Pink-footed Goose
Collision Risk Assessment:
Humber Gateway Offshore Wind Farm

Report to E.ON Renewables

Institute of Estuarine and Coastal Studies
University of Hull

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For and on behalf of the Institute of Estuarine and Coastal Studies

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1. INTRODUCTION

Internationally important numbers of pink-footed geese (*Anser brachyrhynchus*) winter in the northern parts of the UK, with key areas in north-eastern and eastern Scotland, south-west Scotland and north-west England and East Anglia. The main wintering population is currently centred on sites along the North Norfolk coast and in the Wash, as well as a further, smaller population on the Humber Estuary (Lack, 1986, Mander & Cutts, 2005). Despite the relatively small population wintering on the Humber, the species is part of the qualifying interest of the Humber Flats, Marshes and Coast SPA / Ramsar site. In recent years, flocks of up 6,500 individuals have been recorded on the Humber Estuary (Banks *et al.,* 2006), with the birds using the upper estuary to roost at night (Mander & Cutts, 2005). This recent increase in usage followed a localised population crash in the mid 1970s when a carbophenothion poisoning event affected a substantial proportion of the Humber population following the ingestion of treated winter wheat seed. Foraging activity by the species on the Humber is carried out during the day time on the farmland habitat surrounding the estuary (Allen *et al.,* 2003), with the flock remaining within the Humber roost area and adjacent feeding sites for the majority of the winter. The species is also recorded by the Spurn Bird Observatory , indicating that migratory movements also occur along the coast, presumably with for birds moving to and from wintering sites along the East Anglian coast. The ship-based survey programme undertaken for the Humber Gateway Offshore Wind Farm (HGOWF) (28 months of survey) recorded a few pink-footed geese within the survey area, with one flock of six birds recorded in November 2004 and one record of 39 birds in October 2005. On both occasions the birds were observed flying in a southerly direction inshore of the HGOWF site (Mander *et al.,* 2007). This survey programme employed the standard seabird census techniques for use on a boat platform as described by Camphuysen *et al.* (2003).

Using the data from the HGOWF survey programme, an assessment of the collision risk posed by the proposed wind farm was undertaken for several species observed to fly at rotor height (Mander & Cutts, 2007). This assessment did not include the pink-footed geese as the species was scarcely recorded during the survey programme. However, recent discussions with Natural England have highlighted collision risk as being a potential issue for migratory pink-footed geese populations associated with the East Anglian wintering population, particularly in the context of ‘in combination’ or ‘cumulative’ effects from flocks moving through several offshore windfarm sites as they undertake seasonal migration along the east coast of England. As such, E.ON Renewables has commissioned the Institute of Estuarine and Coastal Studies (IECS) at the University of Hull to assess the collision risk to the migratory pink-footed goose population of East Anglia posed by the proposed development of the Humber Gateway Offshore Wind Farm.

Data on the size and timing of recent east coast movements have been provided by Natural England (L. Burton of Natural England, emailed spreadsheet, 21-09-07) and Wetland Bird Survey data (Banks *et al.,* 2006). These data, together with operational information for the turbines provided by E.ON Renewables, have been input into the same collision risk model as that agreed between Scottish Natural Heritage (SNH) and the British Wind Energy Association (BWEA) for the prediction of collision risk for birds at wind farms (Band *et al.*, 2005; Percival *et al.*, 1999), with the risk of birds colliding with the turbines modelled for a “worst case scenario”, in accordance with the “Rochdale Approach”.

The aims of the present study have therefore been as follows:

- Establish the number of collisions for two migratory movement scenarios of pink-footed goose along the east coast of the United Kingdom using the current approved Band *et al.* model.

- Determine the annual predicted level of collision mortality and its impact on the pink-footed goose populations, in terms of additional rates of mortality to those populations.

The following text describes the basic assumptions and methods used to calculate collision numbers, together with the result of pink-footed goose mortality for the several scenarios and the additive effects of the losses due to collision.

2. BACKGROUND INFORMATION ON PINK-FOOTED GEESE

Pink-footed geese start to arrive in Britain during early to mid September with numbers building in early to mid October, when peak numbers occur at the major northern sites in the UK. The distribution of geese changes over the winter period with peak numbers at English sites recorded in mid-winter. From January / February there is a migration northwards with peaks in the northern UK sites during late March / April (Mitchell & Hearn, 2004; Fox *et al.,* 1994)).

Numbers of pink-footed geese in North Norfolk have increased since the early 1990s and in recent years approximately half the UK wintering population has been recorded from this area in mid-winter. A record count in North Norfolk of 147,250 birds was made in December 2004 (Banks *et al.*, 2006). The wintering populations of pink-footed geese in Britain are continuing to increase (Banks *et al.,* 2006).

Birds of the Humber wintering population moving south during the early part of the winter are unlikely to fly across the HGOWF site given its location over 8km off the coast. Similarly, given the flock's inner estuary location, it is considered extremely unlikely that significant regular offshore diurnal movements occur during the wintering period in relation to movements between feeding and roosting sites on and around the Humber.

However, within winter movements recorded from individually marked birds show movements between Scotland and North Norfolk (Fox, 1994) and observations from Spurn and during HGOWF ship-based seabird surveys, show that birds fly south and parallel to the east coast of England, probably towards the Wash and other areas along the North Norfolk coast (e.g. peak of *c.* 6,500 birds recorded flying south on 5 November 2005). Migrating birds have also been observed flying across Bridlington Bay and following the coast south (Geoff Carr, pers. comm., September 2007). Land-based sea watching is most likely to record birds within about 5km of the coastline (i.e. inshore of the HGOWF site). Data on the relative densities of pink-footed geese movements with distance from shore are not known. However, it would be expected, given the lateral coastal nature of the movement undertaken by the pink-footed geese down the east coast, that concentrations would be largely within sight of land, but with movements potentially 'cutting corners' across embayments and estuary mouths. As such, it is not expected that flock movements would be concentrated offshore, in the vicinity of the HGOWF site, but more likely predominantly undertaken within 5km of the coast. Scenarios for a range of relative densities of movement through the HGOWF have been included in the modelling analysis.

In addition to these coastal movement observations, ringing recoveries show that some of the birds recorded in North Norfolk have arrived there via sites in Lancashire, having flown cross-country rather than along the east coast of England (Wernham *et al.,* 2002), although an accurate quantification of the relative importance (in terms of movement numbers) between the East Coast route and the cross-country route are not possible.

Data have been provided by Natural England (L. Burton of Natural England, emailed spreadsheet, 21-09-07) for pink-footed goose movements past east coast observatories in the autumn and early winter of 2005 and 2006. These data indicate that *c.* 60,500 pink-footed geese moved down the east coast in the autumn of 2005, with a lesser amount in 2006, this reduction possibly reflecting a lower recording effort that year. Assuming that not all movements were recorded, it is suggested that a figure of *c.* 75,000 pink-footed geese may move down the east coast margin each year, with a similar number returning during the spring. This accounts for *c.* 50% of the total Wash / North Norfolk population, with additional movements into this area undertaken by flocks crossing the UK mainland, many from staging areas in south-west Scotland and north-west England. Scenarios for the modelling have included both a c. 50% population movement along the east coast based on the Natural England data, and for the entire population moving up and down the east coast as an extreme worst case.

2. METHODOLOGY

The Band *et al.* model employed in this study has been used as a standard tool to estimate the number of bird collisions with wind turbines over a period of time. The model employs two stages of calculation; the first stage estimating the overall number of birds passing the sweeping area of the rotor, and the second stage calculating the probability of collision for birds passing the area swept by the rotor blades (Band *et al.*, 2005). Detailed descriptions for the use of the collision risk model are set in a guidance document available on the Scottish Natural Heritage website (Scottish Natural Heritage, 2000). The methodology followed in the Humber Gateway Collision Risk Assessment Document complies with the rules set out in the aforementioned guidance document.

2.1 Stage 1: Number of Birds Flying Through the Wind Farm

2.1.1 Calculation of Risk Window

The risk window was identified as being the width of the wind farm perpendicular to the most likely migratory flight direction of birds through the development site (north south axis), multiplied by the maximum turbine height. Of the five layouts proposed by E.ON, ranging from the 3.6MW to up to 7.0MW, the 3.6MW layout was identified as being the worst case scenario in terms of the collision risk, as this scenario would involve the greatest numbers of turbines (83 in total).

2.1.2 Numbers of Birds Flying Through the Risk Window per Annum

The approach included the use of both a worst case expected passage population of pink-footed geese likely to move along the Yorkshire coast (estimated to be 75,000 birds based on data provided by Natural England) and the peak population of pink-footed geese recorded along the North Norfolk coast (estimated to be *c.*150, 000 birds based on numbers reported in the latest published WeBS reports) which will represent an extreme worst case.

Each of the above scenarios have then been considered assuming two migration movements (autumn and spring) along the east coast, and thus through the vicinity of HGOWF site. The use of a 90% avoidance rate has been applied in order to allow for pink-footed geese migration often occurring at night with a realistic worst case layout also used following Natural England comments.

Realistically, it is unlikely that all birds moving along the coast would move through the HGOWF site, with only a small percentage of the migratory movements in all likelihood actually passing through the wind farm (see above). Therefore, the modelling allows for three scenarios - assuming that 25%, 50% and 75% of the movement is actually through the wind farm site.

- 75% - an assumption that the movement is largely concentrated through the windfarm site, which would seem unlikely given observed movements, or alternatively, that there is a similar sized offshore movement to that observed from the coastal observatories, with most of these birds moving through the windfarm. Both are considered to be an unlikely scenario.

- 50% - assumption that the observed movement is channelled through the mid near shore c. 5-15km off shore due to weather conditions etc. with the windfarm representing half of this potential fly through area. Considered to be a worst case, but possible scenario.

- 25% - assumption that the observed movement of c. 75,000 is evenly distributed across the coastal margin of a c. 20km band with the windfarm consisting of c. 25% of this band. Considered to be a precautionary likely scenario, given that a movement biased towards the coast (e.g. inshore of the windfarm) would be potentially more likely.

Each of the above scenarios were then considered assuming two migration movements (autumn and spring) across the HGOWF site (i.e. 150,000 birds – 75,000 x2) with a further run for the extreme worst case of the whole North Norfolk population of 150,000 birds moving through the site in both directions.

Following a worst case scenario approach, all pink-footed geese were assumed to fly within the altitude range of the rotor sweep. However, again this is considered to be extremely unlikely.

2.1.3 NUMBERS OF BIRDS PASSING THROUGH THE ROTORS

The second stage of the model set-up required the calculation of the rotor area as a proportion of the risk window ($A = N \times \pi R^2$ - where N is the number of rotors and R is the rotor radius), in order to identify the number of birds passing through a potential rotor swept area (number of birds passing through risk window x proportion occupied by rotors). The numbers of birds passing through the rotor area was derived for the 3.6MW wind farm layout.

2.2 Stage 2: Probability of a Bird Being Hit when Flying Through the Rotor

2.2.1 PROBABILITY OF COLLISION

The probability of collision was calculated on the basis of the size of pink-footed goose species moving through the site (both length and wingspan), the breadth and pitch of the turbine blades, the rotational speed of the turbine and the flight speed of the bird. Bird flight speeds were taken from Campbell and Lack (1985) and body measurements from Cramp (1998).

A rotational speed of 13 evolutions per minute was considered to be the worst case scenario, as the probability of bird collision increases with the rotational speed, and this was applied to the model. The pitch of the blades is also variable and continuously re-positioned to take advantage of optimum conditions, e.g. depending on the direction of the wind. A pitch angle of 90 degrees was identified as being the worst case scenario for collision risk, and applied to the model. The chord width for the 3.6MW machine given by the constructor is estimated to approximate 5m (E.ON, 2006), and this was used in the model set-up.

Based upon the set-up criteria outlined above, the probability of collision with a turbine blade can then be combined with the expected number of bird passes through the rotor swept area, in order to produce an estimate of the likely collision rate.

2.2.2 COLLISION RATE

The probability of collision combined with the number of bird passes through the rotors produces an estimate of the likely collision rate, although this is without any 'avoidance behaviour' by an individual or flock being taken into account. As such, the inclusion of an avoidance factor into the data can offer a more realistic prediction of the probable number of avian collisions. The avoidance factor represents the proportion of birds which are likely to take effective avoiding action. For example a 90.00% avoidance factor would mean that nine out of ten birds flying towards a wind farm would avoid the obstacle and one would enter the wind farm site and thus potentially be at risk of colliding with the turbines.

With the exception of the 87.00% avoidance factor reported at night (Winkelman, 1990), Table 1 shows that avoidance factors derived from direct observations and fatality calculations are all above 97.00%, with the majority at 99.00% and above. These values can be considered as ecologically reasonable as these collision factors are derived from existing wind farms. However, the absence of detailed avoidance factors for pink-footed geese meant that a precautionary approach was followed by using a collision factor of 90.00% to estimate the potential collision risk with the wind farm. An avoidance factor of over 95.00% and probably around 99.00% would provide a more realistic collision scenario.

Table 1: Direct Observation of Avoidance at Onshore/Coastal Wind Farms

	Avoidance factor	**References**
Direct observation of avoidance	100.00% - Barnacle, Greylag & White-fronted Geese (Sweden).	(Percival, 1998)
	99.00% - migrating birds - diurnal and nocturnal data - (Holland).	(Winkelman, 1992a)
	97.50% - waterfowl and waders (Holland).	(Winkelman, 1992b; 1994)
	87.00% - waterfowl and waders at night (Holland).	(Winkelman, 1990)
Calculated avoidance factor	99.00% - avoidance reported for waterfowl, waders and Cormorants (i.e. recorded fatalities compared with measured utilisation rates).	(Percival, 2001)
	99.0% - waterfowl, waders and Cormorants (UK).	(Percival, 2001)
	99.93% - Goose (USA). This is a mean of avoidance factors determined at four wind farm locations (Buffalo	(Fernley *et al.*,

	Ridge - 100.00%; Stateline - 99.91%, Klondike - 99.82%; and Nine Canyons - 100.00%)	2006)

2.3 Stage 3: Annual Level of Collision Mortality and its Impact on Bird Populations

To place the numbers of predicted avian collisions into context and help determine if such mortality levels could be ecologically significant, estimates of the overall annual mortality of each species are given (BTO, 2007), together with a calculation of additional mortality that the operation of the wind farm might have above natural mortality levels.

3. RESULTS

3.1 Predicted Numbers of Collisions per Annum

The following outputs have been calculated using the methods outlined in the above sections. Detailed calculations can be found in Appendices 1 & 2.

3.1.1 NUMBERS OF BIRDS PASSING THROUGH THE ROTOR AREA

The data used for the model are based on data provided by Natural England on the east coast passage numbers (L. Burton of Natural England, emailed spreadsheet, 21-09-07) and population estimation based on the WeBS core counts (Banks *et al.*, 2006). Predictions of the numbers of birds expected to pass through the rotor area are given in Table 2.

Table 2: Numbers of birds passing through the rotor area per annum for the different scenarios.

Scenarios	1 - East coast movement of 75,000 individuals			2 - North Norfolk population movement of 150,000 individuals		
% assuming to fly though wind farm	25%	50%	75%	25%	50%	75%
No. passing through rotors pa	**41,008**	**82,015**	**123,022**	**82,015**	**164,030**	**246,046**

All values rounded to the nearest whole number

It must be emphasised that at this stage of the modelling sequence, the figures represent the numbers of birds which may collide with the rotors, with the probability of a bird being hit when flying through the rotor area yet to be incorporated into the calculation.

3.1.2 PROBABILITY OF BIRDS BEING HIT WHEN FLYING THROUGH THE ROTOR

This stage computes the probability of a bird being hit when making a transit through a rotor. The probability depends on the size of the bird (both length and wingspan), the breadth and pitch of the turbine, the rotation speed of the turbine, and the flight speed of the bird. A probability of pink-footed collision of 12.65% was calculated for the worst case scenario, as descried in previous sections and in accordance with the Rochdale Approach. Detailed calculations are found in Appendix 2.

3.1.3 NUMBER OF BIRDS PREDICTED TO COLLIDE WITH THE WIND FARM

Based on a 90.00% avoidance rate, Table 3 shows numbers of expected collisions to range from 1,038 to 3,112 collisions at the extreme worst case scenario this is assuming that the whole North Norfolk population pass through twice a year. The more realistic movement of 75,000 individuals would result in the numbers of collisions to range from 519 to 1,556 birds per year (Table 3).

Table 3: Number of pink-footed geese predicted to collide per annum based on a 90% avoidance rate.

Scenarios	1 - East coast movement of 75,000 individuals			2 - North Norfolk population movement of 150,000 individuals		
% assuming to fly though wind farm	25%	50%	75%	25%	50%	75%
No. of collisions pa	**519**	**1,038**	**1,556**	**1,038**	**2,075**	**3,112**

All values rounded to the nearest whole number

3.2 Annual Level of Collision Mortality and its Impact on the Pink-Footed Goose Wintering Population

The results of the collision risk assessment for the east coast migrant pink-footed goose population are given in Table 4. These have been expressed as the predicted number of collisions per year, based on avoidance rates of 90%. For each scenario, the additional mortality is examined in the context of the British winter population (wintering birds). To put this into context and help determine if such mortality levels would be significant, annual adult mortality rates are given (BTO, 2007) with the percentage difference that the predicted additional mortality from the proposed wind farm operation would produce, also calculated.

As expected, the potential for the greatest impact on the British wintering population is for the extreme worst case scenario. The 3,112 deaths per year estimated using a 90.00% avoidance factor in the prediction equates to an increase in mortality of 11.83% in the British wintering population (Table 4).

Table 4: Annual level of collision mortality based on a 90.00% avoidance in the context of the British wintering population

Scenarios	1- East coast movement of 75,000 Individuals			2- North Norfolk population movement of 150,000 Individuals		
% assuming to fly though wind farm	25%	50%	75%	25%	50%	75%
Predicted Collisions per annum	519	1038	1556	1038	2075	3112
British population	192,000	192,000	192,000	192,000	192,000	192,000
% Additive mortality [1]	0.27%	0.54%	0.81%	0.54%	1.08%	1.62%
Annual mortality	13.70%	13.70%	13.70%	13.70%	13.70%	13.70%
% Increase in mortality [2]	**1.97%**	**3.95%**	**5.92%**	**3.95%**	**7.89%**	**11.83%**

Note[1] % additive mortality = collisions per annum / British population.
Note [2] % increase mortality= % additive mortality / annual mortality

4. DISCUSSION

Although difficult to determine accurately, given the caveats surrounding the derivation of the Band *et al* model and the extreme worst case scenario modelling discussed in Sections 1 and 2, it is considered that the collision rates estimated from the above studies allow a reasonable indication of the order of magnitude of bird mortality levels likely to be encountered at the proposed Humber Gateway Wind Farm site, based on data provided by Natural England and population estimates derived from the WeBS core counts. However, it is emphasised that these figures are for a series of extreme worst cases, based on the potential 'funnelling' of birds through the offshore wind farm, a very low avoidance factor and a flight height bringing all movements within the rotor swept area.

The outcomes from the model and associated population impact calculations would suggest that the elevated mortality rates would lead to excessive impacts on the British wintering population of pink-footed geese based on the set-up criteria.

However, it must be emphasised that the collision risk model is based on the assumption that an extremely large proportion of the British population will pass through a relatively narrow flight corridor (the wind farm site, at an elevation that presents all birds to the rotor sweep and with a very low avoidance factor). All of these components in their own right have been used in the context of a worst case, and thus the likelihood of all three worst case scenarios for these key components combining is considered to be negligible.

It may be necessary to decouple some of these components within the modelling process in order to get a more realistic worst case, based on a more likely avoidance factor (95% or above) and with a variation in flight height reflecting real world scenarios, e.g. many long distance migration flights by geese are carried out at altitudes above the rotor swept height, and in many cases at an altitude of well over 1000m (e.g. Ebbinge & Buurma, 2000). Alternatively these more focussed parameters could be applied post modelling in order to provide a more transparent analysis and assessment process.

As the migration of pink-footed geese is ongoing and winter movements will occur over the coming months, it would also be possible to undertake some more focused surveys (land observations and boat based combined) to help inform the issue of the proportion of the geese which are likely to cross the HGOWF site.

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6. APPENDICES

Appendix 1: Pink-footed goose Collision Risk Model for the Humber Gateway Offshore Wind Farm

1. Wind farm characteristics

Rotor diameter: 107m
Rotor height: 83m
No Turbines: 83
Numbers of Blades: 3

2. Red-throated Diver characteristics

Bird Speed: 19 m/sec
Bird Length: 0.68m
Wing Span: 1.52m

3 Number of birds flying through the wind farm

3.1 Calculation of risk window

Risk window = width of wind farm perpendicular to the general flight direction * maximum turbine height
Risk window = 5000m*136.5m
Risk window = 682500 m^2

3.2 Numbers of birds flying through risk window per annum

3.3 Numbers of birds passing through the rotors

3.3.1 Proportions of risk window occupied by rotors

Rotor swept area = No of turbines*(rotor dimater/2) ^{2}*π
Rotor swept area = 83 *(107/2) ^{2}*3.14
Rotor swept area = 746337.9565
Rotor proportion = Rotor swept area/risk window
Rotor proportion = 746337.9565/682500 m^2
Rotor Proportion = 1.093535467

3.3.2 Number of birds passing through the rotor area per annum

No passing through rotors = No per annum flying through risk window * Rotor Proportion
No passing through rotors = 225000* 1.093535
No passing through rotors = 246045.5

4. Probability of a bird being hit when flying through the rotor

See appendix 2

5. Predicted numbers of collision per annum (no avoidance rate)

No of collision per annum = No passing through rotors * Probability of collision
No of collision per annum = 246045.5 * 12.65%
No of collision per annum = 31114.68

Appendix 2: Calculation of Collision Risk for pink-footed goose Passing Through the Rotor Area

K: [1D or [3D] (0 or 1)	1	
No Blades	3	
Max Chord	5	m
Pitch (degrees)	90	
Bird Length	0.68	m
Wingspan	1.52	m
F: Flapping (0) or gliding (+1)	0	
Bird speed	19	m/sec
Rotor Diam	107	m
Rotation Period	4.60	sec
Bird aspect ratio: β	0.44	

Calculation of alpha and p(collision) as a function of radius

r/R radius	c/C chord	α alpha	Upwind: collide length	Upwind: p(collision)	Upwind: contribution from radius r	Downwind: collide length	Downwind: p(collision)	Downwind: contribution from radius r
0.025	0.575	10.40	18.68	0.64	0.00080	18.68	0.64	0.00080
0.075	0.575	3.47	8.14	0.28	0.00210	8.14	0.28	0.00210
0.125	0.702	2.08	6.67	0.23	0.00286	6.67	0.23	0.00286
0.175	0.860	1.49	6.56	0.23	0.00394	6.56	0.23	0.00394
0.225	0.994	1.16	6.73	0.23	0.00520	6.73	0.23	0.00520
0.275	0.947	0.95	6.17	0.21	0.00582	6.17	0.21	0.00582
0.325	0.899	0.80	5.71	0.20	0.00637	5.71	0.20	0.00637
0.375	0.851	0.69	5.31	0.18	0.00684	5.31	0.18	0.00684
0.425	0.804	0.61	4.95	0.17	0.00722	4.95	0.17	0.00722
0.475	0.756	0.55	4.61	0.16	0.00752	4.61	0.16	0.00752
0.525	0.708	0.50	4.29	0.15	0.00774	4.29	0.15	0.00774
0.575	0.660	0.45	3.99	0.14	0.00787	3.99	0.14	0.00787
0.625	0.613	0.42	3.74	0.13	0.00803	3.74	0.13	0.00803
0.675	0.565	0.39	3.51	0.12	0.00812	3.51	0.12	0.00812
0.725	0.517	0.36	3.27	0.11	0.00813	3.27	0.11	0.00813
0.775	0.470	0.34	3.03	0.10	0.00806	3.03	0.10	0.00806
0.825	0.422	0.32	2.79	0.10	0.00790	2.79	0.10	0.00790
0.875	0.374	0.30	2.55	0.09	0.00766	2.55	0.09	0.00766
0.925	0.327	0.28	2.31	0.08	0.00734	2.31	0.08	0.00734
0.975	0.279	0.27	2.07	0.07	0.00694	2.07	0.07	0.00694

Overall p(collision) = **Upwind** **12.6%** **Downwind** **12.6%**

Average **12.6%**