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DERIVING AN AVOIDANCE RATE FOR SWANS SUITABLE FOR ONSHORE WIND FARM COLLISION RISK MODELLING

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ABSTRACT

Currently, according to SNH (2010) guidance the recommended avoidance rate for swans under the Band Collision Risk Model (CRM) is 98 %. The objective of the present report is to evaluate available contemporary information on the most suitable value for an avoidance rate for swans that may encounter operational onshore wind farms.

We highlight that the avoidance rates recommended by SNH (2010) consist largely or entirely of a Micro component and do not, as claimed by SNH (2010), encapsulate both potential Micro and Macro (displacement) components. If there is evidence or arguments to support the need for such Macro avoidance measures to be considered as relevant in assessments of wind farm proposals, then the avoidance rates of SNH (2010) should be regarded as minima. We refer to reviews and other studies which document that large wildfowl (including swans) are susceptible to displacement (Macro avoidance).

Whitfield (2010) argued that swans should probably be considered to have similar avoidance rates to geese. At that time, the SNH guidance recommended a 95 % avoidance rate for swans. On the basis of Whitfield (2010) the avoidance rate for swans was increased to 98 % in SNH (2010), although the avoidance rate for geese was given as 99 % in SNH (2010). SNH (2013) later recommended increasing the 99 % avoidance rate of SNH (2010) for geese, to 99.8 %.

Subsequent to Whitfield (2010), based on a later published study by Fijn and colleagues (2012) in a Dutch polder for Bewick's swan, the present report derives an estimated avoidance rate (Micro avoidance only) of 99.7 % or, including displacement of flying birds (Macro avoidance), at 99.8 %[1]. If reported displacement of feeding birds would have been included, the derived avoidance rate would have been still higher.

Despite some previous reviews (e.g. Rees 2012) and the findings of Fijn *et al*. (2012), it is apparent from recent information that feeding large wildfowl (including, likely, swans) are not always dissuaded from feeding within turbine arrays. Hence, we do not recommend that assessments of wind farm proposals that involve feeding swans within proposed arrays should *de facto* increase our derived 99.7 % and 99.8 % avoidance rates to yet higher rates.

In assessments of wind farm proposals where swans are flying across a proposed development area that intercepts a commuting route we would recommend that rates of 99.7 % and/or 99.8 % should be used (according to circumstance), and not 98 % (SNH 2010).

While we acknowledge that these rates are based empirically on only a single study, we present several corroborative lines of other evidence; and note that the study was fundamentally precautionary as regards swan mortality. Our recommended avoidance rates are applicable only to the original Band CRM and not to any subsequent model extensions.

[1] NB: These rates are similar to those for geese according to SNH (2013) *cf* Whitfield (2010).

INTRODUCTION

1. In the onshore environment current guidance on the application of avoidance rates under the Band Collision Risk Model (CRM) is provided by Scottish Natural Heritage (SNH 2010). Accordingly, an avoidance rate of 98 % should be used in wind farm collision modelling for many species, including the whooper swan *Cygnus cygnus*, in the absence of empirically derived figures (SNH 2010). However, as such values are based on limited evidence from onshore wind farms it is necessary to review recent studies of avoidance, collision and mortality rates in relation to onshore wind farms to inform the appropriateness of existing onshore guidance.

2. Previous guidance (following Band *et al*. 2007), based on expert opinion rather than on evidence, was that a precautionary default rate of 95% should be used for all species, but evidence obtained from reported mortality rates, mostly for geese and raptors in the USA (e.g. Pendlebury 2006; Whitfield & Madders 2006; Whitfield 2009) suggested that this value was overly precautionary and a revised default rate of 98 % was subsequently recommended (SNH 2010).

3. SNH has made a number of changes to avoidance rates since the original precautionary default rate of 95 % (e.g. changing the avoidance rate for geese to 99.8 % in May 2013: SNH 2013), but the rate at which changes are made is slow and lags behind the evidence. SNH (2010) recommended a change in the avoidance rate for swans (specifically the whooper swan as this species is the main species occurring in Scotland that is of conservation concern) from the previous recommendation of 95 % to one of 98 %. This change was largely made as a result of Whitfield (2010) who argued that the previous SNH recommendation for a 95 % rate, in equating vulnerability to collision with power lines with vulnerability to collision with turbine blades (repeating Langston & Pullan 2003), had no evidential basis. Whitfield (2010) also pointed to studies from The Netherlands which indicated that swans appeared to be as proficient at avoiding turbine blade collision as were geese. SNH (2010) recommended a 99 % rate for geese, but later increased this to 99.8 % (SNH 2013).

4. The objective of the present report is to evaluate currently available information on the most suitable value for an avoidance rate for swans that may encounter operational onshore wind farms.

5. In addressing this objective, we first consider what an "Avoidance Rate" is, in the context of the Band CRM because such an appreciation is fundamental to the derivation of avoidance rates.

6. We follow this focussed review with an evaluation of the extent to which the Band avoidance rates documented by SNH (2010) involved Macro Avoidance rates (displacement): see, for example Band (2012) on Micro and Macro Avoidance Rates. This evaluation is relevant to whether existing SNH guidance encapsulates the full suite of avoidance scales (if one assumes that displacement is simply [Micro] avoidance at a higher

spatial scale; hence Macro Avoidance term) and so whether the recommended rates may or may not need to be reconsidered in situations where displacement (Macro Avoidance) may occur. This is relevant to the report's objective because according to SNH (2010) much of the default rates set at 98 % (including swans) are at least partially guided by the empirically estimated values for other species/groups.

7. Hence, if the empirically estimated avoidance rate values in SNH (2010) do not include displacement (Macro Avoidance) then those empirically estimated values may be too low as a benchmark for other species/species groups which typically show displacement (Macro Avoidance). In this regard we note that in a review of the effects of wind farms on wildfowl (including swans) Rees (2012) concluded that on available evidence displacement of feeding large wildfowl was common. Other large wildfowl (geese) have shown substantial Macro Avoidance when flying on migration and confronted with offshore wind farms (Plonczkier & Simms 2012).

8. The final section documents the limited new empirical information that has become available since SNH (2010) to derive an avoidance rate for swans under the original Band CRM.

9. We conclude the report with a recommended Band CRM avoidance rate for swans, based predominantly on Bewick's swan *Cygnus columbianus bewickii* but likely applicable to other *Cygnus* species.

WHAT IS AN "AVOIDANCE RATE"?

10. The Band Collision Risk Model (CRM) described by Band *et al*. (2007) attempts to estimate the number of fatalities at an operational wind farm that will result from birds colliding with rotating turbine blades due to given levels of flight activity (Stage 1) and the probability of a bird passing through spinning rotor blades actually being hit by the blades (Stage 2).

11. The Band CRM is essentially a 'no avoidance' model, and to bring predictions towards a semblance of reality (based on empirical studies) a correction factor must be applied as a final element in the calculations ('Stage 3'). Stage 3 is the most influential aspect of the whole CRM process (e.g. Chamberlain *et al*. 2006) despite it not being formally part of the CRM process, and is termed the "avoidance rate".

12. Despite its assigned term, however, the avoidance rate, whilst probably substantially composed of birds' ability to avoid collision (or, more strictly in the context of the model's calculations – to avoid passing through the rotor swept volume of turbine blades) is essentially a catch-all or 'dump' for all factors which the basic 'no avoidance' model fails to account for.

13. This point is important because there are other influences which the Band model probably fails to account for. The avoidance rate is thus a catch-all for any factors that account for

the discrepancy between observed deaths and deaths predicted by the Band model under the combination of Stage 1 and Stage 2 (Madders & Whitfield, 2006). It follows that if there are changes made to the no-avoidance model then this will affect the Stage 3 correction.

14. Hence, an "avoidance rate" estimated using one version of the Band model should not be applied to another version. It was for this reason that Band (2012) cautioned against using avoidance rates that had not been derived using the extensions to the no-avoidance model he described. This means, in effect, that the extensions of Band (2012) to the no-avoidance model are redundant, in practice, until avoidance rates are derived using the extended no-avoidance model. It also means that researchers should be clear as to which version of the Band model a derived avoidance rate refers to.

15. In addition, there are more CRMs than just the Band model (e.g. the Biosis model: Smales *et al*. 2013), and an avoidance rate estimated by one CRM is not applicable to another (Madders & Whitfield 2006). We should, at least, therefore refer to 'Band Avoidance Rates' to be clear, and if rates are derived under extensions of the Band model then they should be termed appropriately. On top of this, it is apparent that with Macro and Micro components (e.g. Cook *et al*. 2012; Band 2012) and Horizontal Macro and Vertical Macro terms (Cook *et al*. 2014), the potential for confusion on terminology is increasing, accentuated by research on avoidance rates continuing to lag well behind CRM theory (e.g. Madders & Whitfield 2006; Chamberlain *et al*. 2006; Cook *et al*. 2012, 2014).

16. Finally, it should be noted that "Micro Avoidance Rates" are not Band Avoidance Rates if they have been estimated out with the Band CRM method (or any other CRM). For example, Everaert & Stienen (2007) provide an estimated collision rate for black-headed gull and common gull of 1 mortality per 2950 birds at rotor swept height (0.034 %), which equates to a non-mortality rate of 99.96 % (100 – 0.034). This is not a Band Avoidance Rate (even at the micro-scale) as it does not take account of Stage 2 of the Band CRM.

SNH (2010) ONSHORE RATES EFFECTIVELY REFER ONLY TO MICRO AVOIDANCE

17. In theory, according to Band *et al*. (2007) and SNH (2010) the "Avoidance Rate" should include both Micro and Macro (displacement) Avoidance (to encompass "Overall Avoidance": see Band 2012, 2013). SNH (2010) notes that if rates have not been derived from a pre-construction baseline then several elements of avoidance (notably Macro or this form of displacement) are intrinsically unlikely to be incorporated. Gove *et al*. (2013) also similarly highlight that 'true' avoidance rates should be based on pre- and post-construction comparisons (although they do not scrutinise what the basic reference source - SNH (2010) - actually involved). To this end, it is appropriate to consider what the avoidance rates recommended by SNH (2010) actually involved by way of their derivation and the scale of incorporated "avoidance".

18. All empirical Band Avoidance Rates presented by SNH (2010) and hence the basis for the default 98 % rate were not derived from pre-construction baseline, but from operational

wind farms. This suggests, fundamentally, that it is unlikely that displacement (Macro Avoidance) rates were actually encompassed by the SNH (2010) guidance.

19. Band Avoidance Rates used in the SNH guidance (SNH 2010) have all been estimated from post-operation studies; have been derived from data gathered at varying spatial scales and it varies as to how obvious it is on whether they include Macro Avoidance. To shed light on the relevance of Macro Avoidance, we consider several of the empirical studies that were used to generate SNH (2010), below.

Red-throated diver: Jackson et al. (in prep)

20. This study simply considered flights over a restricted turbine line close to the observer, and so only Micro Avoidance was probably involved in the derivation of the Band Avoidance Rate.

White-tailed eagle: May et al. (2010)

21. This study, while conducted at a scale at which both 'types' of avoidance may occur, expressly noted that there was no evidence that Macro Avoidance (displacement) was a factor. Therefore, the Band Avoidance Rate derived by the study involved only Micro Avoidance.

Hen harrier: Whitfield & Madders (2006)

22. Eight study sites were involved in the derivation of a Band Avoidance Rate for hen harrier. At two of these sites there was no evidence of displacement and at a third there was evidence of both small scale (< 100m from turbines) and larger scale (> 100 m) displacement from turbines by harriers in the year following windfarm operation (this did not involve complete displacement however – at the scale at which a typical Band CRM is run so far as the distance buffer around the wind farm footprint). For the other five study sites there were no data on displacement, although with the spatial scale of the observations it is unlikely to have been a major influence, if any influence at all.

23. A tentative conclusion would be that an element of Macro Avoidance (displacement) is involved in the Band Avoidance Rate derived for hen harrier, but its influence is probably weak and the majority contributor was probably Micro Avoidance.

Golden eagle: Whitfield (2009)

24. Whitfield (2009) notes that the Band Avoidance Rate derived for this species probably involved only Micro Avoidance and not Macro Avoidance (displacement). Of the four wind farms involved in the Avoidance Rate derivation, displacement was studied at only one (Foote Creek Rim) and there was no evidence for it. At one of the three Californian wind farms also involved (Altamont), although not formally studied by a 'before and after' contrast, the available evidence suggests that displacement was not a factor (Madders & Whitfield 2006).

25. On balance, therefore, it is likely that the Band Avoidance Rate for golden eagle does not substantially include Macro Avoidance (displacement).

Summary

26. There are several examples where Band Avoidance Rates have been estimated directly for species/groups of birds. None of these (*contra* SNH 2010) have been based on the ideal

situation of comparing a pre-operation Band CRM with post-operation collision fatality data; all have been based on post-operation data only, with consequent implications that they may be too low when applied in a pre-operation context (the typical application of the Band CRM).

27. Although, in theory the Band Avoidance Rate could potentially include both Micro Avoidance and Macro Avoidance (displacement), in practice the available rate estimates in SNH (2010) refer exclusively or substantially to Micro Avoidance only. Displacement is either not incorporated or has only a very weak influence.

28. Therefore, the SNH recommended Band Avoidance Rates (SNH 2010) as derived empirically do not appear to include any inherently substantial Macro Avoidance (displacement) component.

29. A consequence of this is that the Baseline ('default') SNH value of 98 % is also potentially too low when applied to other species/groups in a predictive pre-operation context (e.g. wind farm proposal), since it is based on the empirically derived benchmarks. This issue also applies to swans, which SNH (2010) recommended at a 98 % avoidance rate. Several recent reviews (e.g. Rees 2012, Gove *et al*. 2013) have highlighted the susceptibility of large wildfowl (including swans) to displacement (Macro Avoidance).

EMPIRICAL DERIVATION OF AN AVOIDANCE RATE FOR BEWICK'S SWAN

30. Literature searches, contacts with international researchers in the discipline, and the current state of research initiatives from the Scottish Windfarm Bird Steering Group (http://www.swbsg.org/index.php/researchprogramme; accessed 18 December 2014) have revealed little new information that allow much progress in onshore avoidance rate derivation since SNH (2010).

31. SNH (2013) recently produced revised guidance for the avoidance rates of geese under the original Band CRM on a series of sound arguments and reference to empirical studies to produce a recommended 99.8 % avoidance rate. To these arguments for a very high avoidance rate can be added additional subsequent research findings from the Saint Nikola Wind Farm (SNWF) in Bulgaria – on which SNH (2013) partially relied on previous results – these findings have continued to find no collision victims in other winters despite further thousands of geese passing through and feeding within SNWF (Zehtindjiev & Whitfield 2013). For SNWF the latest estimated avoidance rates of geese (Zehtindjiev & Whitfield 2013) are higher than stated by SNH (2013) in its earlier analysis and so there is a high degree of confidence (95 %) that for both red-breasted goose *Branta ruficollis* and greater white-fronted goose *Anser albifrons* the avoidance rate is 99.9 % or higher (with much greater confidence for the more abundant greater white-fronted goose).

32. On geese, further, a study not included by SNH (2013) also indicates and inferentially affirms the very high avoidance rates of geese. In this instance, the example involves bean geese *Anser fabalis* in the study of Fijn *et al*. (2008, 2012) at a Dutch polder, wherein it is noted that, while the primary study species was Bewick's swan, there were also many more bean geese present but which had a similarly low risk of being found as collision victims. As we will describe subsequently, the avoidance rate for Bewick's swan from this Dutch research is empirically high (confirming Whitfield (2010)) and so the inference (unstated explicitly by Fijn and colleagues) is that avoidance rate was likely similar or higher for bean

geese. Affirming, albeit inferentially but by a further example, that the avoidance rate for geese recommended by SNH (2013) is likely at the lower limit.

33. Our searches and contacts were able to locate only one study where sufficient empirical evidence was available to estimate Band avoidance rates, for potential revision of SNH (2010), for Bewick's swan.

Bewick's swan in Dutch polders

34. Post-construction monitoring of swans has been undertaken at some sites across Europe. A recent review identified 41 sites in Europe where swans, and geese, were monitored after construction (Rees 2012). The majority of these studies (23) were conducted in Germany. Swan fatalities at wind farms across Germany, and Europe, have been listed by the Staatlichen Vogelschutzwarte[2] and a recent update (28 October 2014) records a total of 24 swans having collided with turbines in Germany. Across Europe a total of 34 swan collisions have been recorded; however two Bewick's swans reported from the Netherlands by Fijn *et al.* (2007) were not turbine blade collision victims (see Fijn *et al*. 2008, 2012). To put these European findings further into context, aside from recalling the thousands of turbines that coincide with swan wintering grounds on continental Europe, we would also additionally emphasise that being large bodied and with completely white plumage, swans are probably easier than most other birds in being discovered by searches under turbines and will leave more post-scavenging signs of death (as also emphasised by Fijn *et al*. 2012).

35. A problem with much of the data available is that there is little by way of flight activity records before or after construction. This prevents accurate estimation of avoidance rates, although it does allow comparison of recorded collisions with other species/groups where data are available. The premise of this approach is highlighted in SNH's (2010) revision *upwards* of the avoidance rate for wintering swans, following from a report supplied to SNH (Whitfield 2010).

36. Therkildsen & Elmeros (2015) laudably avoided the problem of an absence of the 'before and after' contrast and presented information after the first year of post-construction monitoring of flight activity at a seven-turbine wind farm test facility in Denmark; study species included both whooper and Bewick's swans. Carcass searches were conducted with trained dogs around three turbines every 3 – 4 days. However, this study is understandably inconclusive so far due in large part to its infancy (especially for Bewick's swan as very few were present): it is an interim report. Predicted swan mortality rates due to collision were very low, even for the more abundant whoopers and even when based on the lowly recommended SNH (2010) rate. No collision victims were recorded for any species, and not just for swans, but also for more abundant species. However, under the search regime for carcasses (despite the benefit of using trained dogs) it was highly unlikely that any swan collision victims would have been recorded after one year (regardless of the possible range of avoidance rates) because of the low mortality expectations based on flight activity and that there were relatively few turbines involved in the study. As noted earlier, this study is understandably and presently inconclusive; but may hold promise for the future.

37. As regards displacement (Macro-Avoidance), the interim report of Therkildsen & Elmeros (2015) focusses on vertical altitude shifts pre- versus post-construction: sample sizes were low for swans, however, and other studies (and energetic expectations) would suggest that

[2] http://www.lugv.brandenburg.de/cms/detail.php/bb1.c.312579.de

displacement is more likely in the horizontal axis; which was not considered. While this study holds promise in its design this promise is probably for more abundant species than for swans due to the study site's constraints.

38. The Wieringermeer Polder in The Netherlands is one of the major wintering areas for Bewick's swan in Europe, and is also one of the main areas for wind farms in The Netherlands. Here the swans usually form feeding flocks with bean geese and their exposure to wind turbines involves many scores of thousands of swan-days and several hundreds of thousands of flight movements each winter. Several studies have been carried out on operational effects of wind farms on Bewick's swan and bean goose in the region. The net conclusion of these studies is that this swan is not at serious risk of collision with turbines, and has no greater collision risk than the bean goose (Fijn *et al*. 2007, 2008 and references therein). Fijn *et al*. (2008) note that the number of swan and goose collisions was extremely low, substantially less than expected and orders of magnitude lower than other bird species (which it should be noted, have typically been estimated to have avoidance rates in excess of 98 % under the Band CRM).

39. Fijn *et al.* (2012) intensively studied collision risk of Bewick's swan at 17 turbines in this area of The Netherlands over one winter (2006 – 2007). Fijn *et al.* (2012) did not actually find any casualties of collision during their searches around turbines, and considered that very few were likely to have been missed because of searcher inefficiency and carcass removal but to estimate a putative collision risk they assumed one swan had been killed during their study period. This produced an estimated 0.0009 strikes per 24 h. Fijn *et al*. (2012) also then produced a collision risk estimate, but this did not involve the Band CRM and so (as we highlighted earlier) cannot be taken directly to produce a Band Avoidance Rate. To derive such a rate requires further calculations; primarily (but not exclusively) factoring in Stage 2 of the Band CRM. These calculations, and their basis, follow.

40. Fijn *et al.* (2012) state that on average 42 swans passed through the turbines every 24 hours. The period that swans were present was 15 October to 15 March or 152 days. Therefore the total number of swan transits through turbines is 42*152 = 6384. Next, we turn to the values for parameters necessary for Stage 2 (the "collision probability" for birds passing through the rotor swept volume). To derive these values requires several measures of the turbine specifications, and biometrics and flight speed of Bewick's swan.

41. On the turbine specifications, Fijn *et al*. (2012) do not provide many details, but helpfully note that two schemes (Wieringermeer ECN and Waterkaaptocht) were involved: nine turbines at ECN and eight at Waterkaaptocht. Through background web-based searches for ECN at the time of the study and Krijgsveld *et al*. (2009) for Waterkaaptocht the turbine models were sourced. At Waterkaaptocht the eight turbines were Vestas V66s; at ECN there were five Nordex N80 turbines in one array and four prototype turbines at the second 'test' array: each different (DOWEC NM92, GE2.5, GE2.3, and a Siemens 3.6). Relevant specifications of each model (rotor diameter, blade pitch, maximum blade chord, rotation period) were derived from manufacturers' and related websites.

42. Appropriate Bewick's swan biometrics for Stage 2 calculations were taken as mean values from Cramp & Simmons (1978) and a flight speed of 15 m/s was used. This speed is lower than values given by Provan & Whitfield (2007) and Alerstam *et al*. (2007) as these mostly referred to birds on migration rather than birds that had only recently taken flight, as was more relevant to the study of Fijn *et al*. (2012). Further assuming 'flapping' flight, then each set of turbine specifications (six in total) was run through the Stage 2 calculations to derive

a collision probability for each type of turbine. This gave an overall Stage 2 collision probability for the 17 turbines of: ((11.5*5) + 10.9 + 11.4 + 10.6 + 10.4 + (14.4*8))/17 = 12.71%.

43. With the collision probability of 12.71% and an assumed (industry standard) turbine downtime of 13% then the predicted number of ‘no avoidance’ collisions, given the ‘flux’ of swan flights = 6384*0.1271*0.87 = 705.92. As we noted earlier, Fijn *et al.* (2012) estimated the collision rate to be 0.0009 per turbine per 24 h over the study period. Therefore the total number of collisions over the study season is estimated to be 0.0009 * 17 (turbines) * 152 (days) = 2.33.

44. Following from this, avoidance rate = 1 – (observed mortality/no avoidance mortality), so that avoidance rate = 1 – (2.33/705.92) = 0.9967 (99.7 %).

45. This, however, is only a Micro avoidance rate under the original Band model, and Fijn *et al*. (2012: Table 2) record that on average 49% of swans actively changed their flight path "a few hundred metres at maximum" from the turbines so as not to pass through the turbines. Taking this as a Macro Avoidance (displacement) measure, then the Band avoidance rate = 1 – [(1 – Macro Avoidance) * (1 - Micro Avoidance)] = [(1 – 0.49) * (1 – 0.9967)] = 0.9983 (99.8 %).

46. There are several points that follow on from this rate derivation. The first is that it is precautionary because Fijn *et al*. (2012) found no collision victims in their searches and their experiments with trial carcasses suggested that chances of finding a collision victim were high. The second is that the derived rate is very similar to those for geese (SNH 2013), affirming an earlier premise of similarity between swans and geese, in a common high capacity to see and stay away from rotating turbine blades, made by an unpublished NRIN (Whitfield 2010). Albeit that this premise was based on earlier (pre-2012) publications of Fijn and colleagues; but, in prescience, before the collision risk details presented by Fijn *et al.* (2012).

47. The third point is that, to our knowledge, the work of Fijn *et al* is the only study on which an avoidance rate for swans can be derived, currently. That may infer a weakness through singularity – even though any empirically-based study is better than nothing. Especially given the generic shortage of empirically based avoidance rates under the Band CRM. To this caveat we should add, however, that Fijn *et al*. have commented that Bewick’s swans appeared to be at a similarly low risk of collision across other parts of the Netherlands out with their study area.

48. Our final point is that our derived avoidance rate for Bewick’s swan does not involve pre- and post-construction comparisons under the Band CRM; and so the rate is the same as for virtually all avoidance rate derivations. Post-construction displacement (Macro avoidance = displacement) was relevant in the derivation of the avoidance rate for this swan species (<u>in flight</u>), but Fijn *et al*. (2012) also document displacement of <u>feeding</u> swans from around turbines. While their study was not made within a Band CRM framework it was a before-and-after comparison that included swans feeding within the prospective turbine locations.

49. In other words, if collision risk and an avoidance rate would have been estimated using pre-construction data (and applied as if in a pre-construction assessment context) it is obvious that the avoidance rate would have been even higher than we have derived here (since macro avoidance should have been higher, due to displacement of feeding birds). Nevertheless, our derived avoidance rate is arguably most relevant to situations where

swans are commuting between a feeding site and a roosting site where a wind farm intercepts the flight route; or as a minimum measure of a rate for swans on longer flight route (as then the displacement [Macro avoidance] may be greater: Plonczkier & Simms 2012).

50. We have not included the Macro avoidance element that displacement of <u>feeding</u> birds would have contributed through the work of Fijn *et al*. (2012) because while Rees (2012) concludes that wind farm displacement of feeding large wildfowl is essentially nigh-on ubiquitous in her review, this may not be always the case (Zehtindjiev & Whitfield 2013) and/or may also be dependent on time (Madsen & Boertmann 2008) and/or the relative availability of food within and out with wind farms (Fijn *et al*. 2012).

CONCLUSIONS

51. The “Avoidance Rate” is a catch-all add-on correction factor to account for the failure of ‘no avoidance’ theoretical CRMs to predict empirical estimates of collision mortality. This failure is substantial, and so the avoidance rate’s influence on CRM outputs is substantial. While probably mostly composed of the unerring capacity of most birds in most situations to avoid collision with rotating turbine blades, the avoidance rate – as a (large) correction factor that is an add-on – is entwined within whichever CRM or CRM variant for which it is needed to correct for. Thus, each CRM or CRM variant (“extension”) requires its own “avoidance rate”.

52. We highlight that the avoidance rates recommended by SNH (2010) consist largely or entirely of a Micro component and do not, as claimed by SNH (2010), encapsulate both potential Micro and Macro (displacement) components. If there is evidence or arguments to support the need for such Macro avoidance measures to be considered as relevant in assessments, then the avoidance rates of SNH (2010) should be regarded as minima.

53. Our literature searches and contacts with researchers in this field have revealed little additional relevant empirical information since the production of the SNH (2010) guidance.

54. For Bewick’s swan, based on studies by Fijn and colleagues in a Dutch polder, an estimated avoidance rate (Micro Avoidance only) was derived at 99.7 % or, including displacement of flying birds (Macro Avoidance), at 99.8 %. If reported displacement of feeding birds would have been included, the avoidance rate would have been still higher.

55. While these estimates are based on one study, there is no information in the literature to dispute that they are atypically high; other information, while less objective, suggests that they are representative.

56. It should be noted that the Avoidance Rates presented here refer to the original Band CRM and not to the extended models (Band 2012, 2013).

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