Use of Avoidance Rates in the SNH Wind Farm Collision Risk Model

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Summary

The SNH Collision Risk Model (CRM) provides an estimate of the potential number of bird collisions likely to occur at a proposed wind farm. Birds react to a wind farm in different ways. Some may be displaced from the area of the wind farm, while others may avoid turbines or take other evasive action to prevent a collision. The CRM first estimates the number of collisions that would occur if the birds were to take no avoidance action. It then applies an avoidance rate to take account of the likely degree of successful avoidance.

The CRM involves three stages:

1. Assessment of the probability of a bird colliding, if it flies through an operational turbine[1].

2. Estimation of the number of birds passing through the zone swept by the rotating turbine blades. This is calculated from data collected on bird flight activity in the field - see SNH Survey Methods Guidance.[2]

Multiplying (1) and (2) yields an estimate of the number of birds colliding with turbines, based on birds taking no action to avoid the turbines.

3. Lastly, application of an **avoidance rate**[3], to take account of the fact that many birds may either avoid the wind farm entirely as a consequence of being displaced (changes in the habitat or prey base, the presence of turbines and associated activities, or other factors may dissuade birds from using the area), or fly high or low so that their flight does not pass through the turbines, or perform ‘emergency’ manoeuvres to avoid a moving turbine blade. Avoidance rates are expressed as a percentage, e.g. 98% means that 98% of birds are expected to avoid the turbine(s). The result is used to estimate the number of collisions, either on a yearly basis, or over the lifetime of the wind farm.

Avoidance rates are generally derived by comparing data on actual observed collisions with the predicted no-avoidance collision estimate. Avoidance rates for most species are still not known with accuracy, due to the paucity of collision monitoring data collected at operational wind farms.

Information is, however, available for a number of species. The **Table** below lists estimates of avoidance rates and source information for a number of critical species. We would hope that developers’ collision risk assessments will make use of avoidance rates no greater than the values in this Table.

[1] This is based on bird dimensions, flight speeds and turbine characteristics.
[2] Available at http://www.snh.gov.uk/docs/A305435.pdf
[3] The factor to be used is (1-a) as it is the number of collisions that we are interested in not the number that successfully avoid collision.

For species not listed in the Table, we recommend that a default avoidance rate of 98% should be used. This reflects the information available to date on a range of species and updates the earlier default value of 95% which we have previously advised on a precautionary basis. The default rate may change in the light of new evidence brought to our attention.

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SNH's Collision Risk Model

1. There is now a wealth of evidence to support the view that a range of bird species do collide with wind turbines, but that overall, collision events are uncommon or rare (e.g. Still *et al* 1996; Langston & Pullan 2003; Drewitt & Langston 2006). There are some exceptions to this and some species, such as white-tailed eagles and old world vultures, seem to be particularly prone to collisions (e.g. Lekuona & Ursúa 2006, Bevanger *et al* 2009).

2. The SNH Collision Risk Model (CRM), at times known as the Band Model, provides a means of estimating collision risks and hence the potential bird mortality which may be caused by a wind farm.

3. The model begins by estimating a 'no-avoidance risk', i.e. the rate of collision assuming that birds fly as if the wind turbine structures and rotors were not there and take no avoiding action whatsoever. The calculation of no-avoidance risk is the product of two factors, as described by Band *et al*. (2007); (1) the number of bird transits through the rotor-swept area, and (2) the probability of a bird colliding as it does so.

4. The number of bird transits is based on levels of flight activity in and around the wind farm site (calculated on the basis of empirical evidence collected <u>before</u> the wind farm is built), while the probability of collision requires some knowledge of the design parameters for the turbines, their number and operational characteristics (e.g. blade speed and pitch), as well as size and flight speeds of the relevant bird species.

5. Estimates of collisions based on no-avoidance assumptions are always gross overestimates of likely deaths, because they take no account of the behavioural response of birds in avoiding the wind turbines or the moving blades. SNH therefore uses a figure, known as an avoidance rate, to make allowance for the likelihood that a high proportion of birds will take some form of avoiding action.

6. Monitoring of collisions and flight activity at constructed wind farms has yielded information, for some bird species, on levels of avoidance. However these data are as yet limited and some behavioural responses are likely to be local to a site and may depend on factors such as topography, weather conditions and/or habitat amongst others. There is therefore a need to build in a degree of precaution when using an avoidance rate to predict the likely level of collision mortality at a proposed wind farm. The table at the end of this paper sets out accepted avoidance rates for different bird species, for use within the SNH Collision Risk Model. These have a built-in element of precaution. We would hope that developers, when preparing impact assessments on a proposed wind farm, would use avoidance rates no higher than those in this Table.

Bird Behaviour at Wind Farms

7. When considering bird interactions with wind farms, the term avoidance has been used in a varied, and sometimes unspecific, range of ways. It has been used to describe a number of specific behavioural responses that are shown by birds when flying near operational wind farms. These may be divided into two very different behavioural responses: **behavioural avoidance** and **behavioural displacement**. Another response shown by some species of birds is **behavioural attraction**.

8. **Behavioural avoidance** is action taken by a bird, when close to a wind farm (that is operational), which prevents a collision. Such behaviour implies that a bird sees a wind turbine or a moving turbine blade, evaluates the potential risk, and takes action to prevent what might be a fatal collision. Such action may be taken early enough so that the bird flies around the edge of the wind farm; or gains altitude to fly over it; or flies a course between or below turbines. In some cases they may, at close quarters, see an oncoming blade and take emergency evasive action.

9. **Behavioural displacement** operates at a different level, in that a bird may (possibly over time) change its home range, territory, or flight routes between roosting areas and feeding areas, so that its range use (or flight paths) no longer bring the bird into the vicinity of an operational wind farm. In effect behavioural displacement is equivalent to habitat loss, as regardless of its intrinsic suitability, the habitat is no longer available to the bird for whatever purpose it was previously used.

10. **Avoidance rates, as used by SNH, make allowance for both of these behavioural responses, and avoidance rates are a numerical expression of these behaviours.**

11. **Behavioural attraction** to wind farms (i.e. birds making more use of the area around a wind farm after construction) has been reported for several bird species, including common kestrel and cormorant. The reasons for this behaviour are not clear, but they may be due to changes in habitat management, or the use of wind farm infrastructure for perches or nesting.

Deriving Avoidance Rates for Birds

12. To derive an avoidance rate requires knowledge of how many birds have actually collided with wind turbines. Searching for corpses of birds killed in collisions is technically simple (refer to SNH Guidance on Methods for Monitoring Bird Populations at Onshore Wind Farms at:- http://www.snh.gov.uk/docs/C205417.pdf). However, there may be significant problems in that finding birds in some vegetation types can be difficult and corpse removal by scavengers means that the number of corpses counted may be underestimated. As long as these factors are corrected for, through properly conducted search methods and the calculation of scavenger removal rates, then accurate figures for collision mortality can be estimated. However, given the infrequent nature of collisions, it is likely that long datasets or amalgamation of datasets from a number of wind farms will be needed for some species.

13. By comparing the number of birds that *actually* collide with wind turbines at an operational wind farm - calculated from carcass search studies - with the

number of collisions *predicted* pre-construction before allowing for avoidance, an 'observed' avoidance rate, i.e. that exhibited in practice, can be calculated.

$$\text{Avoidance rate} = 1 - \frac{\text{No. of observed collisions}}{\text{No. of predicted collisions with no avoidance}}$$

14. We strongly recommend that avoidance rates for use within the SNH collision risk model should be derived using pre-construction activity levels and post-construction collision mortality figures. If observed avoidance rates are calculated using only post-construction data on flight activity, they will not take account of the proportion of birds which have shown behavioural displacement, and moved away from the windfarm site, thereby reducing levels of flight activity and collision risk. The use of such an observed avoidance rate may lead to an over-estimate of likely collision risk if that avoidance rate is applied to collision risk assessment for a new wind farm where only pre-construction flight data are available.

15. For many species, due to the current low number of post-construction studies (specific to these species) and the low numbers of corpses found in systematic searches (however sound these monitoring studies are), avoidance rate estimates are not particularly accurate. SNH therefore seeks a precautionary approach, by using avoidance rates which are at the lower end of the range of estimates, until such time as better empirical evidence becomes available.

Avoidance Rates for Birds

16. When SNH devised its collision risk model a precautionary avoidance rate of 95% was chosen. This figure was based solely on expert opinion and has little or no empirical basis, as no sound, relevant data were available at the time.

17. Our expectations were that data from operational wind farms would become available which would provide better evidence for deriving realistic, objective avoidance rates. However, it was always realised (and still is) that avoidance rates would be both species-specific and related in part to weather conditions, topography and other site-specific factors, such as variation in wind farm design and layout. These factors mean we should always exercise caution over the use of a single figure of avoidance rate for any given species.

18. Over the past few years, flight activity and corpse search data have become available for a range of species, including golden eagle, hen harrier, red kite, common tern and geese. This has allowed independent consultants to derive avoidance rate estimates for a range of species. Whilst this is helpful, most of these studies have not appeared in the peer-reviewed literature. Therefore, SNH decided that if these avoidance rates were to be used widely, they should be subject to an independent scientific review, as though the work was being put forward for formal publication. The British Trust for Ornithology (BTO) review of collision rates for geese is a good example of this (see below).

19. Observed avoidance rates need to be used with care, because of the uncertainties that surround some of the data and the differences between sites. For example, studies conducted in the US are not likely to be directly comparable with UK conditions (e.g. topography, habitat and weather may all be different), and some studies may have either underestimated collision victims (through inadequate searching) or over- or under-estimated activity

levels. Because of this, SNH has always chosen to apply a degree of precaution in adopting an agreed avoidance rate figure for use within the Collision Risk Model. This recognises that there are as yet very few published studies, and that observed avoidance rates vary between sites.

20. This approach has led to our decision to publish a set of proposed avoidance rates which include a degree of precaution. The Table at Annex 1 provides avoidance rates for key sensitive species, based on best available knowledge, which we will accept for use within the SNH Collision Risk Model when predicting bird collisions within a wind farm. The table will be updated as further information becomes available. Where appropriate, referenced source material is provided. The list of sensitive species is similar to that drawn up for other Guidance (e.g. Assessing significance of impact from onshore windfarms on birds outwith designated areas[4] (July 2006)). The table includes (i) references to observed avoidance rates - drawn from monitoring studies, and (ii) the precautionary avoidance rates accepted by SNH for use in the Collision Risk Model.

The determination of avoidance rates for wintering grey geese

The means by which the avoidance rate for wintering grey geese was derived provides a useful example of the approach we have adopted.

SNH received a draft paper on goose avoidance rates (Fernley *et al.* 2006). We had the paper reviewed by the BTO, in essence to: check the source data for veracity in both recording of collision victims and mathematical calculation; and verify the calculated avoidance rate for geese.

The BTO review (Pendlebury 2006) confirmed that, apart from some minor differences, the avoidance rates derived by Fernley *et al.* were sound. Some deficiencies in the source data were identified, which points to the need to improve the quality of post-construction monitoring studies. Importantly, BTO added one final and important refinement: they calculated avoidance rates using significantly inflated figures of collision mortality, a form of sensitivity analysis. Most wind farms only reported 1-2 collisions, BTO amended this to 10 per wind farm site to see what effect this had on avoidance rates.

In all cases, the calculation of avoidance rates led to an estimate that exceeded 99%, including those using the inflated collision mortality figures. Fernley *et al.* derive an avoidance rate of 99.93%. BTO's revised calculations give avoidance rates of 99.91% and 99.89% using two slightly different methods. Even using the inflated figure of collisions only reduces the avoidance rate to 99.81%, or 99.77% using the two approaches set out by BTO.

SNH have now agreed to adopt a figure of 99% avoidance, lower than any of the estimates calculated by Fernley *et al.* or BTO. The reason for this is that, firstly, SNH wished to retain a strong precautionary approach to adopted avoidance rates. Secondly, it was felt that circumstances and conditions in the UK are likely to be sufficiently different to the US wind farms (from which most of the data were derived), so adopting any value that was close to 99.9% was not fully justified. However, the empirical

[4] Available at http://www.snh.gov.uk/docs/C206958.pdf

> information obtained from these wind farms is sufficiently robust and relevant to allow a revision of SNH's prior estimate of an avoidance rate for geese (i.e. the default 95% avoidance rate) to produce an estimate using the precautionary approach *and* the likelihood values generated by Fernley *et al.* and the BTO.
>
> Finally, both the BTO and Patterson (2006), have concluded that wind farms appear to cause very few collisions of geese in United States, UK and Europe. The limited data from operational wind farms in UK support this view, and while it is still too soon to be certain, the BTO view that such events are rare is entirely consistent with all the currently available field-based evidence. In Europe, with thousands of wind turbines and large wintering populations of Arctic breeding geese, only about 9 goose casualties have been recorded (6 barnacle geese, 1 greylag goose, 1 bean goose and 1 bean/white-fronted goose - Hötker *et al.* 2005).

21. In the majority of cases where avoidance rates have been derived from empirical data, the avoidance rates are higher than 95%. **We therefore propose that, apart from a small number of particularly susceptible species, the *default* avoidance rate for bird species not listed on this table should be changed to 98%.** This change still incorporates a significant element of precaution, yet adopts an avoidance figure that is likely to be closer to actual avoidance values (even under conditions of poor visibility or at night).

Sensitivity of Avoidance Rates Used

22. The SNH Collision Risk Model has been critically reviewed (Chamberlain *et al.* 2005) and was found to be mathematically sound. However a number of improvements were identified. The review focussed attention on the sensitivity of the model to small changes in the value of the avoidance rate used, a point recognised by SNH (see Band *et al.* 2007). This is because although the difference between 99% and 99.98% may appear like a small difference in avoidance rate, it is of course a 50-fold change in the number of predicted collisions.

23. Having recognised the model's sensitivity to the value of avoidance rate, we do not agree with the view (Chamberlain *et al*. 2005, 2006) that it is such a problem as to warrant abandoning the use of collision risk models. Alternative methods of estimating risk are no more robust (e.g. risk exposure indices) and at least there appears to be a broad consensus that avoidance rates are generally very high (e.g. Chamberlain *et al.* 2006, Band *et al*. 2007), that there is scope for deriving realistic values from monitoring bird activity at operational wind farms, and that for a given species, an avoidance rate appears to be relevant across different sites.

24. It is also good practice to quote results from analysing a range of avoidance rates (e.g. 95% - 99%) for developments where there is uncertainty over the avoidance rate. This may be particularly valuable with marine wind farms where actual avoidance rates will be hard to calculate with any certainty. In this way, different scenarios can be explored which will allow the necessary assessment of species and population impacts.

Conclusions

25. Collision Risk Models provide an accepted method of predicting likely collision mortality of birds with wind farms. An inherent element of the SNH model is an estimate of the proportion of times that birds will act to avoid collision with turbines. The models do not assess whether birds will demonstrate behavioural avoidance or behavioural displacement (or a combination of both), rather they inform judgements about the likely effects of collision on bird populations, when avoidance is factored in.

26. Because of uncertainties inherent in the data on avoidance rates and the lack of substantial empirical data for many species, SNH recommends a precautionary approach in the use of avoidance rates. Having reviewed that available data, this document publishes a set of avoidance rates for different bird species, which include a degree of precaution, for use within the SNH Collision Risk Model.

27. Annex 1 proposes avoidance rates for a number of vulnerable species, which we suggest should be accepted and adopted as standard rates for use with the SNH Collision Risk Model. For any species not listed, and where there is no existing empirical evidence otherwise, SNH will accept a default avoidance rate of 98%. This represents a change from our previous advice that a default avoidance rate of 95% should be used. We believe this change is justified given the data now available on a range of species.

28. Ideally, avoidance rates need to continue to be derived empirically using information from wind farm monitoring of actual collisions. They need to be species-specific as well as relevant to environmental conditions at UK wind farms. It is also important that studies leading to estimates of avoidance rates are adequately peer-reviewed.

29. As the knowledge of bird interactions with wind turbines increases, SNH will continue to review and revise avoidance rates for sensitive species in accordance with published and/or peer-reviewed studies. Where studies are published informally (i.e. in the grey literature) SNH will seek to ensure that the work is adequately peer-reviewed before adopting a revised avoidance rate (as has been done for geese). SNH will continue to publish recommended bird avoidance rates, for use within the SNH Collision Risk Model, on our website and these should be checked periodically for updates.

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Annex 1: Proposed avoidance rates for sensitive bird species commonly identified in wind farm environmental statements.

Species	Accepted avoidance rates for use within SNH's Collision Risk Model	SNH avoidance rate derived from
Red-throated diver	98%	flight behaviour and collision monitoring studies [1]
Black-throated diver	98%	default value
Whooper swan	98%	flight behaviour studies/comparability with other species/collision monitoring studies[2]
Greylag goose	99%	http://www.snh.org.uk/pdfs/strategy/renewable/BTOResearch455.pdf
Pink-footed goose	99%	http://www.snh.org.uk/pdfs/strategy/renewable/BTOResearch455.pdf
Greenland white-fronted goose	99%	http://www.snh.org.uk/pdfs/strategy/renewable/BTOResearch455.pdf
Barnacle goose	99%	http://www.snh.org.uk/pdfs/strategy/renewable/BTOResearch455.pdf
Red kite	98%	http://www.natural-research.org/documents/NRIN_3_whitfield_madders.pdf
Hen harrier	99%	http://www.natural-research.org/documents/NRIN_1_whitfield_madders.pdf
Goshawk	98%	default value
Golden eagle	99%	http://www.snh.org.uk/pdfs/strategy/renewables/B362718.pdf
White-tailed eagle	95%	flight behaviour and collision monitoring studies[3]
Osprey	98%	default value
Merlin	98%	default value
Peregrine falcon	98%	default value
Kestrel	95%	flight behaviour and collision monitoring studies[3]
Short-eared owl	98%	default value
Black grouse	98%	default value
Golden plover	98%	default value
Dunlin (*Calidris alpina schinzii*)	98%	default value
Curlew	98%	default value
Greenshank	98%	default value
Skua (all species)	98%	default value
Gull (all species)	98%	default value
Tern (all species)	98%	default value

Notes:

1. Jackson D, Whitfield DP, Jackson L & Madders M (in prep). Red-throated diver collision avoidance of wind turbines. Natural Research Ltd.
2. Whitfield, DP. (in prep). Avoidance rates of swans under the 'Band' Collision Risk Model. Natural Research Ltd.
3. Two species are retained at 95% because there is sufficient evidence for their vulnerability to collisions: white-tailed eagle (evidence of a disproportionate number of collisions at Smøla, than *might* be expected, see http://www.nina.no/archive/nina/PppBasePdf/rapport/2009/505.pdf ; and kestrel, see http://www.natural-research.org/documents/NRIN_3_whitfield_madders.pdf.