AVOIDANCE RATES FOR WINTERING SPECIES OF GEESE IN SCOTLAND AT ONSHORE WIND FARMS
# Table of contents

<table>
<thead>
<tr>
<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>Background &amp; Purpose</td>
<td>3</td>
</tr>
<tr>
<td>Method adopted</td>
<td>4</td>
</tr>
<tr>
<td>AES Geo Energy Wind Farm</td>
<td>7</td>
</tr>
<tr>
<td>Literature review (includes summary of findings from Rees (2012)</td>
<td>8</td>
</tr>
<tr>
<td>Assessment and analysis</td>
<td>12</td>
</tr>
<tr>
<td>Recommendation for changing the default Avoidance Rate for Wintering Geese</td>
<td>13</td>
</tr>
<tr>
<td>References</td>
<td>16</td>
</tr>
<tr>
<td>Annex 1: US wind farms used in analysis</td>
<td>18</td>
</tr>
</tbody>
</table>
This document discusses and recommends a revised avoidance rate for wintering geese which may encounter operational onshore wind farms in Scotland. It assumes that readers will have a basic understanding of the collision modelling approach recommended by SNH and adopted in many environmental assessments for proposed wind farm developments. While the recommended avoidance rate should be applied to onshore developments, it is suggested that its application to offshore developments is likely to be justifiable, given the current state of knowledge.

**Summary Position**

SNH recommends that an avoidance rate used in the currently used Band (SNH) collision risk model for wintering geese at onshore wind farms is set at 99.8%.

**Background & Purpose**

1. Applications for onshore wind farms continue to require assessment from SNH staff given their potential impact on breeding and wintering bird populations. Indeed, the number of applications shows little sign of declining and the additional problem on assessing cumulative impacts adds to the challenges faced by SNH staff when making such assessments.

2. Experience has shown that species of greatest concern in most environmental statements are raptors, waders (breeding predominantly) and wintering waterfowl, especially geese and swans. One of the key reasons for this is that Scotland hosts large numbers (many thousands) of wintering geese and swans, especially pink-footed geese, greylag geese (Icelandic as well as native breeding individuals) and species of conservation concern such as barnacle geese, white-fronted geese (Greenland sub-species) and a few pale-bellied brent geese.

3. A particular problem encountered with wintering geese is that the sheer size of the wintering population means that many wind farm proposals located in agricultural areas overlap with wintering geese (especially grey geese). Such overlap means that effects such as collision, displacement and disturbance must be taken into account. While impacts that arise from individual developments are invariably small, the number of developments means that cumulative impacts can reach significant levels for some species in some areas, at current default avoidance rates for wintering geese.

4. In 2006, SNH commissioned the BTO to review a paper (unsolicited) from John Fernley, Stuart Lowther and Phil Whitfield (Fernley et al., 2006) which re-evaluated the likely avoidance rate used in the SNH approach to estimation collision mortality (Band et al., 2007). The summary position emanating from the BTO review is set out later (extract taken verbatim from the BTO report). The full report is available on the BTO web site.

5. SNH staff in 2006 evaluated the report and concluded that changing the default avoidance rate from 95% was justified but we did not support the value advocated in the Fernley paper and recalculated in the BTO report. (It is important to note that BTO did not advocate any particular value, but simply reviewed the evidence base). SNH took a decision to adopt a precautionary avoidance rate of 99%. This was based on a number of separate factors:

   a) The data were largely based on casualty studies from the USA (on Canada and snow geese).
b) The data were not corrected for factors such as carcass losses and searcher efficiency, although BTO looked at the sensitivity of the avoidance rate to changing carcass numbers by increasing the number found to reflect 'missing' casualties.

c) There were few European data that suggested that conditions at US farms were broadly similar to those in Scotland/Europe.

d) It was believed that adopting a precautionary value for the avoidance rate reflected residual uncertainty and the level of statutory protection (site or species) that wintering geese possess.

6. Since this decision was taken, six years have elapsed during which further data have been collected, especially in Europe. Furthermore, it is increasingly apparent that use of an avoidance rate of 99% in collision risk models does not reflect levels of mortality that are being detected at operational wind farms. The consequences of this are that collision risk models appear now to exaggerate mortality, leading to two difficulties: predicted mortality assessments (especially cumulative assessments) become more inaccurate; and secondly, collision risk modelling itself becomes distrusted by key stakeholders (i.e. by developers, consultants and academics), thereby devaluing the insight into likely effects that it can offer in environmental assessments. While collision risk models have frequently been accused of under-estimating collision mortality, there is no evidence of this.

7. There are two main ways that models can over-estimate collision mortality. Firstly they can over-estimate the collision probability derived from the Band Collision Risk Modelling (CRM) spreadsheet. The reason for this is that models tend to assume that flight heights are evenly distributed across the rotor plane when in fact most goose movements occur at relatively high altitudes; therefore proportionally more flights occur towards the outer part of the rotor plane. This will reduce collision risk. Secondly they can under-estimate avoidance, and therefore avoidance rates, so collision mortality is likely to be estimated high.

8. This note re-examines the current avoidance rate for geese recommended by SNH and proposes a new value that reflects the improved evidence base available on goose collisions with operational wind turbines.

Method adopted

9. As part of the review a number of key factors were addressed. These included the following:

i) Review wind farm projects looked at in the Fernley et al. paper and the BTO report. These are:
   a) Stateline Wind project (US);
   b) Buffalo Ridge (US);
   c) Top of Iowa (US);
   d) Klondike (US);
   e) Nine Canyons (US); and
   f) Kreekak (Netherlands).

ii) A review of recent publications from US and Europe on geese and wind farms, though the requirement for much of this element was reduced because of the Rees (WWT) review, now published in Wildfowl (Rees, 2012);
Checking the EU database of casualties compiled by Tomas Durr, Brandenburg, Germany (see later for web address and details of this).

10. The information from the above was synthesized into a recommendation for a revised avoidance rate for wintering geese. For the avoidance of doubt there are two options:

- Retain the existing avoidance rate (i.e. do nothing); or
- Revise *upwards* the avoidance rate for wintering geese, to a value that may more accurately reflect ‘true’ avoidance.

**The Fernley et al. (2006) paper and subsequent BTO review report (Pendlebury, 2006)**

11. Using data from wind farms in the US, Fernley et al. (2006) calculated that goose avoidance rates were likely to be of the order of 99.9%. Before adopting this value SNH asked BTO to undertake a review of the paper. The BTO report (Pendlebury, 2006) identified a number of key shortcomings in both the analysis and the data used to derive avoidance rates. It was difficult to use the available bird flight data to derive figures that could be incorporated into the CRM and as already stated, carcass searches were incomplete and did not account for searcher efficiency or carcass loss (e.g. due to predators). Indeed the collision victims identified were all found as incidental outcomes from other work at the wind farm. Despite this, Pendlebury (2006) re-calculated avoidance rates, deriving figures that were still high but lower than those suggested by Fernley et al. (2006). Box 1 reproduces relevant text from Pendlebury (2006), directly from the BTO report (with some minor editing). **Values given in the report have not been changed.**


The following estimates of avoidance rates are based on the four wind farm sites at which both bird-use and corpse surveys were carried out (Stateline, Buffalo Ridge, Klondike and Nine Canyons wind farms). Top of Iowa and Kreekak wind farms have been excluded since data were not available for bird-use. I agree with Fernley et al. (2006) that, even though the avoidance rate at the Top of Iowa could be assumed to be 100 % since no goose fatalities were found, the use of this site would introduce a bias in that for wind farms without bird-use data, avoidance rates can only be determined when they are 100 %.

Fernley et al. (2006) calculated a mean avoidance rate of 99.93 % (Stateline wind farm: 99.91 %; Buffalo Ridge wind farm: 100 %; Klondike wind farm: 99.82 %; and Nine Canyons wind farm: 100 %). I have calculated mean avoidance rate for Canada goose using two methods (equations [1] and [2]) of calculating the mean distance through an 800 m radius vantage point viewing area. Using equation [1], mean Canada goose avoidance rate was calculated as 99.91 % (Stateline wind farm: 99.89 %; Buffalo Ridge wind farm: 100 %; Klondike wind farm: 99.81 %; and Nine Canyons wind farm: 100 %). Using equation [2], mean Canada goose avoidance rate was calculated as 99.89 % (Stateline wind farm: 99.87 %; Buffalo Ridge wind farm: 100 %; Klondike wind farm: 99.77 %; and Nine Canyons wind farm: 100 %). Both equations [1] and [2] resulted in
similar estimates of avoidance rate. These were lower than the value calculated by Fernley et al. (2006): our figures suggest collision rates of 1.22 to 1.51 times greater than those of Fernley et al. (2006).

It is important to note that in these calculations (Table 3.2-1) I have followed Fernley et al. (2006) in including the incidentally-discovered fatalities at Stateline and Klondike wind farms. If these had not been included, avoidance would have been calculated as 100 % at all sites. This suggests that the survey period for corpse searches, the number of search plots, and/or the frequency of searches need to be increased in order to observe these rare events, and produce reliable estimates of avoidance rates.

Confidence intervals were calculated for corpse search completeness for both Stateline and Klondike wind farms — 95 % confidence intervals for Stateline wind farm and 90 % confidence intervals for Klondike wind farm. It should be noted that if 95 % confidence intervals had been derived for Klondike wind farm, rather than 90 %, the intervals would have been slightly wider. The upper and lower values of these stated intervals were used to investigate the impact on avoidance rates for the two sites, and mean avoidance rate (table 3.2-1). The mean avoidance rates using these values were 99.82 to 99.95 using equation [1], and 99.79 to 99.94 using equation [2].

To investigate the possibility that corpses were not detected, and the effect of corpse search completeness being relatively low for some sites (Buffalo Ridge wind farm especially), N CORPSE was increased by ten for each site, to look at the effect of there being up to ten unfound corpses, on each of the avoidance rate estimates. The mean avoidance rate value for Stateline wind farm decreased from 99.89 % to 99.64 % using equation [1], and 99.87 % to 99.55 % using equation [2] (Table 3.2-2). The mean avoidance rate value for Buffalo Ridge wind farm decreased from 100.00 % to 99.70 % or 99.63 %, using equation [1] and equation [2] respectively (Table 3.2-2). The mean avoidance rate value for Klondike wind farm decreased from 99.81 % to 99.35 % using equation [1], and 99.77 % to 99.20 % using equation [2] (Table 3.2-2). The mean avoidance rate value for Nine Canyons wind farm decreased from 100.00 % to 96.76 % or 96.26 %, using equation [1] and equation [2] respectively (Table 3.2-2). The avoidance rate estimate for this latter site was the most sensitive due to N COLL being relatively small. A total of ten unfound corpses at any site would decrease overall avoidance rates from 99.91 % to 99.81 % using equation [1], and from 99.89 % to 99.77 % using equation [2], producing an estimate of 2.20 times more goose collisions.

There are a number of important points raised here. These are:

- Avoidance rates calculated at wind farms in the US where there are some data on collisions and flight activity, all suggest avoidance rates are greater than 99%.
- Casualties used in the analysis were found incidentally, not through targeted survey work; and
- Even assuming the actual number of casualties was underestimated, by the addition of 10 ‘unfound’ corpses, estimated avoidance rates were still greater than 99%.

Clearly there are a number of methodological issues (beyond the control of Fernley et al. 2006 or Pendlebury, 2006) that bring a level of uncertainty to the analyses. It was for this reason that SNH chose a precautionary avoidance rate of 99% (except for Canada geese).

These uncertainties include:
• The degrees to which conditions at US wind farms match those in UK (and Scotland).
• Species specificity, i.e. do all geese behave the same?
• Some data on flight behaviour was collected post-construction¹ and some collected pre-construction.
• Low detection of corpses at wind farms suggests that systematic surveys were unlikely to detect all casualties; and
• Incomplete detection and scavenger removal before corpse searches will underestimate casualties. It should be noted, though, that goose carcasses are likely to be detected proportionately more than smaller birds, both because they can be seen easily and because scavenger removal is proportionately lower than smaller birds (simply because of their size). Indeed Gill & Smith, (2001) found that about 83% of goose carcasses were found in trials putting out dead geese at Dun Law wind farm. This would suggest that corpse searches do not under-estimate mortality to any great extent.

15. While the study designs at these US wind farms were far from perfect, the inescapable conclusion is that casualties are rare at operational wind farms in the US. All wind farms are sited in areas where large numbers of wintering Canada and/or snow geese congregate, which suggests that collisions, if they occur, would be detected. While some collisions are almost certainly not found, carcass search trials show that monitoring schemes do detect the majority. Moreover, mass mortality events, if they ever occur, would almost certainly be detected.

16. The first part of this review was to see whether there are new data for all or any of the wind farms used in the analysis undertaken by Fernley et al. (2006) and Pendlebury (2006). Further years’ data could be expected to show whether the collision frequency indicated in Fernley et al. (2006) is a true reflection of casualty frequency or not. The wind farms are listed in Appendix 1 along with web references, a description of the site, climate conditions and the monitoring undertaken (updated where available).

17. Web searches for monitoring reports were conducted in Google Scholar and Web of Science. Unfortunately, while monitoring continues at some, and possibly all of the selected wind farms, no further data on goose collisions could be found. No apparent reasons for this were obtained, although at some (e.g. Stateline) further construction work and a new round of monitoring are known to be in place. This may have brought some ongoing monitoring to a temporary halt. At others, the focus of monitoring may have changed.

AES Geo Energy Wind Farm

18. Zehtindjiev & Whitfield (2011) assesses collision probabilities at the Saint Nikola Wind farm in Bulgaria. The two species encountered are red-breasted geese and Greater white-fronted goose. Particular concerns were raised about the declining conservation status of red-breasted geese (RBG) as the wind farm is located in an area that is important for this species.

¹ Note though that this will underestimate avoidance as some behavioural displacement may not be detected if recording of bird flight activity does not include a large enough sampling area.
19. Flight heights, frequencies and numbers were monitored in the wind farm envelope and regular carcass searches undertaken. The results of this were then fed into the Band CRM, using known turbine parameters and operation times, to predict potential collision mortality for the two species which could then be compared against actual mortality. Data was gathered over two years: 2009/10 and 2010/11.

20. Depending on the year and the avoidance rate used, collision mortality of red-breasted geese ranged from 0.13 birds per annum (99.9% AR for 2010/11 data) to 8.9 (99% AR in 2009/10 data). Collision probabilities for greater white-fronted goose were 1.7 birds per annum (99.9% AR for 20010/11 data) to 86.1 birds per annum (99% AR in 2009/10 data).

21. Carcass monitoring detected no goose casualties of either species in either year. As for other species, zero collision rates imply an avoidance rate of 100%. There are two problems with this. Firstly we know that geese collide with wind farms so a 100% avoidance rate is unlikely at any site over a long period of time. Secondly, when collision rates are low, it is likely that collision probabilities, despite the assumption of constancy, will vary around the mean estimate from the output of a CRM. So for example, if the mean collision rate is two birds per year, there is a possibility that in any one year the actual number of collisions will range from zero to a number greater than two. Given that each flight of a bird through a moving turbine may result in a collision or no collision (at whatever avoidance rate), then the distribution of the total number of collisions will follow a standard binomial distribution, because each flight is, in essence, a single Bernoulli trial. We can therefore determine the avoidance rate (or more correctly collision probability) that would lead to a zero collision total at a particular quantile of the cumulative binomial distribution. The following analysis does this for greater white-fronted geese as the number of predicted collisions for red-breasted geese is statistically too small for the analysis to be meaningful. However, there is no reason to believe that red-breasted geese have a lower (or higher) AR than greater white-fronted geese.

22. Taking the 5% quantile as our level of significance (in a one-tailed test), then for greater white-fronted geese in 2010/11, an avoidance rate of 99.7% is the minimum avoidance rate that could account for zero collisions at the 5% level. For the 2009/10 data, the minimum avoidance rate for zero collisions is >99.9% at the 5% level. For the combined data (both years amalgamated), the probability of zero casualties is again <<0.001 for an avoidance rate of >99.9%.

23. If we accept that some casualties may have been missed, then it is reasonable to suppose that the actual avoidance rate for greater white-fronted geese is likely to be at least 99.7%.

Literature review (includes summary of findings from Rees (2012))

24. Some post-construction monitoring at wind farms in Europe has been undertaken in recent years, and some data exist in the public domain. For

---

2 A Bernoulli trial is a single event such as the rolling of a dice or the tossing of a coin. A bird flying through a wind farm will either collide or not collide.

3 The exact probability becomes almost impossible to calculate at this probability level because the normal approximation to the binomial distribution for large sample sizes breaks down when probabilities are so small because the normal distribution is symmetrical about the mean).
example Rees (2012) identified 41 wind farms in Europe where some monitoring has occurred after construction. Many of these are in Germany, where a major expansion of wind power has taken place in recent years. Although some monitoring of casualties was recorded for wind farms in nine European countries (listed in Table 1 in Rees, 2012), few sites had reliable bird monitoring either pre or post construction. Indeed it is only in Germany where systematic monitoring of wind farms is now beginning, involving dedicated carcass searches combined with monitoring of flight activity from vantage points. This is discussed in further detail below.

25. Wind farm casualties from across operational wind farms in Europe are listed in the table below. Data come from incidental detection, and summarized by T. Dürr (2012).

<table>
<thead>
<tr>
<th>Species</th>
<th>Number found dead</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anser anser</td>
<td>13</td>
</tr>
<tr>
<td>Anser anser f. domestica</td>
<td>3</td>
</tr>
<tr>
<td>Anser albifrons</td>
<td>4</td>
</tr>
<tr>
<td>Anser fabalis</td>
<td>3</td>
</tr>
<tr>
<td>Anser albifrons / fabalis</td>
<td>3</td>
</tr>
<tr>
<td>Branta bernicla</td>
<td>1</td>
</tr>
<tr>
<td>Branta canadensis</td>
<td>1</td>
</tr>
<tr>
<td>Branta leucopsis</td>
<td>7</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>35</strong></td>
</tr>
</tbody>
</table>


26. In Sweden Rydell et al. (2012) summarised wind farm impacts on species. Data came from about 20 wind farm locations in the southern province of Skane, where large numbers of greylag geese occur. Despite this only two goose casualties have been detected during the monitoring undertaken (Ahlen, 2010). Note that several years of monitoring is referred to but, as data are amalgamated, it is unclear how many. Rydell (2012) concludes that geese show a high avoidance (not quantified) of wind farms, unlike other species (including raptors).

27. In Norway, three greylag goose collisions have been detected at the Smola wind farm: one during 2003-2005 and two in 2008 (Bevanger et al., 2009). Greylag goose densities (breeding birds) are thought to be high at this location. It is important to note that Smola is one of the best monitored wind farms in Europe, so it is highly unlikely that casualties are going undetected, not least because dogs have recently been used to find bird and bat carcasses. The rate of casualties found equates to about one goose every 2-3 years on average. It is not possible to use these data to determine an avoidance rate (for the Band Collision Risk Model) because flight activity around the wind farm does not appear to have been quantified.
28. In Belgium, three domesticated geese and one greylag have been found dead at operational wind farms in Flanders (Everaert, 2008). The level of monitoring is unknown, though systematic monitoring at Zeebrugge has occurred. The data were gathered over an indeterminate period of years, though the casualties were reported from 2003-2008, i.e. at least nine years, with a minimum collision rate of about 3 per year at several wind farms.

29. In the Netherlands, only three geese have been recorded as casualties (including one Brent goose, one greylag goose and one Canada goose (Krijgsfeld et al., 2011; Musters et al., 1996). Krijgsfeld et al. (2009) undertook work at three large wind farms in the Netherlands and showed that collision rates were comparable with earlier estimates and that collision victims tended to be diurnally active local birds, despite the fact the wind farms are in migratory pathways. The authors ascribed this to the fact that diurnally active birds were ‘exposed’ more frequently to collision risk than migrants which tended to pass a wind farm only once or twice. Furthermore, observations (based on radar) showed that periods of poor weather, even at night, tended to produce few victims. Indeed it was concluded that it is diurnally active birds, maybe flying at dusk or dawn, intent on other ‘activities’ such as foraging that might enhance collision risk. No geese were found dead at any of the three wind farms despite searches and the fact that observations showed that many geese were present in large numbers at the wind farms, using the open agricultural landscape characteristic of the area.

30. Work by Fijn et al. (2007), from Bureau Waardenburg, showed that collision rates for geese and swans were very low, indeed no geese were found to have collided with the wind farm despite the area being heavily used by foraging and migratory geese. In a reply to a query by the author, Ruben Fijn remarked:

“We didn’t find any collisions of geese and swans during our research period. For Bean Geese we found significant decreasing distances to turbines (cf. the Bewick’s Swans) within the season. So, foraging of geese was closer to the turbines later in the season, with an average distance to turbine of 465 m (median 414) and a smallest distance of 161 m. Our radar work showed that geese were able to avoid the park and turbines effortlessly during dusk but avoided to fly through the park (sic) in the dark. This is probably also the reason that we did not find any collisions of geese during the entire study period (October to March searches every two to three days).” Ruben Fijn, pers. comm., 2013.

31. Some of the most intensive monitoring of wind farms has taken place in Germany, often in areas heavily used by wintering geese. As of December 2012, the number of casualties recorded by T. Durr is set out in the table below.

<table>
<thead>
<tr>
<th>Species</th>
<th>English name</th>
<th>Number of collision victims</th>
</tr>
</thead>
<tbody>
<tr>
<td>Anser anser</td>
<td>Greylag goose</td>
<td>4</td>
</tr>
<tr>
<td>Anser albifrons</td>
<td>White-fronted goose</td>
<td>4</td>
</tr>
<tr>
<td>Anser fabalis</td>
<td>Bean goose</td>
<td>3</td>
</tr>
<tr>
<td>Anser albifrons /</td>
<td>White-fronted goose/Bean goose</td>
<td>3</td>
</tr>
<tr>
<td>Branta leucopsis</td>
<td>Barnacle goose</td>
<td>6</td>
</tr>
</tbody>
</table>
32. A total of 20 geese have now been recorded as casualties at various wind farms, over approximately 12 years, many of them in Brandenburg. Data come from 23 wind farms, though records of goose collisions have not been recorded at all of them. All four species are abundant winter visitors to Germany, where they use similar habitats to the rest of continental Europe and the UK. Many of these victims are the result of casual finds so this may underestimate the number of casualties that are actually occurring. To overcome this, a new project has been initiated in Germany called PROGRESS which aims to characterise collision mortality (and work out avoidance rates) from a sample of 54 wind farms spread across different areas of Germany. During this work, only three geese have been recorded as collision victims compared to the overall total of 109 collisions of all species combined (Marc Reichenbach pers. comm.) over a period of just over a year. It is not possible to ‘correct’ figures in the above table to actual collision victims because the records are incidental records and have no systematic search methodology, but it is clear from the PROGRESS work, and other systematic surveys that few geese are recorded as collision victims at onshore wind farms.

33. A key problem with much of the data from Germany (and elsewhere) is that there are few data available on flight activity before or after construction. This (as discussed below) hampers accurate estimation of avoidance rates, but equally it is important to highlight that at the regional spatial scale, German wind farms show strong overlap with the wintering distribution of geese. To illustrate this we can compare the species distribution of Taiga bean geese (left) from http://monitoring.wwt.org.uk/species.php with the map showing distribution of wind farms in Germany (right). This shows a strong concentration in the north of the country, overlapping with distribution of bean geese. Similar overlap occurs for European white-fronted geese, greylag geese and smaller numbers of barnacle geese.

34. In the UK there are a small number of wind farms where SNH are aware that goose monitoring and carcass searches have been undertaken. It is also clear
that at some of these we also have pre-construction movement information. Unfortunately at the time of writing the data from some of these studies have not been made available due to concerns over commercial confidentiality.

35. Rees (2012) quotes two wind farms where monitoring has occurred (Hellrigg and Barrow), but where no collisions have been recorded. It is not clear at the time of writing whether this information might be sufficient to allow calculation of an avoidance rate. As discussed below, there are several sites in Scotland where some monitoring is known to have taken place but in cases that the author is aware of, flight data and carcass search data are not currently available.

36. At one wind farm (name and location withheld) no geese were found over a single monitoring season, though geese were observed flying over the wind farm and systematic carcass searches undertaken. Pre-construction observational data on flight lines may be available, but have not been obtained so far. Such data would, as for the Saint Nikola wind farm, allow calculation of a minimum avoidance rate.

Assessment and analysis

37. A number of evidential sources have been used for this review. These include calculation from US wind farm data, collision data from the German collision database, and observational and radar data from offshore.

38. There has been a considerable amount of research undertaken at onshore and offshore wind farms, often involving examination of bird movements using observations and radar of offshore wind farms (e.g. Blew et al., 2008, Plonczkier & Sims, 2012). However, few data combine movement information and collision rates into a single analytical unit that permits detailed analysis of avoidance rates. Data gathered in the UK at a number of wind farms should permit this once carcass search data become available. Possible sources of this will be the Scottish Wind Farm Bird Steering Group (SWFBSG) and the German PROGRESS research programme, which will assess movements at coincidental carcass searches at a number of wind farms in Germany.

39. The outcome of this limited review of wind farms and geese is unsurprisingly similar to that of Rees (2012) who also noted the absence of much quantitative information allowing assessment of avoidance rates. However Rees erroneously identified movement data for constructed wind farms as the key data to gather, while the Band Model, used by SNH and others to quantify wind farm impacts, actually requires pre-construction movement data as movements post-construction will be reduced by behavioural displacement i.e. the macro-avoidance as defined by the Strategic Ornithological Support Services (SOSS)\(^4\). This is a cogent criticism of many avoidance rates (Whitfield pers. comm.) namely that using bird movement data that are contemporaneous with a wind farm’s operational phase will over-estimate collision risk (i.e. underestimate avoidance) simply because birds that are displaced will not necessarily be detected and identified as displaced birds. This is one reason why the Fernley/Pendlebury analysis of US data may in fact over-estimate collision rates not vice versa as Rees claims.

\(^4\) SOSS - Strategic Ornithological Support Services – the management group tasked with developing further guidance for offshore wind farm projects. BTO act as the Secretariat. See [http://www.bto.org/science/wetland-and-marine/soss](http://www.bto.org/science/wetland-and-marine/soss)
40. The absence of additional data from the US wind farms included in the original Fernley/Pendlebury review is particularly frustrating as such data would have indicated whether the low casualty rates observed at these wind farms was typical. It is not clear whether monitoring has been undertaken (and not reported) or whether monitoring goose collisions has ceased due in part to the low rate of collisions in the first place. Either way, it makes the analysis problematic.

41. The inclusion of the Bulgarian data is, however, helpful and although the report itself is not published, there is no reason to suppose that the output in terms of collision likelihood is any different to that proposed in the report.

42. All the lines of evidence examined point to a single, consistent conclusion which is that geese do not collide with wind farms in numbers that are of conservation concern. It has often been suggested that collisions are more likely at night or in poor visibility, but this is predicated on geese continuing to fly close to wind farms and, therefore, failing to take the avoidance action which they would in better light. The problem with this is two-fold. Firstly, avoidance is an aggregate of two different types of behaviour – behavioural displacement (also known as macro-avoidance by SOSS) and behavioural avoidance (also commonly known as micro-avoidance). It is likely (e.g. see Krigsveld et al, 2009a, Krigsveld et al. 2009b & Krigsveld et al. 2011) that most geese exhibit a high degree of displacement (i.e. macro-avoidance) which means that an individual goose’s capacity to take avoidance action (i.e. evasive behaviour) is largely unnecessary. Displacement is likely in species that regularly use an area, such as a foraging area, at the end of a flight line from a nocturnal roost. Given this, it is considered likely that geese can and do learn about their environment and the hazards that it poses. This may differ for birds that undertake infrequent journeys (e.g. migratory geese) where familiarity with obstacles is less likely to be learnt. However, migratory geese often fly at altitudes above wind farm height (generally >150m) so avoidance (whether ‘intentional’ or consequential) is implied.

Recommendation for changing the default Avoidance Rate for Wintering Geese

43. The current avoidance rate used for wintering geese is 99%. The reason for this value being selected was that, at the time of the Fernley/Pendlebury reviews, the evidence base from other sources of data (as set out above) was limited or absent. For example we had little or no observational or radar data and the carcass search database maintained by Tobias Dürr was in its infancy. Given the uncertainties around the US wind farm data, SNH adopted a precautionary avoidance rate for wintering geese, in case evidence began to show collision probabilities at other wind farm sites that were higher than those at the US wind farms selected by Fernley et al. (2006) and reviewed by Pendlebury (2006).

44. It is concluded here that, while the evidence base remains imperfect, there is no evidence from any source of a risk to geese that is significantly higher than at the US wind farms. The work at Saint Nikola wind farm in Bulgaria (located in an area of high goose use) demonstrates the low risk to geese albeit over a short timescale of two successive winters. However, even with only two years of data, the probability of avoidance rates being as low as 99% is extremely unlikely.
45. In considering what to recommend as an avoidance rate for wintering geese, we have reverted to the Pendlebury review, but have retained a level of precaution that takes into account a number of factors, namely:

- Monitoring timescales at most wind farms have been short;
- Carcass searches may have missed birds that had been killed, especially if numbers are small (search images are more difficult to develop and proportionally fewer birds are detected when such events are rare); and
- The potential for periodic collision events is unlikely to be easily predicted, when processes are likely to be non-homogeneous.

46. Given this, we have adopted the precautionary approach taken by Pendlebury and assumed that, by missing corpses, the actual collision totals are greater than those observed. Pendlebury offers a basis against which to adjust for missed corpses when he calculates that “A total of ten unfound corpses at any site would decrease overall avoidance rates from 99.91 % to 99.81 % using equation [1], and from 99.89 % to 99.77 % using equation [2], producing an estimate of 2.20 times more goose collisions.”

If we take this as a valid approach to setting avoidance rates, then it would be justifiable to adopt a new (and higher) avoidance rate of 99.77-99.81%. On this basis SNH now recommends that an avoidance rate for wintering geese at onshore wind farms is set at 99.8%. It is SNH’s view that expressing avoidance rates to more than one decimal place is unwarranted.

47. The consequence of changing the avoidance rate to 99.8% can be seen in the following example for a wintering goose population in which 1,000 geese are calculated as being the ‘no-avoidance’ collision rate (this is a reasonable total for some wind farm sites in Scotland).

<table>
<thead>
<tr>
<th>No avoidance</th>
<th>95% avoidance</th>
<th>99% avoidance</th>
<th>99.8% avoidance</th>
<th>99.9% avoidance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1,000</td>
<td>50</td>
<td>10</td>
<td>2</td>
<td>1</td>
</tr>
</tbody>
</table>

48. Moving to an avoidance rate of 99.8% involves a reduction in collision probability of 80% or 20% of the figure at 99%.

SNH Contact:

Dr Andrew Douse
Policy & Advice Manager, Ornithology
Scottish Natural Heritage
Great Glen House
Leachkin Road
Inverness
IV3 8NW

Tel.: 01463 725241 (direct)
Tel.: 021463 725000 (switchboard)
Email: andy.douse@snh.gov.uk
References


End.
Annex 1: US wind farms used in analysis

<table>
<thead>
<tr>
<th>Name of wind farm &amp; location</th>
<th>Brief description &amp; source data</th>
<th>Primary habitat &amp; topography</th>
<th>Climate &amp; weather</th>
<th>Monitoring results (as used &amp; updated)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stateline Wind project, Vansycle Ridge, Oregon.</td>
<td>The Stateline Wind Farm is a wind farm located on Vansycle Ridge, between Washington and Oregon. With 86 turbines currently operating in both states and 279 more approved for construction, it is the largest wind project in the North-western United States and will be the largest in the world. It began operation in 2001. <a href="http://en.wikipedia.org/wiki/Stateline_Wind_Farm">http://en.wikipedia.org/wiki/Stateline_Wind_Farm</a></td>
<td>Dry-land, cultivated for wheat and other arable crops. Scattered trees and woods (?) as evidenced by need for tree nesting raptor studies. Pictures suggest low, gently undulating topography at best.</td>
<td>Warm summers, relatively cool winters with low precipitation though frequent snow to some depth. The site receives 16 to 18 mph (26 – 29 km/h) average wind speeds from the Columbia Gorge, on the border</td>
<td>NFATALITIES reported by Fernley et al. (2006) was one Canada goose. Erickson et al. (2004) reported this fatality as an incidental discovery, rather than found during standardised searches. Since the corpse was found incidentally, this could suggest that standardised searches were too infrequent (16-17 times per year; corpse search completeness of 24 %) to adequately detect infrequent fatalities. Geese are known to use the area, and counts have been made. No further monitoring reports have been located, though carcass monitoring still continues. The wind farm has been extended and monitoring includes Stateline 3.</td>
</tr>
<tr>
<td>Buffalo Ridge, Minnesota</td>
<td>Buffalo Ridge Wind Farm is a large wind farm near Lake Benton, Minnesota that is located on the geological Buffalo Ridge. <a href="http://en.wikipedia.org/wiki/Buffalo_Ridge_Wind_Farm">http://en.wikipedia.org/wiki/Buffalo_Ridge_Wind_Farm</a></td>
<td>The land where the wind farm resides is privately owned farmland. Flat except ridge itself.</td>
<td>Warm summers, cold winters with snowfall frequent but overall precipitation low in winter. Winds fairly even throughout year. Often cloudy/overcast. No indication of particular extreme events except above average tornado risk.</td>
<td>NFATALITIES was as provided by Johnson et al. (2000) and Osborn et al. (2000). One Canada goose fatality was found during the searches, but the probable cause of death was predation according to Johnson et al. (2000), so was not included by Fernley et al. (2006). This was included in a review of goose collisions (Patterson 2006), however. Data on goose use available post-construction but it’s not clear if there are pre-construction data.</td>
</tr>
<tr>
<td><strong>Top of Iowa</strong></td>
<td><strong>Klondike, Oregon</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>-----------------</td>
<td>---------------------</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| **Top of Iowa Wind Farm** is approximately 100 miles south of Minneapolis and 110 miles north of Des Moines. The wind farm consists of 89 NEG-Micon 900 kilowatt wind turbines mounted on 237-ft (72 m) tubular towers. Each turbine blade is 85 feet (26 m) long, making the rotor diameter 171 feet (52 m). [http://johnrsweet.com/personal/wind/TopOfIowaWindFarm.pdf](http://johnrsweet.com/personal/wind/TopOfIowaWindFarm.pdf) The wind farm covers roughly 5,900 acres of cropland on 49 separate land parcels and interconnects to the local electrical grid. Iowa, like most of the Midwest, has a humid continental climate throughout the state with extremes of both heat and cold. Winters are often harsh and snowfall is common. Spring ushers in the beginning of the thunderstorm season. Tornadoes are common during the spring and summer months. Summers are known for heat and humidity, with daytime temperatures often near 90 °F (32 °C). Average winters in the state have been known to drop well below freezing. N\textsc{FATALITIES} was as provided by Jain (2005) though none were detected. Large numbers of geese have been recorded in agricultural habitats close to the wind farm, but pre-survey use of the wind farm air space is not available. Largely a rolling, undulating country dominated by arable (mainly wheat) farmland. **Klondike Wind Farm** is located in Sherman County, east of the small agricultural community of Wasco, in the north-central part of the U.S. state of Oregon. The wind farm benefits from being near the Columbia River plateau and its associated winds. [http://en.wikipedia.org/wiki/Klondike_Wind_Farm](http://en.wikipedia.org/wiki/Klondike_Wind_Farm) The project spans thousands of acres of private land, the actual footprint is less than 2% of the total area. Landowners continue using the remainder of the land for dry land wheat farming, ranching and other traditional activities. Generally dry with warm/hot summers and cool winters. Occasional fog (freezing) recorded but frequency unknown. Low precipitation, especially in summer but with significant snowfall events in winter though lower than US average in general. Wind speeds measured at Wasco don’t seem particularly favourable for wind energy. N\textsc{FATALITIES} reported by Fernley et al. (2006) was two Canada geese. Johnson et al. (2003) reported these fatalities as incidental discoveries, rather than found during standardised searches. Since the corpses were found incidentally, this could suggest that standardised searches were too infrequent (13 times per year; corpse search completeness of 49 %) to adequately detect infrequent fatalities. Some pre-survey use of the area has been reported though classed as ‘low’ (though not clear what ‘low’ is being compared with).
| Nine Canyon, Washington | Nine Canyon, developed by Energy Northwest, is a 64 MW project located in an agricultural landscape in Benton County, Washington. Construction of Phase I of the project (48 MW) was completed in fall 2002, and Phase II (16 MW) of the project was completed in December 2003. The entire project consists of 49 1.3 MW Bonus turbines. [http://www.energy-northwest.com/generation/nine_canyon.php](http://www.energy-northwest.com/generation/nine_canyon.php) | N\textsuperscript{FATALITIES} was as provided by Erickson et al. (2003a). No fatalities detected. Some pre-construction monitoring of bird use, but no explicit data on goose use are available. Some suggestion that use by geese was low but situation is unclear. |
| Kreekak | [http://www.winvast.nl/kreekak.html](http://www.winvast.nl/kreekak.html) | N\textsuperscript{FATALITIES} was as provided by Musters et al. (1995). One fatality detected. Some pre-construction monitoring of geese is available but insufficient to quantify flight activity. |