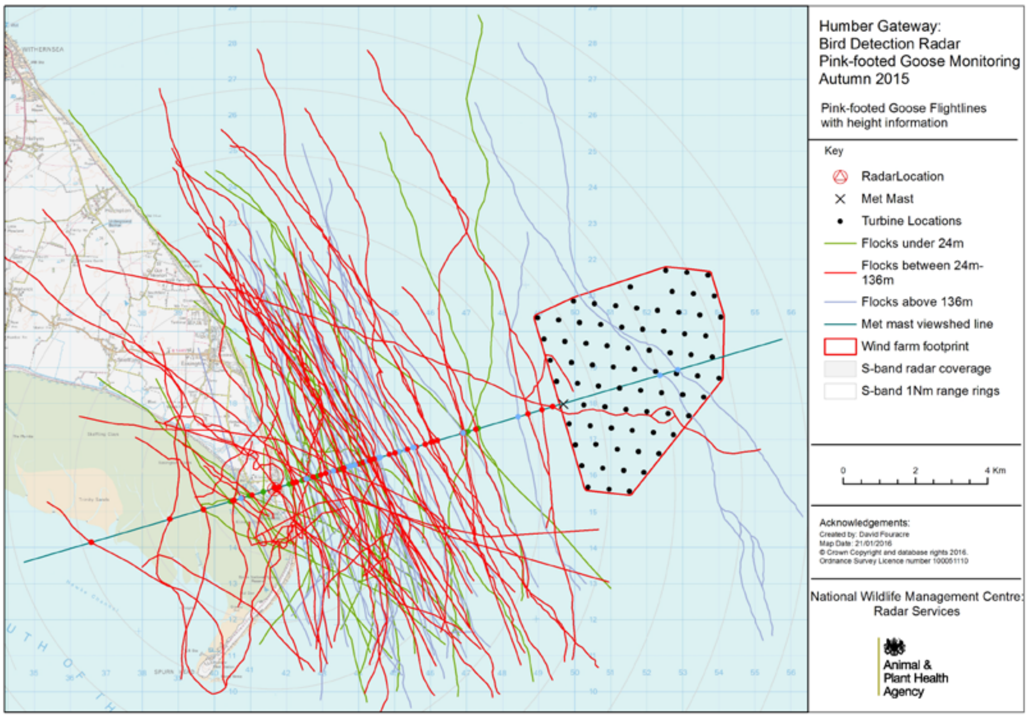

Figure 21. Map showing all groundtruthed tracks with associated altitude data. Green tracks were made by flocks recorded as flying below 24m (below the rotor-swept zone), red tracks were made by flocks recorded as flying between 24m and 136m (within the rotor-swept zone) and grey tracks were made by flocks recorded as flying above 136m (above the rotor-swept zone).

Flight altitude data is limited to tracks that were groundtruthed. There were 105 groundtruthed goose tracks that had associated altitude data. This data is collated in Table 5 and shown in Figure 21. The results show that, of the groundtruthed goose tracks, 28 (a total of 1259 birds) flew below the rotor-swept zone (0-24m: band A), 51 (a total of 1800 birds) flew within the rotor-swept zone (24-136m: band B), and 26 (a total of 1547 birds) flew above the rotor-swept zone (136m+: band C). (Note that the altitude bands used in this analysis differ from those used in the 2012 report. This is because the turbine dimensions used in the 2012 pre-construction study differed from those of the turbines that were actually built. The actual rotor-swept zone (24-136m) is therefore different to the rotor-swept zone used in the 2012 analysis (56-136m) and the other altitude bands have thus also been adjusted accordingly.)

Of the 51 groundtruthed tracks recorded flying at altitudes within the rotor-swept zone (48% of flocks observed and 39% of the total number of birds with altitude data), only one, comprising 14 birds (0.9 % of flocks and 0.3% of birds observed with altitude data) also flew within the wind farm footprint. Two of the 26 flocks recorded flying above the rotor-swept zone flew within the wind farm footprint, but these were obviously not at risk, as they were observed flying well above the wind farm. No flocks were recorded within the wind farm footprint flying below the rotor-swept zone. Section 3.3.7 deals with tracks recorded within the wind farm footprint in more detail.

Table 5. Altitude distribution of goose tracks in relation to the Humber Gateway Wind Farm footprint in 2015

	No. of goose tracks (No. of geese)		
	Within wind farm footprint	Outside wind farm footprint	Total
Altitude band A (0 – 24m)	0	28 (1259)	28 (1259)
Altitude band B (24 – 136m)	1 (14)	50 (1786)	51 (1800)
Altitude band C (136m+)	2 (260)	24 (1287)	26 (1547)
Total	3 (274)	102 (4332)	105 (4606)

3.3.5 The effects of wind

Wind direction was averaged for each day and the results recorded as the prevailing wind direction for that day (this can be seen in Table 8 in the Appendix). South-west and west were the most common prevailing winds for the study period (15 days each). The most tracks were recorded on days when the prevailing wind came from the west (158 tracks in total), followed by days when the prevailing wind came from the south-west (77 tracks in total), south (46 tracks), east (17 tracks), north-east (5 tracks), and south-east (1 track). There were therefore significantly more tracks recorded on westerly days than for other wind directions.

The average wind direction and wind speed for each hour were applied to the tracks that were recorded during those hours. Figures 22 to 26 show the trajectories of tracks divided according to average prevailing wind direction for the hour in which they were recorded. Wind directions for which no tracks were recorded are excluded. Wind speeds above and below 5 m/s, and above 10m/s are shown in different colours.

In north-easterly winds (see Fig. 23), goose tracks were concentrated closer to the coast and even some inland over the estuary, and followed a more southerly trajectory than on average. When the wind was from the north-west (Fig. 24), the tracks appear to be slightly further from the coast and heading on a more south-easterly trajectory.

In south-westerly winds (see Fig. 25) the geese appear to have been pushed further out to sea and towards a more easterly trajectory. In westerly winds (see Fig. 26), the tracks are also spread out more towards the east.

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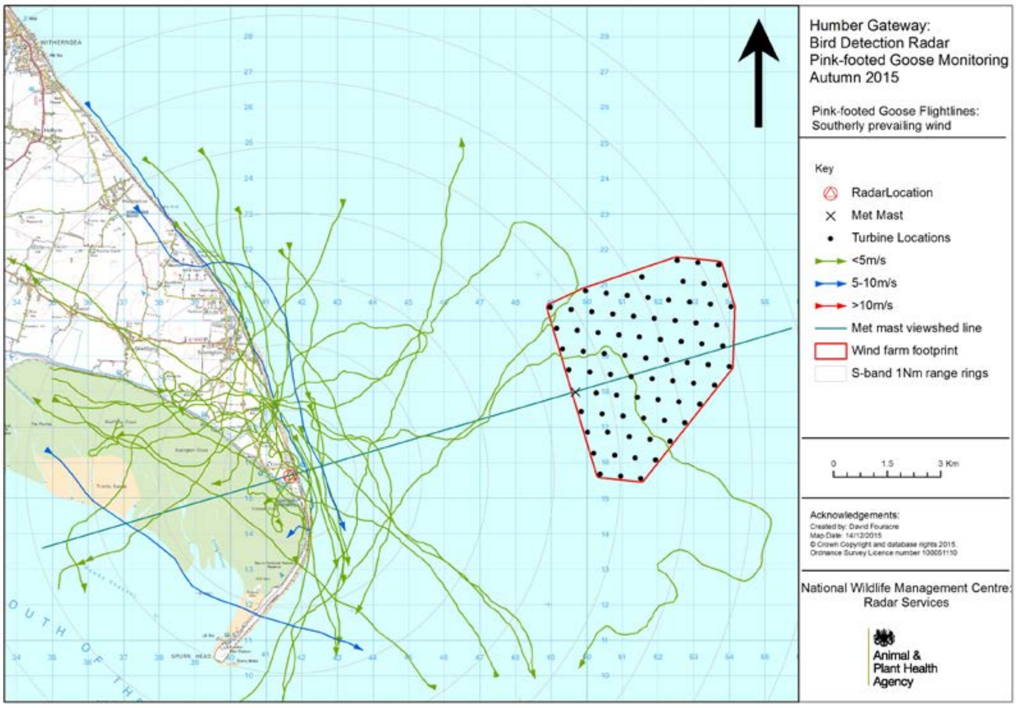

Figure 22. Map showing tracks recorded when the prevailing wind was from the south. The black arrow shows the prevailing wind direction.

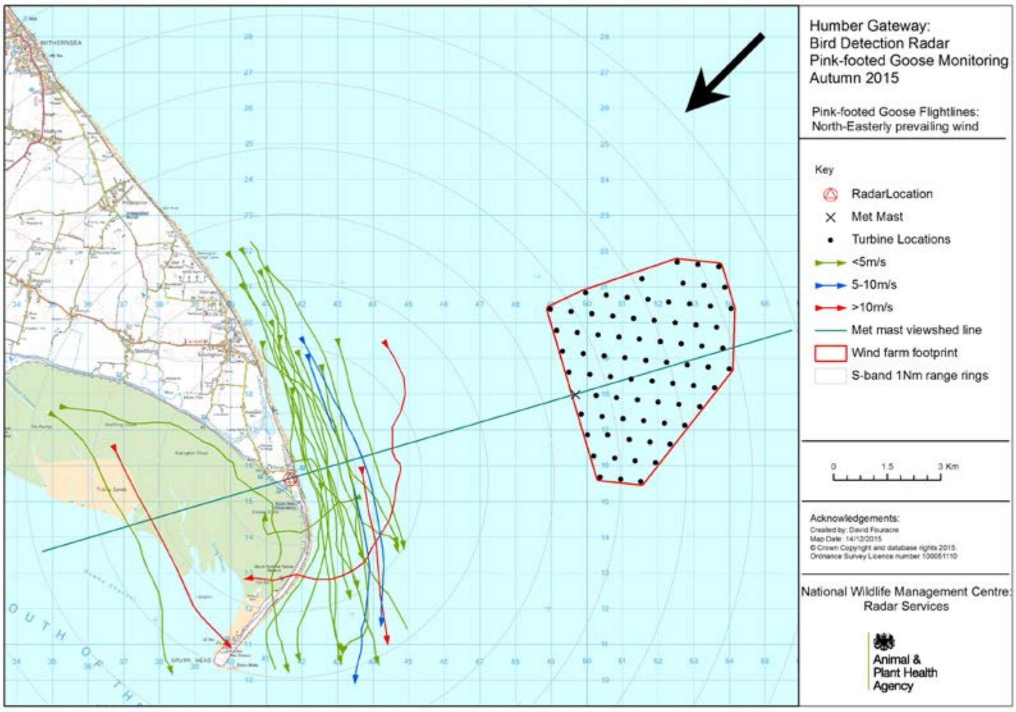

Figure 23. Map showing tracks recorded when the prevailing wind was from the north-east. The black arrow shows the prevailing wind direction.

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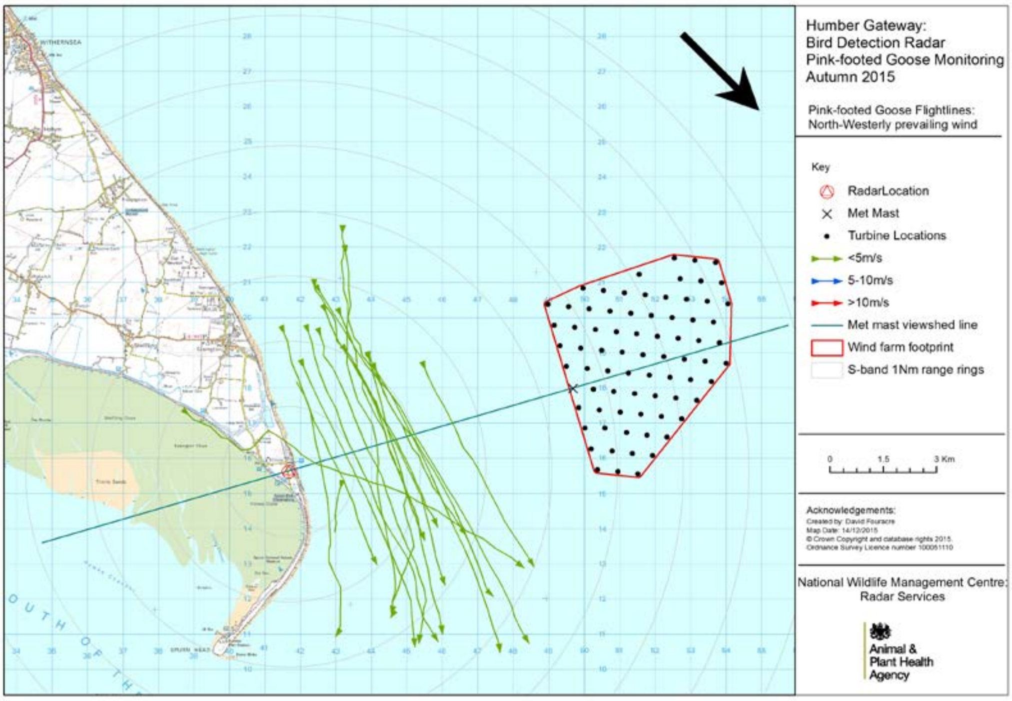

Figure 24. Map showing tracks that were recorded when the prevailing wind was from the north-west. The black arrow shows the prevailing wind direction.

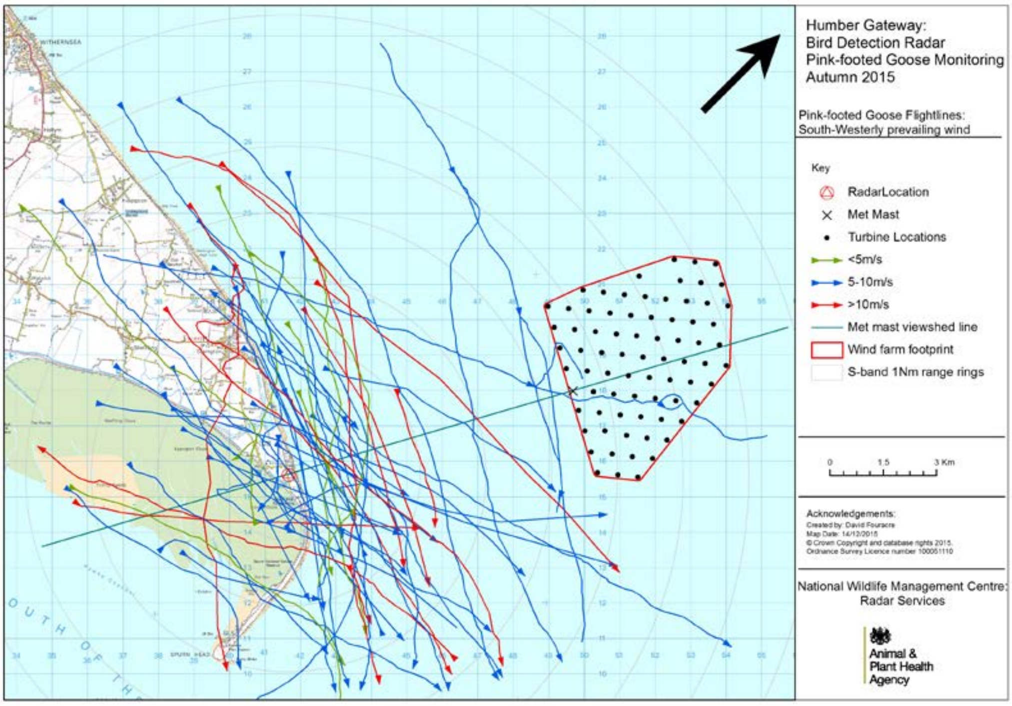

Figure 25. Map showing tracks recorded when the prevailing wind was from the south-west. The black arrow shows the prevailing wind direction.

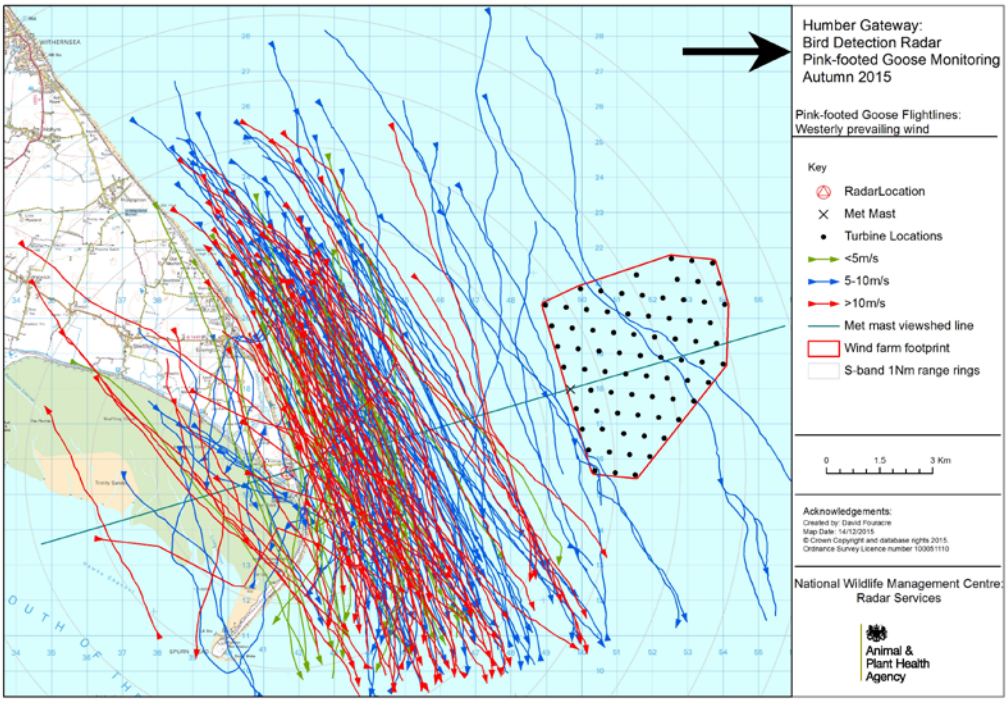

Figure 26. Map showing tracks recorded when the prevailing wind was from the west. The black arrow shows the prevailing wind direction.

3.3.6 The effects of reduced visibility

Visibility was estimated and recorded by fieldworkers in nautical miles. Visibility data therefore only exists for the times when field observations took place. Days of reduced visibility were defined as days when the average visibility for the day was below 2 nautical miles.

There were only five days of reduced visibility during the study period, all caused by fog: 27 October, 28 October, 2 November, 3 November, and 4 November. No tracks were recorded on either 27 or 28 October. A total of 26 tracks were recorded on the three other days, with 8 tracks, 10 tracks, and 8 tracks recorded on the 2, 3, and 4 of November, respectively. Visibility was particularly poor on 2 and 4 November, with average visibilities recorded as 0.5 nm on 2 November, and 0.4 nm on 4 November.

In total, 7 of these 26 tracks also occurred during the hours of darkness. On 2 November, 7 tracks occurred during daylight and 1 during the hours of darkness. On 3 November, 5 tracks occurred during daylight and 5 during the hours of darkness. On 4 November, 7 tracks occurred during daylight and 1 during the hours of darkness.

Figure 27 shows these tracks, with different colours for daytime and night-time tracks.

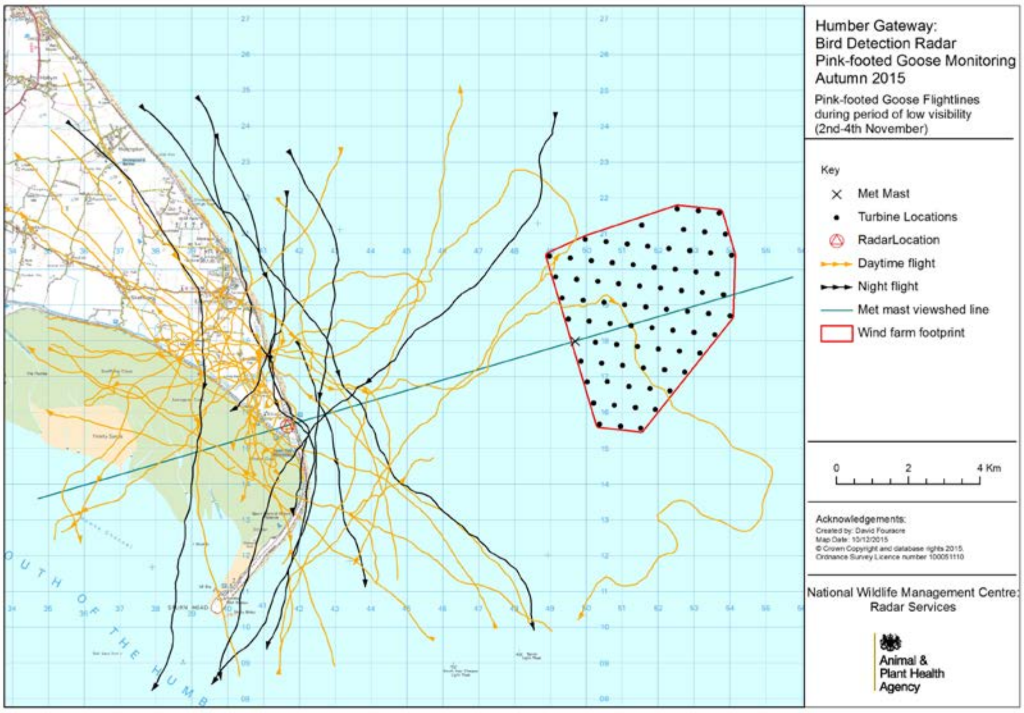

Figure 27. Map showing tracks recorded during times of reduced visibility

3.3.7 Tracks within the wind farm footprint

Eight tracks went through the wind farm footprint, out of a total of 312 tracks recorded during the study period (2.6% of all tracks). Of these, 3 were groundtruthed and have associated altitude data. These tracks are shown in Figure 28.

Two flocks (tracks E and F, see Fig. 28) were observed taking clear evasive action by gaining altitude at least 1nm north of the wind farm and flying above the turbines (vertical avoidance).

Track E was groundtruthed at 12:03 on 16 November. This flock consisted of 100 Pink-footed geese that were following a south-easterly trajectory similar to that of most other recorded tracks, but further east. This put them on course to intersect with the wind farm. However, on approaching the wind farm, the geese were observed to gain altitude at least 1nm before reaching the wind farm. When their altitude was recorded near the middle of the wind farm (see section 2.4), they were at approximately 384 m, which puts them well above the rotor-swept zone.

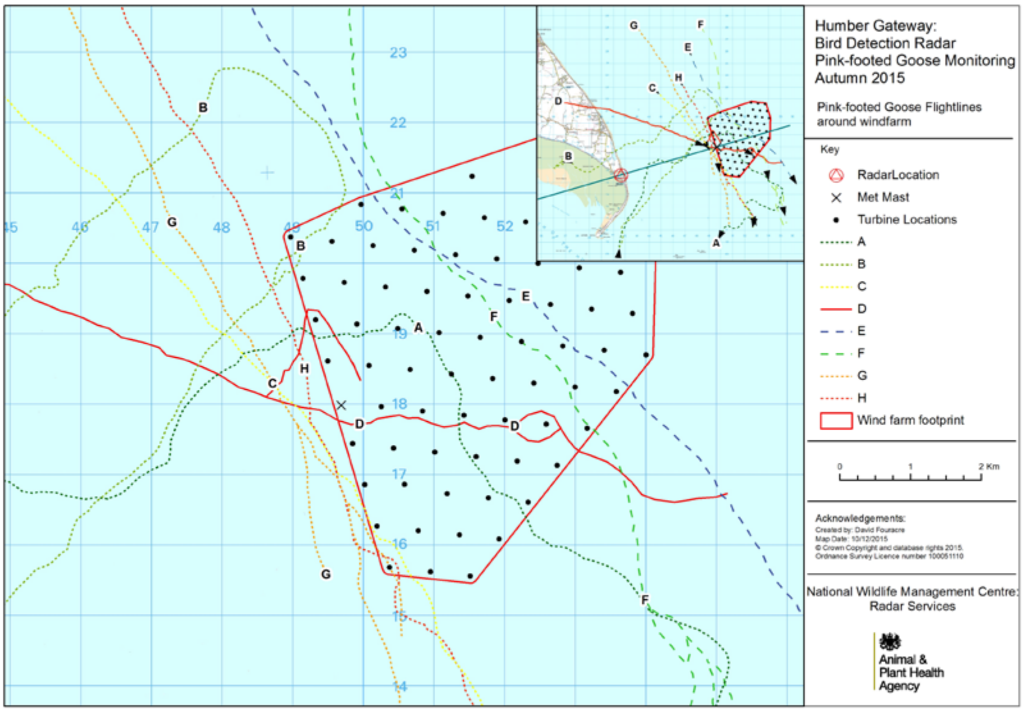

Figure 28. Map showing tracks recorded during the study period that entered the wind farm footprint

Track F was groundtruthed at 12:18 on 16 November and followed a very similar trajectory to that of track E. The flock consisted of 160 Pink-footed geese that were also observed to gain altitude on approaching the wind farm. This flock was estimated to be at an altitude of 220 m by the centre of the wind farm, which also puts them well above the collision risk zone.

The only other track within the wind farm footprint to be groundtruthed was track D (see Fig. 28). This is the only track recorded by the radar during this study to have entered the wind farm footprint and to have been recorded as flying at an altitude that was within the rotor-swept zone. This flock was first detected by the radar over the land at 10:00 on 10 November. It consisted of 14 Pink-footed geese that flew overland north of the radar and headed out to sea on a south-easterly trajectory that put them on course to intersect with the wind farm. On approaching the wind farm, they were not observed to take any vertical evasive action and their altitude at the edge of the wind farm was estimated at 93 m, which put them within the rotor-swept zone. Unfortunately, fieldworkers lost sight of the flock at this point and were unable to observe the flock's movements within the wind farm. Because of the small size of the flock and the clutter and interference generated by the turbines themselves, it was very difficult for the radar to track the movements of this flock within the wind farm footprint. This difficulty was further exacerbated by the splits that reduced the size of the flock even further. What could be traced is shown in Figure 28. It appears that the flock split just before reaching the wind farm, with one group turning north while the majority entered the wind farm. The group that turned north then turned again to enter the wind farm further north. It is assumed that at this point this group were attempting to re-join the rest of the flock, but the track was lost. The main flock was tracked following a meandering trajectory within the wind farm, with a clear split around one of the turbines before re-joining and leaving the wind farm to continue south-east.

Tracks A and B were first detected by the radar on 2 November at 15:39 and 16:43, respectively. Sunset on 2 November was at 16:27, (see section 3.3.6), so combined with the foggy conditions, this is likely to have reduced visibility considerably at these times. Both flocks were initially detected by the radar heading north along the coastline; possibly having turned back due to poor weather conditions (see section 3.3.6). Both then veered off towards the north-east and towards the wind farm.

Track A entered the wind farm near its north-west corner and followed an easterly trajectory for a short time before turning south, eventually leaving the wind farm and continuing south.

Track B passed through the north-west corner of the wind farm. There was a brief split when it entered the wind farm. After leaving the wind farm footprint, the track turned back on itself and headed south-west, before eventually being lost at the estuary, where the geese may have landed.

Tracks C, G, and H showed a similar pattern, with all three following south-easterly trajectories similar to those of most of the tracks recorded, but which, being further out at sea than most, caused them to intersect with the south-west corner of the wind farm. Given the usual south-easterly trajectories of the geese, it was to be expected that the south-west corner of the wind farm was the most common intersection point. All three of these tracks occurred within the hours of darkness or reduced light, with track C first detected at 22:22 on 7 November, G at 6:51 on 19 November, and H at 20:13 on 19 November. It seems likely that these flocks entered the wind farm footprint because reduced visibility meant that they did not see the turbines in time to avoid the whole wind farm. Tracks C and H appeared to show clear avoidance of the last turbine. Track G split before reaching the turbines, but one of the resulting groups appeared to have intersected with the final turbine. It is possible, however, that these birds were not within the rotor-swept zone at this time.

3.4 Comparison between the 2012 and 2015 studies

3.4.1 Weather conditions in 2012 and 2015

Table 6 shows a summary of weather conditions during the 2015 and 2012 study periods. This shows that, overall, temperatures (average 11.3 °C) and wind speeds (max 24.6 m/s) were slightly higher in 2015 than in 2012 (average temperature 9.5°C, maximum wind speed 23.2 m/s). However, prevailing wind direction was south-westerly in both years.

Table 6. Summary of weather conditions recorded during the 2012 and 2015 studies

	2012 (16 Sept – 12 Nov)	2015 (14 Sept – 21 Nov)
Average temperature for study period	9.5°C	11.3°C
Maximum temperature for study period	18.4°C (19 Sept)	23.5°C (19 Sept)
Minimum temperature for study period	3 °C (4 Nov)	2.8 °C (20 Nov)
Prevailing wind direction	SW	SW
Maximum wind speed	Max 23.2m/s (16 Oct)	24.6 m/s (18 Nov)
Minimum wind speed	Min 0.4 m/s (23 Oct)	0 m/s
Average pressure	1.005 bar	0.987 bar
Maximum pressure	1.023 bar (23 Oct)	1.019 bar (28 Sept)
Minimum pressure	0.974 bar (1 Nov)	0.955 bar (17 Nov)
Average cloud cover during observation time	69%	67.5%
Percentage of observation time when visibility was below 3nm	12%	11%

3.4.2. Numbers of tracks recorded and groundtruthed in 2012 and 2015

Table 7 shows a summary of the numbers of goose tracks detected by the S-band radar during the 2012 and 2015 studies. More tracks were recorded in 2015 than in 2012. This may be because the 2015 study was longer than the 2012 study (68 days in 2015 compared to 57 days in 2012). However, in 2015, a smaller proportion of the tracks were groundtruthed (37.5% of total tracks recorded, compared to 53.7% in 2012). This is likely due to more nocturnal tracks being recorded in 2015 (see section 3.4.5). Figures 29 and 30 show the total number of goose tracks recorded during the 2012 (pre-construction) and 2015 (post-construction) studies, respectively.

Table 7. Summary of the numbers of goose tracks detected by the S-Band radar
(Note: the 2012 figures differ from those presented in the 2012 report because both the wind farm footprint and the rotor-swept zone differ from those originally proposed)

	No of tracks (% of total no of tracks)	
	2012	**2015**
Total no of tracks	205	312
Total groundtruthed	110 (53.7%)	117 (37.5%)
Groundtruthed at time of observation	-	84 (26.9%)
Observed but groundtruthed retrospectively	-	33 (10.6%)
Identified through radar video analysis	95 (46.3%)	195 (62.5%)
With altitude data	95 (46.3%)	105 (33.6%)
In daylight	187 (91.2%)	175 (56.1%)
At night	18 (8.8%)	137 (43.9%)
Within the wind farm footprint	23 (11.2%)	8 (2.6%)
Within rotor-swept zone	24 (11.7%, 25.3% of tracks with altitude data)	51 (16.3%, 48.6% of tracks with altitude data)
Within footprint and rotor-swept zone	2 (1%, 2.1% of tracks with altitude data)	1 (0.3%, 0.9% of tracks with altitude data)

3.4.3 Numbers of tracks recorded within the wind farm footprint in 2012 and 2015

Fewer tracks occurred within the wind farm footprint in 2015 than in the 2012 pre-construction 2012 study. The 2012 study recorded 48 tracks out of a total of 205 (23.41%) flying through the proposed wind farm footprint. However, the south-west boundary of the proposed wind farm footprint was changed before construction, reducing the total area of the actual wind farm footprint. A large proportion of the tracks recorded within the proposed wind farm footprint in 2012 occurred within the area that was not constructed. Therefore, the number of tracks recorded in 2012 within the actual footprint is considerably reduced. Using the actual current wind farm footprint, 23 tracks out of a total of 205 (11.2%) flew through the footprint in 2012. However, this is still considerably more than occurred within the wind farm footprint in 2015 (8 tracks out of a total of 312 = 2.6%).

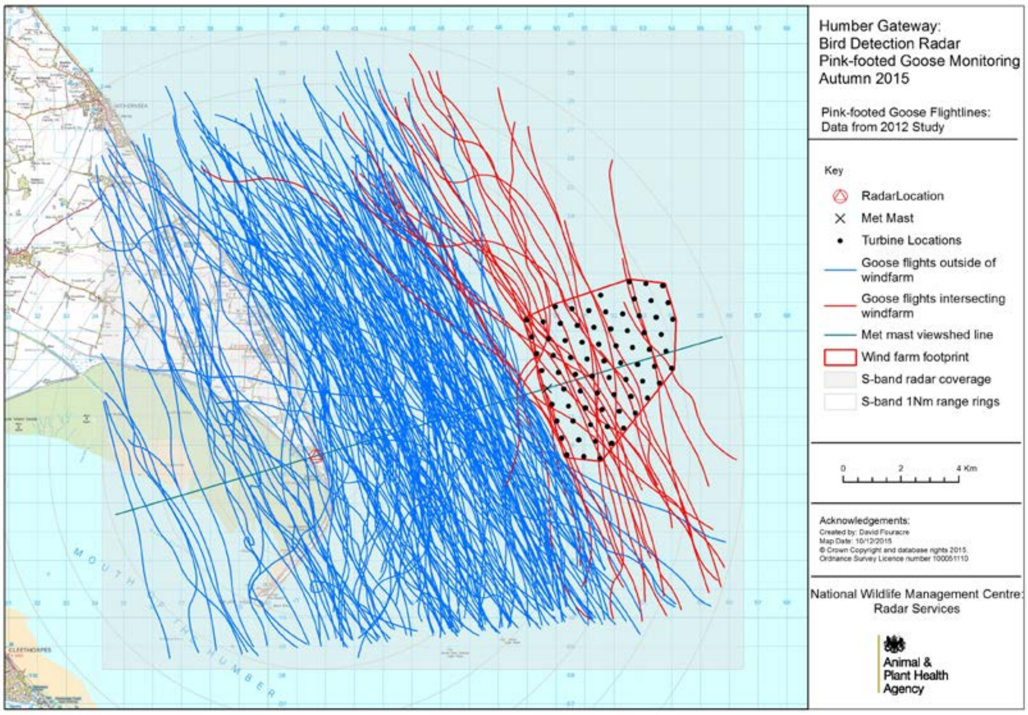

Figure 29. Map showing all tracks recorded during the study period 2012. Tracks that enter the wind farm footprint are in red.

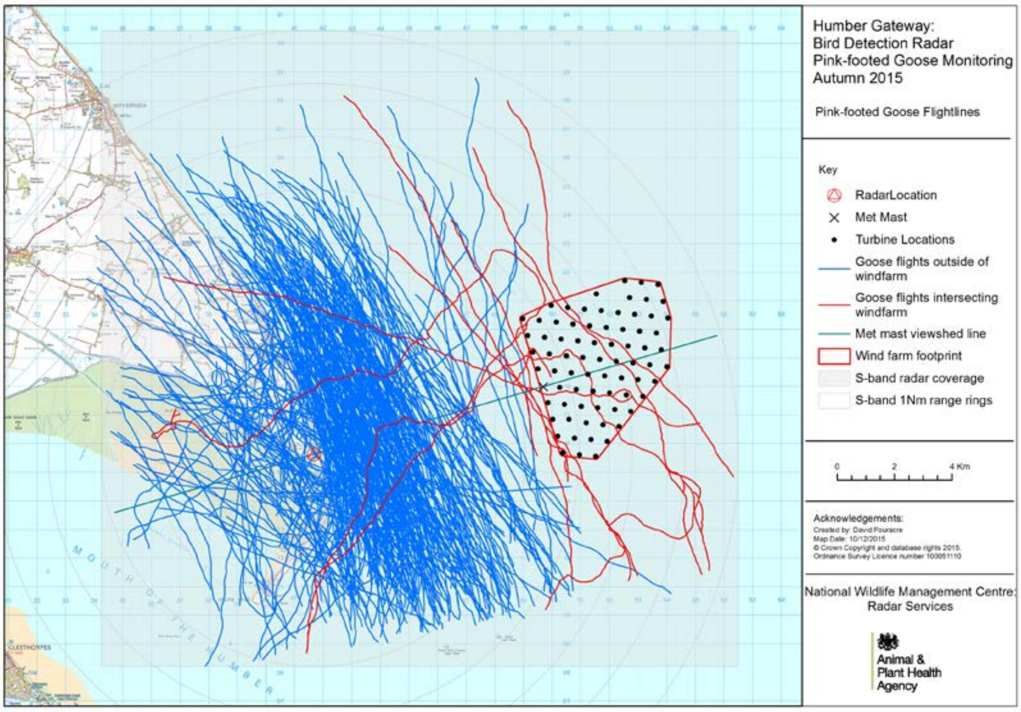

Figure 30. Map showing all tracks recorded during the study period 2015. Tracks that enter the wind farm footprint are in red.

3.4.4. Distribution of tracks in 2012 and 2015

Tracks recorded in 2015 were more concentrated towards the coast. All goose tracks from 2012 and 2015 were categorised into 1 nautical mile bands, using the nearest point to the wind farm footprint from each track. These bands, and the percentages of tracks that fell within them in 2012 and 2015, are shown in Figures 32 and 33, respectively.

A Kruskal-Wallis rank sum test was used to test whether there was a difference in the distances from the wind farm footprint that the Pink-footed geese flew between 2012 and 2015. This showed that there was a significant difference (Kruskal-Wallis chi-squared = 51.12, df = 1, p-value <0.001) (see Fig. 31): geese flew further away from the wind farm footprint and closer to the coast in 2015 than in 2012.

We also calculated the linear directional means for all tracks recorded for both sets of data, using the start and end points of each track. Each year was also assigned a measure of circular variance, which gives the variability of the underlying directions. The directional means for 2012 and 2015 are shown in Figure 34. Overall flight direction for both years was almost identical (SSW). However, the mean distance of the flightlines from the wind farm footprint is greater (by ~1nm) for 2015.

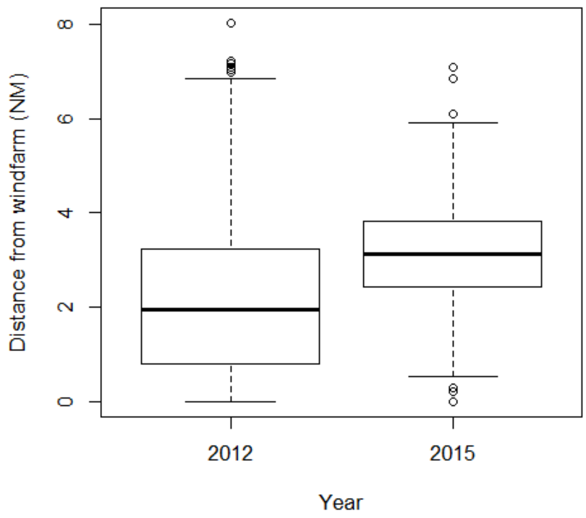

Figure 31. Boxplots showing the distance of goose tracks from the wind farm footprint in 2012 and 2015. The boxplots represent the median value (horizontal line), interquartile distances (boxes), non-outlier range (whiskers), and extreme values (points).

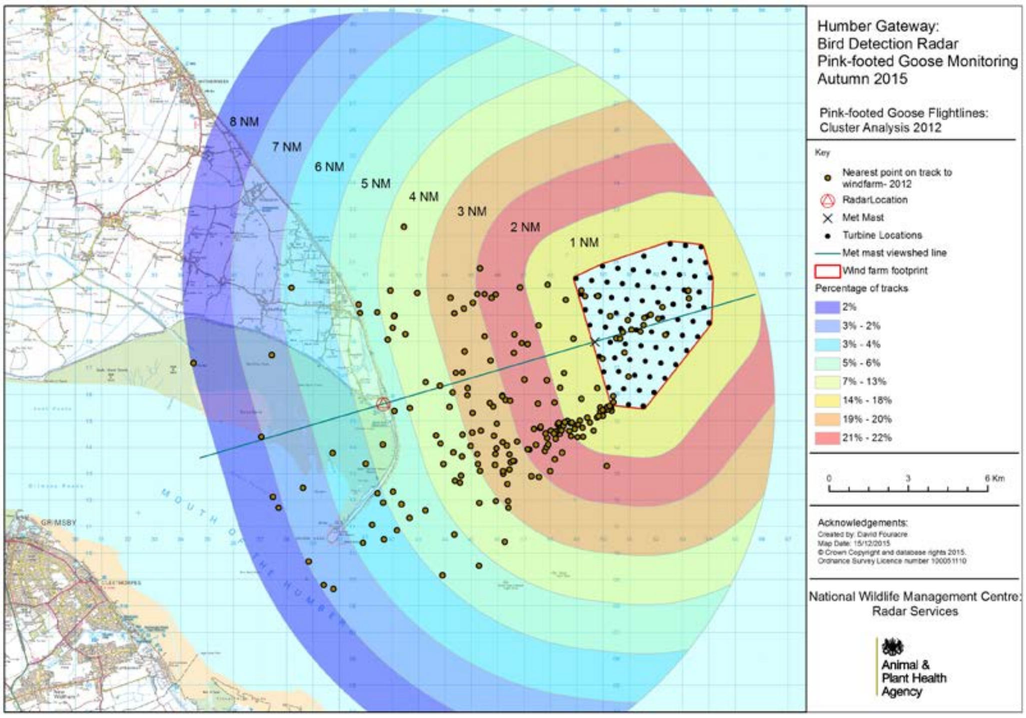

Figure 32. Map showing the 1 nautical mile bands used for the cluster analysis and the percentages of tracks recorded that fell within each for 2012. At this time, the wind farm was in pre-construction.

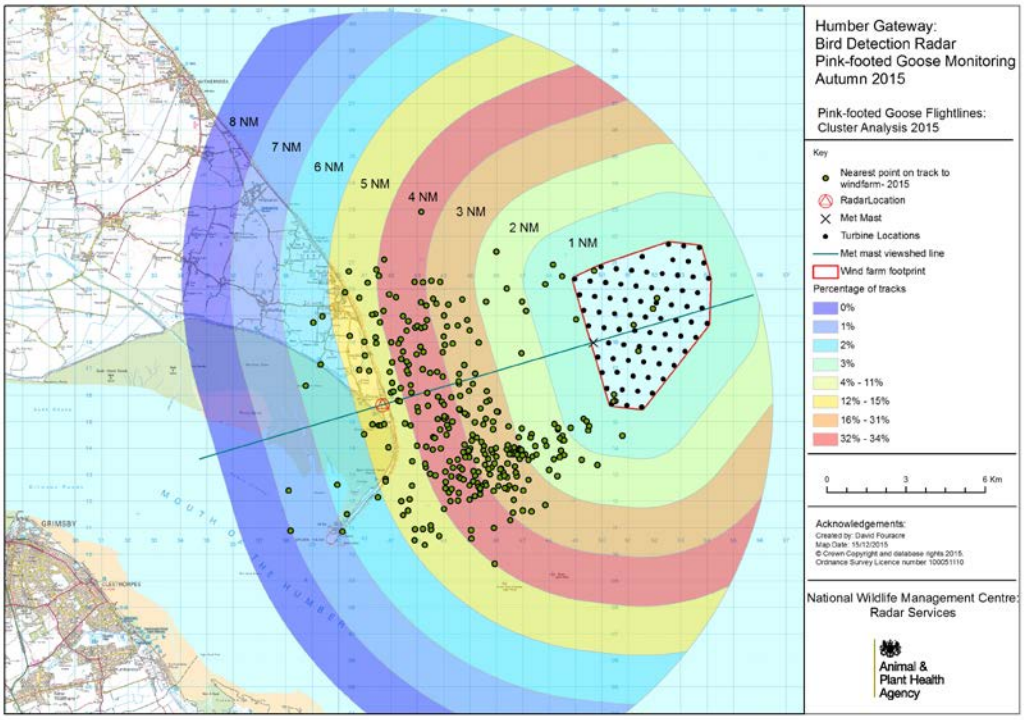

Figure 33. Map showing the 1 nautical mile bands used for the cluster analysis and the percentages of tracks recorded that fell within each for 2015.

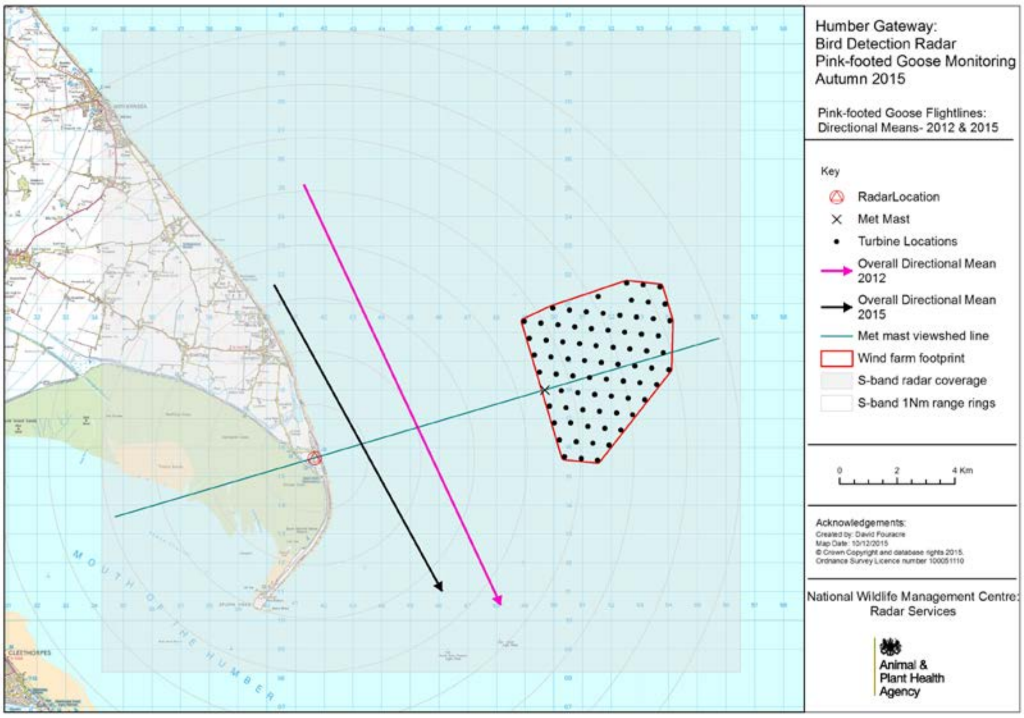

Figure 34. Map showing overall directional means for both study periods

3.4.5 Diurnal and nocturnal tracks recorded in 2012 and 2015

There were more nocturnal tracks detected in 2015 than in 2012. Out of a total number of 312 tracks detected in 2015, 137 (43.9%) were at night, compared to 18 out of 2015 (8.8% of tracks) in 2012.

Having categorised all goose tracks from 2012 and 2015 into 1 nautical mile bands (see section 3.4.4), a Bartlett test of homogeneity of variances was used to test whether the distribution of goose tracks was significantly different between day and night for 2012 and 2015 (see Fig. 35). In 2012, the distribution of goose tracks was significantly narrower at night than it was during the day (p=0.005393). In other words, the tracks were more concentrated towards the coastline at night. However, in 2015, there was no significant difference in the distance from the windfarm between day and night (p=0.08607).

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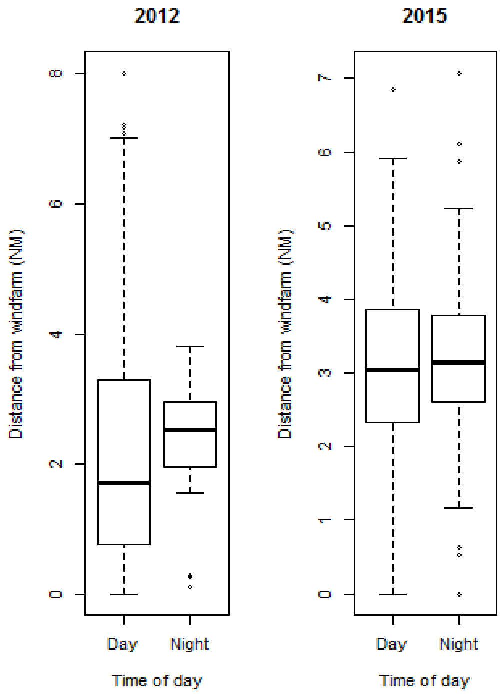

Figure 35: Boxplots showing distribution of goose tracks recorded during day and night in 2012 and 2015. The boxplots represent the median value (horizontal line), interquartile distances (boxes), non-outlier range (whiskers), and extreme values (asterisks).

3.4.6 Flight altitude in 2012 and 2015

In 2015, altitude data was recorded for 105 goose flocks (33.6 % of all goose flocks detected by the radar). Although altitude data was recorded for fewer flocks in 2012 (95), the percentage was higher (46.3%). This is a reflection of the higher percentage of nocturnal movements in 2015, when visual observations on flight altitude could not be made.

In 2015, 51 flocks (48.6% of all flocks with altitude data) were observed at altitude that would put them within the rotor-swept zone if they were within the wind farm footprint. This is a higher percentage than recorded in 2012, when 24 flocks (25.3% of all flocks with altitude data) were recorded at altitudes that would have put them within the rotor-swept zone. There were therefore nearly twice as many tracks recorded within the rotor-swept zone in 2015 as in 2012 (see Table 7). However, in 2015, tracks recorded within the rotor-swept zone were mostly flying close to the coastline and away from the wind farm footprint, and only one flock was observed to be within the rotor-swept zone and within the wind farm footprint.

4. Discussion

4.1 The effects of weather on migration

4.1.1 The effect of weather on the timing of migratory movements

Autumn migratory movements of geese are usually associated with favourable tail winds (in this case north-westerlies), decreasing temperature, increasing barometric pressure, and clear skies (Plonkzkier & Simms, 2012b; Wege & Raveling, 1983).

Pink-footed goose migration in 2015 occurred later in the season than usual. A BTO analysis of BirdTrack data showed that reports of arrivals of Pink-footed geese were delayed by about a week compared to historical data (BTO, 2015). The first autumn 2015 record at WWT's Martin Mere was on 11 September, compared to 30 August in 2012 (WWT, 2015) and first sightings at five regular visible migration watch points (Long Nab, Flamborough Head, Spurn Point and Oxenhope in Yorkshire, and Winter Hill. This apparent delay in migration could be explained by the fact that temperatures were relatively high in 2015 and were thus not forcing geese southwards.

The first peak in movements recorded by the radar on 25 and 26 September could be explained by the change in prevailing wind direction from west to east on the 25, slight drop in wind speeds (down to 1-2m/s at some points), and slight increase in barometric pressure. Visibility was also good on these days and there was no precipitation. This may have created more suitable conditions for migration. The decision to move on these days is also likely to have been affected by weather conditions further north, which must have been favourable, as the 25 and 26 September were busy days for Pink-footed goose migration around the UK, with 14,000 geese counted heading south-west on the coast of Angus, Scotland and 3100 nearby at Lintrathen, plus 2800 recorded south past Long Nab, Yorkshire and 1800 past Spurn Point.

The increase in activity from 31 October may be explained by a slight drop in wind speeds, and may also have been affected by weather conditions in other parts of the UK. On 1 - 2 November, 3,900 geese were counted heading south-east past Winter Hill towards Norfolk and 2,700 were counted south past Long Nab (RSPB, 2015). The final peak was observed between 18 and 21 November. This could be explained by the fact that the wind direction changed from south-west to west on 18 November (see Table 8 in the Appendix). Although not creating a tailwind, this may still have provided slightly better conditions for migration. The average daily temperature also dropped by just over 3 degrees between 19 and 20 November, and this may have encouraged geese to move south.

4.1.2 The effects of wind on migratory movements

The results indicate that geese preferred to move in westerly winds than in south-westerly winds, which could be because they faced less direct resistance. Movements in southerly winds mostly occurred during a period of extremely reduced visibility and wind direction is unlikely to have been the most important factor defining their trajectories. The lack of north-westerly tailwinds during the study period may have forced geese to move in less favourable winds. However, wind direction is unlikely to be the only factor influencing the times of their movements (see section 4.1.1).

Wind direction seems to have an effect on the trajectories of goose flocks migrating down the coast, as is to be expected (see Figs 22 – 26). This is likely as a result of geese being blown off their ideal with the results seeming to show geese being 'pushed' from their ideal course by the wind. It would be expected that the effect of wind direction would be increased with increased wind speeds, but in fact the results show that geese stayed closer to the coast in higher winds (see Figs 25 and 26). In these cases the geese may have responded to the difficult conditions by staying closer to shore, possibly using the coast to shelter from the worst effects of the wind.

4.1.3 The effects of reduced visibility on migratory movements

Goose tracks recorded during days when visibility was reduced by fog were erratic, did not follow the usual south-easterly trajectory, and changed direction often. Five of the tracks recorded during this time were heading north. Two of the tracks that intersected with the wind farm footprint occurred during this period (see section 3.3.7 tracks within the wind farm footprint).

The effect of fog on the geese's ability to navigate is known (Plonczkier & Simms, 2012a; Pendlebury, 2006; Marques et al., 2014) and is clear from these flightlines. This type of disorientation in migrating birds has been observed by previous radar studies, usually in conditions of low visibility such as fog (Alerstam, 1990). However, it is unlikely that the geese would have become so disoriented as to confuse north and south. In addition to the use of visual landmarks, migrating birds also use several other orientation mechanisms, including celestial and geomagnetic cues, which help to compensate in conditions of reduced visibility (Poot et al., 2008; Alerstam, 1990). When birds do become severely disorientated, they usually orientate correctly with respect to the north-south axis (Alerstam, 1990). The tracks recorded heading north are more likely to be those of geese that have turned back due to poor weather conditions.

Generally, geese tend not to migrate in conditions of reduced visibility. During the Humber Gateway 2012 study, no Pink-footed goose movements were recorded during the period of lowest visibility, while during a four-year study (2008-2011) of Pink-footed goose autumn migratory movements off the Lincolnshire coast, only 14 diurnal tracks were recorded in conditions of reduced visibility (Plonczkier & Simms, 2012a; Plonczkier & Simms, 2012b). The goose movement observed during this period of reduced visibility may be due to unfavourable weather conditions throughout the autumn leaving geese with fewer windows of opportunity in which to move. Wind speeds dropped at the end of October/beginning of November, and this might also have influenced their decision to move at this time (see Table 8 in the Appendix). The weather conditions may also have been different further north when the geese began their journey. Pink-footed geese were also recorded moving on these days elsewhere in the UK (see section 4.1.1). This would suggest that conditions overall were favourable to migration on these days, but that geese flew into a patch of fog encompassing the study area that affected their ability to navigate.

4.2 Avoidance behaviour

4.2.1 Macro-avoidance

Overall, the number of goose tracks to enter the wind farm footprint was low (8 out of 312). Fewer tracks occurred within the wind farm footprint in 2015 than during the pre-construction 2012 study (2.6 % of tracks in 2015, compared to 11.2% in 2012) and geese flew significantly closer to the coast (and further from the wind farm) in 2015 than in 2012 (see section 4.6). In addition, some tracks recorded in 2015 appear to show clear macro-avoidance behaviour with respect to the wind farm by altering their trajectories horizontally (see Fig. 35). Of the 8 recorded goose tracks that entered the wind farm footprint, 2 were made by flocks that were observed to gain altitude on approaching the wind farm and fly well above the rotor-swept zone (vertical avoidance). Five of the tracks that were recorded entering the wind farm footprint were not groundtruthed because they occurred at night or in periods of low visibility. Therefore, no flock size or altitude data for these tracks were recorded and there is no way of knowing whether vertical avoidance occurred. Only one goose track was groundtruthed entering the wind farm footprint within the rotor-swept zone (track D). Visibility was good on 10 November, when track D was recorded, so it is extremely unlikely that these geese could not see the wind farm. It is therefore uncertain why they did not take evasive action before reaching the wind farm and chose to fly through it. However, the wind was from the south-west and wind speeds were moderately high (daily average of 9.12 m/s), which may have pushed this flock towards a more easterly trajectory than it would otherwise have taken and caused it to intersect with the wind farm (see section 4.3.1).

The results suggest that Pink-footed geese migrating down the Yorkshire coast could usually see the Humber Gateway Wind Farm and take evasive action, either horizontally or vertically, before reaching it.

4.2.2 Micro-avoidance

Figure 28 shows that goose flocks that did enter the wind farm footprint often seem to have altered their trajectories horizontally to avoid individual turbines (micro-avoidance). Previous studies have shown that when geese do enter wind farms, over 99% avoid individual turbines (Croft et al., 2015). Unfortunately, we do not know whether they also took vertical evasive action within the wind farm, because 5 of these tracks were not groundtruthed and the one that was could not be observed once within the wind farm. Plonczkier & Simms (2012a) observed vertical avoidance in 84 out of 93 Pink-footed goose flocks within a wind farm in 2009 and 2010, so it seems likely that there will have been some vertical avoidance.

Only one track was groundtruthed within the wind farm footprint and within the rotor-swept zone (see section 3.3.7). The movements of this flock within the wind farm suggest that the geese altered their flightpath to avoid individual turbines. The two points of entry into the wind farm area and the point of exit were also all between turbines. Because there were no visual observations of the movements the flock made within the wind farm, there is no altitude data for this time, so it cannot be known whether the geese took vertical evasive action at all within the wind farm.

The ability of the radar to track geese within the wind farm footprint and thus to study micro-avoidance rates is limited, due to interference generated by the turbines themselves. Although the tracks detected by the radar within the wind farm footprint in this study represent the movements of the majority of the flock, the radar cannot be relied on to track each individual bird within the wind farm footprint. Also, without visual observations, flight altitude cannot be estimated, which means that any vertical evasive action will be missed.

With the exception of tracks E and F, which were observed to fly above the turbines, the possibility of collisions having occurred involving birds in the flocks represented by tracks A, B, C, D, G, and H cannot, therefore, be ruled out. Without altitude data for A, B, C, G, and H, the possibility that these birds were within the rotor-swept zone cannot be eliminated, and we know that flock D was at rotor height when they entered the wind farm footprint. Although part of track D was lost by the radar within the wind farm footprint, this does not necessarily mean that these birds collided with turbines, because the radar will struggle to track birds within the wind farm, particularly small numbers of birds. However, this also means that, although these tracks were all detected leaving the wind farm footprint, we cannot be sure of the numbers of birds involved. Individual birds may not be detected by the radar within the wind farm and therefore undetected individual collisions with turbines are possible. Visual observations of these flocks would be necessary to confirm or rule out such collisions. Modelling, ideally informed by the radar data, may also provide a better idea of micro-avoidance behaviour and therefore collision risk within the wind farm.

Interestingly, the tracks of the two flocks that were observed flying above the wind farm (see Fig. 28) also show a meandering trajectory that suggests a reluctance to fly above individual turbines even though they were well above the rotor-swept zone. Fieldworkers also noted that geese appeared to avoid flying directly over the radar.

4.3 The effects of weather on avoidance behaviour

4.3.1 The effects of wind on avoidance behaviour

Six out of the eight tracks recorded entering the wind farm footprint occurred when the prevailing wind was from the west or south-west. The remaining two occurred when the wind was from the south but at times of extremely reduced visibility, and it is likely that reduced visibility rather than wind direction was the primary factor causing these two tracks to intersect with the wind farm footprint. It appears that when the wind was from the west or south-west, geese were pushed further out to sea, and this made intersection with the wind farm footprint more likely. In the case of the flocks that were observed to use vertical avoidance of the wind farm (tracks E and F), it seems likely that these geese were being pushed out to sea by the strong westerly winds on 16 November, so that gaining altitude to fly above the turbines was easier than turning into the wind to fly around them.

4.3.2 The effects of reduced visibility on avoidance behaviour

Two of the eight goose tracks recorded as entering the wind farm footprint occurred in conditions of extreme fog, and 3 occurred in darkness or twilight, suggesting that reduced visibility was a factor in causing geese to intersect with the wind farm. The fact that the timings of many of these tracks coincide (with two tracks on 2 November, 2 tracks on 16 November, and 2 tracks on 19 November) confirms that weather conditions are likely to have been an important contributing factor.

The second of November, when two of the tracks to enter the wind farm footprint were recorded, was an extremely foggy day, with visibility recorded by fieldworkers as 0 for the afternoon. All of the tracks recorded on this day were erratic, suggesting that geese were having difficulty navigating in the fog (see section 3.3.6). Throughout their recorded trajectories, both tracks meander considerably, changing direction frequently, which suggests that the geese were finding it difficult to navigate. It has been well documented that geese find it difficult to navigate in conditions of reduced visibility and that collisions with turbines are more likely to occur at these times (Plonczkier & Simms, 2012a; Pendlebury, 2006; Marques et al., 2014) and it seems likely that these flocks intersected with the wind farm footprint because of the reduced visibility caused by the foggy conditions: they may simply have not seen the turbines. Within the wind farm footprint, both tracks appear to have passed mostly between turbines, so it is possible that at close range the geese were able to see the turbines and navigate successfully through them. One of these tracks (Track A) seems to intersect with one of the turbines slightly, but may just have been very close. The geese may also have been above or below the rotor-swept zone at this time.

It is possible that, having lost sight of the coast, the geese represented by these two tracks may have headed towards the wind farm deliberately. If this is the case, then they must have been attracted to it for some reason. It is not known whether the turbines were lit up at this time, but if they were it is possible that the geese were attracted by the lights. It is known that many species of birds are attracted to lit structures, particularly in darkness and fog, and particularly at sea, with white and red lights being the most powerful attractants (Poot et al., 2008; Marques et al., 2014). Most reports on the attractant effects of light have concerned migrating passerines, rather than waterfowl, however, and it is not known whether geese are susceptible or if they are, to what extent. It is also possible that the geese were attracted to the sound of waves breaking against the turbine bases which may have sounded like waves breaking against land.

4.4 Diurnal and nocturnal movement

Goose tracks were more concentrated towards the coastline at night than during the day in 2012. This is likely to be because migrating geese use landmarks to navigate and during the hours of darkness need to be closer to the land to see them. However, in 2015, there was no significant difference in the distribution of goose tracks between day and night. This is likely because, in 2015, all tracks (both day and night) were concentrated more towards the coast, possibly as a result of avoidance of the wind farm, which was still in pre-construction in 2012.

This study recorded much higher numbers of nocturnal tracks than previous studies. During the 2012 study, only 9% of flocks recorded were at night (2012b), and over a four-year study of Pink-footed goose autumn migration off the Lincolnshire coast, only 15% of all tracks recorded were at night (2012a). This contrasts with the 44% of nocturnal tracks recorded in this study. Numbers of nocturnal tracks were also higher at the end of November than they were in September.

Geese are often observed migrating at night and waterfowl in general have a flexible attitude towards migrating by day or night that has many advantages (Wege & Raveling, 1983; Alerstam, 2009). Turbulence and strong winds are often reduced at night, creating more favourable conditions for migration, and migrating by night increases the time available for daytime foraging (Wege & Raveling, 1983; Alerstam, 2009). There was also a full moon on 25 November, so moonlight levels would have been higher at the end of the study period, when the greatest numbers of nocturnal tracks occurred. Increased visibility due to moonlight has been reported as a factor influencing nocturnal migration in geese (Wege & Raveling, 1983). It is also possible that migration was delayed by unfavourable weather conditions to the extent that geese were forced to be more flexible in the timing of their migration, particularly towards the end of the study period.

4.5 Differences to usual Pink-footed goose autumn migration pattern in 2015

In addition to being later than normal (see section 1.1 & section 4.1.1), the 2015 autumn migration of Pink-footed geese in the UK seems to have followed a different pattern to most years, with more geese than normal taking the inland Pennines route south to the Humber Estuary. Data from regular migration watch sites showed that 15,600 Pink-footed geese were recorded migrating past Spurn Point in autumn 2012, while only 7,100 were recorded in 2015 (Trektellen, 2015). On 1 and 2 of November 2015, 2700 Pink-footed geese were counted at Long Nab (north of Scarborough), but only a few hundred were counted at Spurn Point. It would appear that a high proportion of migrating Pink-footed geese chose to divert inland from the coast near Scarborough. The reasons for this change are not known, but weather conditions are likely to have been influential.

4.6 Comparison between the 2012 and 2015 studies

Geese flew significantly further away from the wind farm footprint in 2015 than they did in 2012 and were more concentrated around the coast. Of the few tracks that were recorded flying further out at sea, some did intersect with the wind farm footprint. However, fewer tracks occurred within the wind farm footprint in 2015 than in the pre-construction 2012 study (2.6 % of tracks in 2015, compared to 11.2% in 2012). Some 2015 tracks also appear to show clear avoidance by altering their trajectories. Most had already moved closer to the coast before they were detected by the radar. This could be because geese flew closer to the coast in order to avoid the wind farm, which was still in pre-construction in 2012. It is also possible that geese took evasive action with respect to the Westermost Rough Wind Farm (approximately 9-13 nm north-west of the Humber Gateway Wind Farm), which did not exist in 2012 either (construction began in 2014 and was completed in 2015). This could explain why most goose tracks were already close to the coast when first detected 4-7 nm north-west of the radar and the Humber Gateway Wind Farm. Figure 36 shows the positions of both wind farms along with all tracks recorded in 2015.

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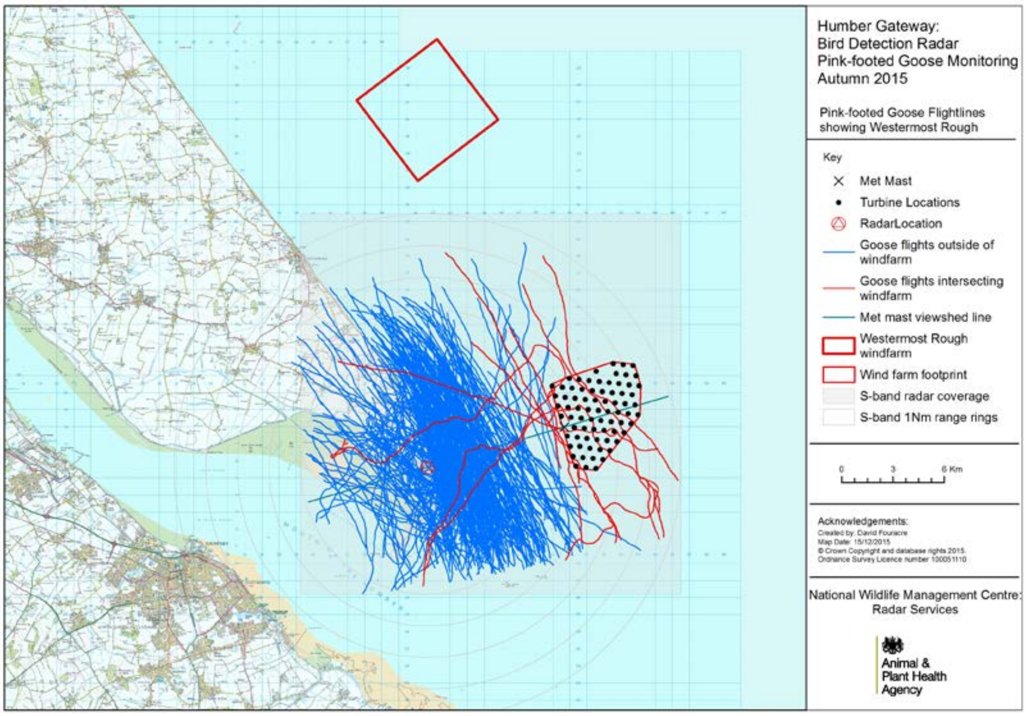

Figure 36. Map showing the wider context of the Humber Gateway Wind Farm, including the Westermost Rough Wind Farm footprint.

It cannot be claimed with absolute certainty that geese flew further from the wind farm footprint because they were avoiding the wind farm. Weather conditions, for example, may have been a factor. However, weather conditions were broadly similar in 2012 and 2015. If anything, the stronger westerly and south-westerly winds in 2015 should have been more likely to push the geese further east, although it is possible that they flew closer to the coast in high winds in order to take shelter. It is likely, however, that the geese in 2015 were taking clear evasive action with respect to the wind farm. Previous studies have shown similar avoidance in Pink-footed geese (Plonkzkier & Simms, 2012a; Plonkzkier & Simms, 2012b) and geese in general are usually good at avoiding wind farms, with collision rates low and usually restricted to poor weather and reduced visibility (Marques et al., 2014). In a four-year radar study of autumn migrating Pink-footed geese off the Lincolnshire coast, Plonkzkier & Simms (2012a) saw significant and increasing avoidance of the wind farm, while the 2012 Humber Gateway study (Plonkzkier & Simms, 2012b) noted avoidance of the vertical weather mast. It would therefore be expected that geese would exhibit avoidance with respect to the wind farm unless weather conditions were very poor, and this is what our results appear to show.

4.7 Validation of predicted avoidance and collision estimates

The ornithology impact assessment undertaken in the Environment Impact Assessment (EIA) phase of the project and reported in the Environmental Statement (ES) predicted that the impact of construction and operation of the Humber Gateway Offshore Wind Farm posed no significant impact to the population of Pink-footed geese. The results of the 2012 radar campaign completed during the pre-construction phase provided further evidence that the risk of collision was low, with only 1% of all tracks recorded to be within the offshore wind farm foot print and at rotor swept area. The 2015 radar campaign undertaken during operation corroborated those findings, with only 0.3% of all tracks recorded to be within the offshore wind farm footprint and at rotor swept area, and thus at risk of collision. The increasing avoidance behaviour observed in 2015 combined with the nearshore distribution movement observed during the 2012 and 2015 radar surveys therefore supported the ES which predicted no significant impacts due to avoidance and near-shore distribution.

With regards to collisions, it is of note that the predictions of no significant impact in the ES were based on a prediction of 519 collisions per annum and an increase in mortality rate of approximately 1.97% (at the British wintering population level), and based on the extreme worst case i.e. assuming that 25% of the east coast movement of 75,000 individuals move through the wind farm site at rotor height and assuming a 90% avoidance rate (Mander & Cutts, 2007). Since these predictions were made, evidence of avoidance behaviour and near-shore distribution during migration have been produced at other offshore wind farms along the east coast (Plonczkier & Simms, 2012a), and both confirmed the low collision risk of Pink-footed geese at existing offshore wind farms. Furthermore, in the light of the radar study findings at the Humber Gateway Offshore Wind Farm and other sites along the east coast, it is highly likely that the predictions of collision produced at the ES stage were extremely conservative, with the mortality rate expected to be lower than 2% in a more ecologically realistic scenario.

As for change in distribution, although the 2015 radar study shows increasing avoidance behaviour at the Humber Gateway Offshore Wind Farm, the displacement is of very limited impact on the overall distribution, given that the bulk of migration movement takes place inshore of the wind farm site. Again, this corroborates the findings of the ES which predicted no significant impact on distribution as it was expected at the ES stage that flock movements would more likely to be predominantly undertaken within 5 km of the coast.

5. Conclusion

The 2012 study was based on goose movements during the pre-construction of the offshore wind farm and the post-construction/post-functioning stage in 2015. Pink-footed geese flew further from the wind farm footprint (closer to the coast) during the 2015 autumn migration than they did in 2012. There were also fewer tracks recorded within the wind farm footprint in 2015 than in 2012. The results suggest that geese were exhibiting avoidance behaviour with respect to the wind farm. Furthermore, previous studies have shown increasing avoidance of wind farms by Pink-footed geese in the years following construction of (Plonczkier & Simms, 2012a).

However, there are other factors that could potentially have influenced goose movement in the area, such as weather conditions. Weather conditions overall were similar in 2012 and 2015, although temperatures were higher on average in 2015, and this may have delayed migration. The migration pattern of Pink-footed geese also seems to have been unusual in 2015, with more geese than usual taking an inland route to the Humber Estuary. The presence of the Westermost Rough wind farm to the north, which was also in pre-construction in 2012, may have influenced flight trajectories of geese before they reached our study area.

Regardless of the cause of the change in track distance from the windfarm the number of flocks within the windfarm footprint are very low. There were only 8 goose flocks recorded flying within the wind farm footprint in 2015 (2.6%) and only one of these flocks flew within the rotor-swept zone (0.325%). Therefore, taking into account the literature that geese exhibit avoidance behaviour, other factors that can influence goose movement, such as weather conditions, and the radar research suggest that the risk of collision and concern for the Pink-footed goose in the area of Spurn Point can be interpreted as very low in 2015.

The 2015 radar survey corroborated the findings of the ES which predicted no significant impacts to Pink-footed geese. The 2015 radar surveys indicated a low risk of collision due to a near-shore distribution (as shown in 2012).

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7. Appendix

Table 8. Summary of weather data for the 2015 study period

Date	Average wind speed (m/s)	Prevailing wind direction (8 pts)	Average temperature (°C)	Average pressure (bar)	Number of tracks recorded by radar
14/09/2015	5.62	E	12.6	0.987	0
15/09/2015	5.79	SW	11.9	0.996	0
16/09/2015	5.45	NE	12.3	0.984	0
17/09/2015	5.59	W	12.8	0.989	0
18/09/2015	3.81	NE	13.5	1.002	0
19/09/2015	2.89	NW	13.1	1.013	0
20/09/2015	2.70	W	13.8	1.011	0
21/09/2015	5.72	SW	11.8	0.996	0
22/09/2015	4.37	W	11.5	0.996	0
23/09/2015	5.62	W	12.7	0.993	0
24/09/2015	6.97	W	13.1	0.994	0
25/09/2015	5.28	W	12	1.004	42
26/09/2015	2.82	E	11.7	1.011	17
27/09/2015	3.37	E	13	1.017	4
28/09/2015	3.06	SE	13.2	1.019	0
29/09/2015	4.27	E	13.6	1.018	0
30/09/2015	5.47	E	13.7	1.016	0
01/10/2015	3.72	E	13.7	1.013	0
02/10/2015	2.76	SE	12.2	1.004	0
03/10/2015	3.35	NE	12.2	0.993	0
04/10/2015	3.06	E	11.3	0.991	0
05/10/2015	6.90	SE	12.8	0.982	0
06/10/2015	5.04	SE	13.6	0.974	0
07/10/2015	4.96	W	12.6	0.980	0
08/10/2015	4.08	W	11.4	0.993	6
09/10/2015	2.70	SE	12.3	1.000	1
10/10/2015	4.94	E	12.3	0.995	0
11/10/2015	7.59	E	11.5	0.992	0
12/10/2015	5.20	NE	11	0.992	1
13/10/2015	10.20	NE	10.3	0.996	0
14/10/2015	10.73	NE	10.3	0.995	0
15/10/2015	10.07	NE	10.9	0.993	0

16/10/2015	11.43	NE	11.1	0.993	0
17/10/2015	11.13	NE	10.7	0.991	3
18/10/2015	6.68	NE	10.3	0.995	1
19/10/2015	5.92	NE	11.5	0.994	0
20/10/2015	3.49	W	10.2	0.993	3
21/10/2015	6.88	SW	11.1	0.981	1
22/10/2015	6.99	W	11.4	0.981	0
23/10/2015	4.95	SW	9	0.986	0
24/10/2015	6.39	SW	9.2	0.979	1
25/10/2015	5.62	W	8.2	0.989	2
26/10/2015	6.05	SE	10.6	0.982	0
27/10/2015	5.72	SE	11.2	0.976	0
28/10/2015	4.37	SE	10.7	0.972	0
29/10/2015	7.52	S	10.7	0.975	0
30/10/2015	6.40	S	11.5	0.981	0
31/10/2015	3.79	S	10.8	0.986	1
01/11/2015	2.00	S	11.9	0.990	15
02/11/2015	3.64	S	8.1	0.985	9
03/11/2015	3.01	S	8.9	0.978	9
04/11/2015	2.42	S	10.2	0.974	9
05/11/2015	4.30	S	11.3	0.972	1
06/11/2015	5.68	SW	12.4	0.972	5
07/11/2015	7.85	SW	11.8	0.974	14
08/11/2015	7.53	S	10.1	0.977	2
09/11/2015	11.91	SW	10.8	0.972	1
10/11/2015	9.12	SW	13.9	0.975	14
11/11/2015	9.61	SW	12.4	0.975	7
12/11/2015	8.57	SW	10.9	0.975	4
13/11/2015	12.69	W	7.3	0.971	11
14/11/2015	9.52	SW	7.5	0.972	5
15/11/2015	10.75	SW	13.1	0.962	5
16/11/2015	9.83	SW	9.7	0.962	14
17/11/2015	9.68	SW	9.4	0.955	6
18/11/2015	11.72	W	9	0.960	17
19/11/2015	9.43	W	8.1	0.964	30
20/11/2015	10.22	W	5	0.959	47