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Sent: 08 February 2019 21:10
To: KJ Johansson; Kay Sully; Hornsea Project Three
Cc: Andrew Guyton; Stuart Livesey
Subject: Hornsea Project Three (UK) Ltd response to Deadline 6 (Part 3)

Dear Kay, K-J

Please find attached the 3rd instalment of documents.

Best regards,
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[redacted]

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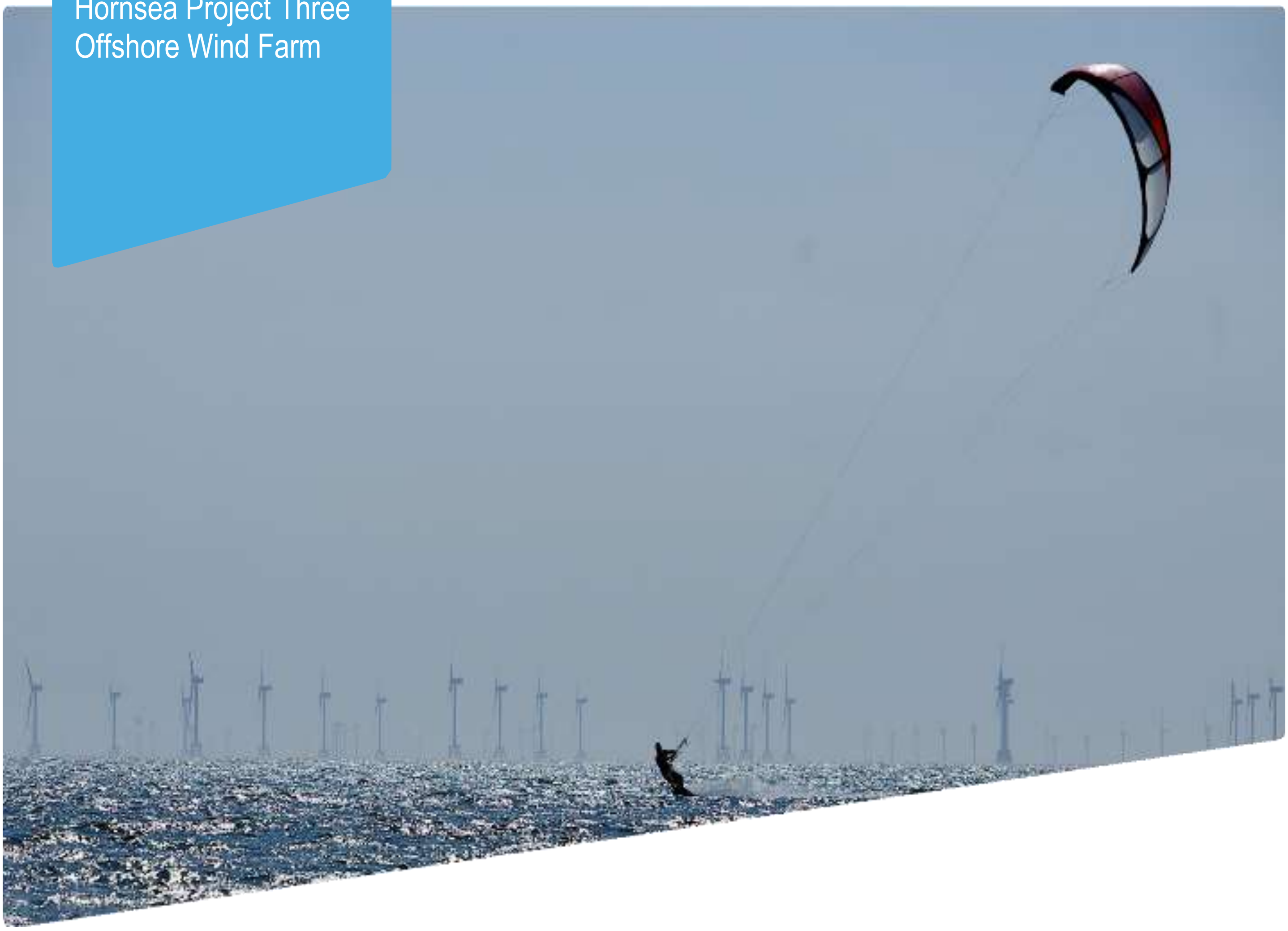
Hornsea Project Three
Offshore Wind Farm



Hornsea Project Three

Offshore Wind Farm

Appendix 8 to Deadline 6 submission – Smart Wind and Forewind 2014 Report

Date: 8th February 2019

Hornsea 3
Offshore Wind Farm

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Front cover picture: Kite surfer near a UK offshore wind farm © Ørsted Hornsea Project Three (UK) Ltd., 2019.

SMart Wind

Hornsea Offshore Wind Farm Project One

Review of Avoidance Rates in Seabirds at Offshore Wind Farms and Applicability of use in Band Collision Risk Model

Appendix O to the Response submitted for Deadline II

Application Reference: EN010033

20 January 2014

Review of Avoidance Rates in Seabirds at Offshore Wind Farms and Applicability of Use in the Band Collision Risk Model

DECEMBER 2013

REVIEW OF AVOIDANCE RATES IN SEABIRDS AT OFFSHORE WIND FARMS AND APPLICABILITY OF USE IN THE BAND COLLISION RISK MODEL

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Contents

1 Introduction 1

2 Background 2

3 Study Components 5

4 The evidence base for avoidance rates in seabirds 7

5 Derivation of the default 98% avoidance rate and its applicability to seabirds in the marine environment 9

6 Selection of an appropriate avoidance rate to use in Options 3 and 4 of the extended Band Model 11

7 Conclusions 14

8 References 17

Appendices

1 Review of assumptions used in generating avoidance rates for onshore wind farms and applicability for conversion to avoidance rates for offshore wind farms.

2 Reverse calculation of Option 3 numbers to show the avoidance rates that would be required to produce an equivalent collision rate to those derived from Option 1:

2A – Calculations for Dogger Bank Creyke Beck
2B – Calculations for Hornsea Project One

3 Review of avoidance rate estimates for seabirds.

4 Review of avoidance rates used in the assessment of consented offshore wind farms.

1 Introduction

1.1 Outputs from the Band collision risk model (CRM) for use in the impact assessments and Habitats Regulations Assessments for recent Round 3 offshore wind farms, including Dogger Bank Creyke Beck and Hornsea Project One, have been derived through use of the extended model (Band 2012a).

1.2 Following submission of Development Consent Order (DCO) applications, representations have been received from the statutory nature conservation bodies (SNCBs) and the Royal Society for the Protection of Birds (RSPB) in relation to the use of the extended model and how certain avoidance rates may, or may not, be appropriate for use within the extended versions of the Band model. As the selection of avoidance rate plays such a critical role in determining predicted collision numbers (and therefore potential impact on bird populations), deriving a rate that is appropriate for use with the selected model option is an important consideration (Chamberlain et al., 2006). Given the potential implications raised by the issue in respect of the assessment outcomes for the current Round 3 offshore wind farms, it is considered necessary to review the application of existing avoidance rates in the Band Model and confirm whether or not these rates can be justifiably applied in situations where the extended model is used.

1.3 This Report provides a synthesis and review of the information relevant to determining which avoidance rates are appropriate for use with the extended model and presents the findings to inform discussion with relevant parties.

2 Background

2.1 The standard method to estimate collision risk to bird populations is based on pre-construction counts of bird activity at a proposed wind farm site and the input of such data into a model to assess numbers likely to be killed by collisions. The assessments are normally made using the Band model (Band et al., 2007; Band, 2012a). The Band model calculates the proportion of birds flying at rotor height that would be expected to pass through a turbine unscathed and the proportion expected to collide if no evasive action was taken. In practice, birds tend to take evasive action, and the numbers likely to be killed are mainly determined by the extent of evasive action rather than by features of turbine design or species' flight speed or bird size (Chamberlain et al., 2005 and 2006).

2.2 To use the Band model, a correction factor has to be applied to account for the extent to which birds avoid turbines. The specific avoidance correction factor (generally referred to as an avoidance rate), which needs to be applied should be species specific and take into account observed avoidance behaviour (SNH 2010)).

2.3 Before data on bird behaviour at wind farms were available, SNH recommended use of a precautionary avoidance rate estimate of 95%, but with accumulation of data at terrestrial wind farms this has been revised to 98% for most species, except kestrel (95%), golden eagle and hen harrier (99%) and geese (99.8%), (SNH 2010; 2013). With development of offshore wind farms, there is a need to consider whether avoidance rates of seabirds, and appropriate avoidance correction factors for application of the Band models, are the same as, or different from those of terrestrial birds.

2.4 The updated Band Model (Band, 2012a) differs from the original (developed for onshore wind farms (Band et al., 2007)) in two key ways. Firstly, bird numbers are input as densities rather than raw counts, which better reflects the way in which data are collected in the offshore environment. Secondly, the updated Band model takes better account of the distribution of birds in relation to the rotor swept area and is capable of incorporating the following options for considering the input of flight heights:

- Option 1 - using the basic model, i.e. assuming a uniform distribution of flight heights between lowest and highest levels of the rotors; and using the proportion of birds at risk height as derived from site survey;
- Option 2 - again using the basic model, but using the proportion of birds at risk height as derived from generic flight height information;
- Option 3 - using an 'extended' version of the model and taking account of modelled flight height distributions for each of the study species; and
- Option 4 - .using an 'extended' version of the model and taking account of flight height distribution for each of the study species derived from specific observational data.

2.5 Options 3 and 4 provide the most sophisticated representation of the way that birds are likely to interact with turbines because, as Band (2012a) points out, they take account of the fact that seabirds tend to fly at relatively low altitude over the sea surface and that the distribution of flight heights will tend to be skewed towards lower altitudes. This influences modelling in 3 ways:

i. The proportion of birds flying at potential collision height will decrease with the height of the rotor above the sea surface. That is, there will always tend to be more birds distributed towards the lower part of the potential collision height window than its upper part.

ii. The risk of passing through the area swept by a rotor is lower at the lower part of the potential collision height window, because the rotor circle occupies less width at that level than, for example, at the midpoint of its diameter. This reduces the number of transits predicted to pass through the rotor swept area and. Band (2012a) estimates, for some species, this could represent a reduction of 50% or more resulting in a corresponding reduction in collision risk.

iii. If birds fly through the rotor swept area close to the extremity of the blades, the single-transit probability of collision there is less than for passages closer to the hub. Whilst a smaller effect than that expected in (ii), this may still account for a reduction in collision of about 10%.

2.6 Option 1 is the least sophisticated approach and takes no account either of the distribution of birds within the zone of potential collision risk nor their differential risk of collision with the turbine.

2.7 Option 2 offers an intermediate position as it takes account of the distribution of birds within the zone of potential collision risk but uses the less sophisticated, basic model to calculate the risk of those birds colliding with a turbine blade.

2.8 Avoidance rates for use in the Band model have been derived from reported mortality rates (rather than direct observations of avoidance) following the formula given in SNH (2010), whereby observed mortality is divided by the mortality expected in the absence of avoidance based on the flux of birds through the rotor-swept area:

$$Avoidance\ Rate = 1 - \left(\frac{observed\ collisions}{collisions\ expected\ in\ the\ absence\ of\ avoidance}\right) \text{ [eq. 1]}$$

2.9 The resultant avoidance rates have then been used to infer likely avoidance rates for species for which insufficient data exist to allow such a calculation. Estimation of the number of collisions expected in the absence of avoidance requires details of the flux rates of the species through the focal site and for an assumption to be made as to the species' flight height distribution. In the studies reported in SNH (2010), avoidance rates have been derived assuming a homogenous flight height distribution (i.e. all birds are distributed equally within the rotor-swept area of the turbine) within the framework of the basic Band model (Band, 2012a). However, as birds are unlikely to be distributed evenly within the rotor-swept area of a turbine, this assumption is unlikely to realistic. Indeed, as seabird flight height distributions are skewed towards lower altitudes (Cook et al., 2012, Johnston et al., in press), such an assumption will lead to an overestimate of the total number of birds at risk, and therefore an overestimate of the total avoidance rate.

2.10 In respect of the use of avoidance rates when using the extended model, the following statement is provided in Band (2012a):

> "*In particular, if the extended model taking account of flight height distribution is used, it is important that the calculations on which avoidance rates are based also start with a no-avoidance collision rate derived using the extended model*."

2.11 This statement relates to the skewed nature of bird flight density, as noted above, and the effect that this has on collision risk as noted above.

2.12 The extended model already takes account of the high proportion of low flying birds which will miss the rotor discs without taking avoidance action. As these birds may have contributed to avoidance statistics calculated in respect of the basic Band model (Option 1), using the avoidance rate calculated for use with Option 1 in conjunction with the extended model would effectively lead to double counting of this proportion of birds.

2.13 The significant influence that the choice of avoidance rate has on model predictions is recognised and the need to consider the appropriate avoidance rates to use with the extended model (Options 3 and 4) is not under question. It should not be assumed though that this implies that 98% is not the appropriate rate to use with the extended model. In the first instance, there is now a significant body of work indicating that avoidance rates for seabirds when at sea may be very high because of the interplay of a range of factors linked to bird ecology and behaviour, topography and weather and that a 98% avoidance rate (as regularly advocated by the statutory nature conservation bodies) is overly precautionary for seabirds (see Appendix 3). Furthermore, it is clear that where avoidance rates have been derived from observations of behaviour (rather than being inferred from a comparison of predicted and actual collision rates) that these rates will provide a better representation of the level and reality of collision.

3 Study Components

3.1 There are four key components to the overall study, as set out below, and these are discussed in this report. The outputs from each of these are important in providing an integrated view and understanding in respect of the use of appropriate avoidance rates in the extended Band model. While the information presented relates to general aspects of avoidance rate derivation for the offshore environment, there is a focus on those seabird species that have been identified through the project specific assessment work to be at particular risk of collision, namely: northern gannet, black-legged kittiwake, great black-backed gull and lesser black-backed gull.

Component 1 – review of assumptions and data used to support the avoidance rates utilised for onshore wind farms using Option 1 of the Band model

3.2 Limited consideration appears to have been given to the applicability and transferability of the avoidance rates derived for use with terrestrial bird species at onshore wind farms to use with seabirds at offshore wind farms.

3.3 This component of the study provides a review of the assumptions / precautions used in the derivation of avoidance rates used in CRM for onshore wind farms. On the basis of the review, consideration is given as to whether these assumptions specifically apply to the transposition of the same avoidance rates in assessing the collision risk associated with offshore wind farms. Where it is considered that the assumptions are invalid or should be modified the implications with regard to the use of the terrestrially derived default 98% avoidance rate in collision risk assessment for offshore wind farms are provided. The results of this work are presented in Appendix 1.

Component 2 - comparison of avoidance levels between the basic Band model (Options 1 and 2) and the extended Band model (Options 3 and 4)

3.4 This part of the study considers what avoidance rates would need to be applied in order to achieve parity in the impact outputs (i.e. number of collisions) between the basic model (Option 1) and extended model (Options 3 and 4). This was undertaken for the four seabird species under consideration. Some initial results for northern gannet are presented in the worked example presented as part of the Strategic Ornithological Support Services (SOSS) 2 project on collision risk (Band, 2012b). From this it is apparent that in order to generate collision numbers that are the same or similar to the outputs from Option 1, that the avoidance rates required to be used for Options 3 / 4 would be lower than is acknowledged to be realistic. It is expected that such a situation also applies to other seabird species. The outputs of these two analyses are presented in Appendices 2A and 2B.

Component 3 - review of available studies providing information on seabird avoidance rates

3.5 Only limited work has been undertaken in recent years to review existing observational data that may be of use in providing a more accurate idea of avoidance rates for seabird species. This aspect of the study provides a comprehensive review of the available avoidance rate (macro-avoidance and micro-avoidance) data from coastal, offshore and selected onshore wind farms. The findings of the review are used to determine whether the default 98% avoidance rate currently used in the majority of assessment work is reflective of the observational data for seabirds and, if not, what avoidance rates would be appropriate. The review is presented at Appendix 3.

Component 4 - review of avoidance rate evidence base in consent decisions

3.6 This part of the study considers the evidence base that has been utilised in previous offshore wind farm consent decisions where avoidance rates have changed from those previously acknowledged by the industry. Where it is apparent that deviations from use of the standard 98% avoidance rate have been made, then there may be either useful evidence put forward to justify specific rates or principles of position that are relevant to the discussion regarding the applicability of rates in respect of the extended model. The outputs from this component of the review are presented in Appendix 4.

4 The evidence base for avoidance rates in seabirds

4.1 For the purposes of the assessment of collision risk at offshore wind farms, the general practice has been to adopt the default 98% avoidance rate (SNH, 2010) derived for terrestrial bird species and transpose this to seabirds in the offshore environment. This situation has arisen largely due to the 98% rate being viewed as 'safe' because of the inherent precautionary considerations built into the rate and also, historically, due to the limited evidence base to indicate that avoidance rates should be any different for seabirds in the offshore environment.

4.2 When SNH originally devised its collision risk model (Band et al., 2007) a precautionary avoidance rate of 95% was chosen. This figure was based solely on expert opinion, with little or no empirical basis, as no sound, relevant data were available at the time. The SNH (2010 & 2013) updates of the use of avoidance rates in the SNH CRM, used data from a number of studies to propose revised avoidance rates for a number of species (e.g. 99% for golden eagle and hen harrier, 99.8% for geese) and a default avoidance rate of 98% for species where there was no existing empirical evidence to suggest an alternative rate. The change from the previous default value of 95% (for the majority of species) to 98% was justified on the basis of a number of studies and reviews of available data, many of which dated back to at least 2006-2007.

4.3 Since publication of the SNH (2010) guidance there has not been a comprehensive review of the evidence base for avoidance rates in seabirds in order to update and inform the use of CRM outputs in the assessment process for offshore wind farms. It is now apparent, however, from monitoring work undertaken over the past 5-10 years that there is a significant body of information that provides a strong evidence base that enables appropriate (and realistic) avoidance rates to be determined for seabirds in the marine environment. This work is reviewed in Appendix 3 and summarised for key species groups below:

- **Gulls**: Post-construction monitoring data from a variety of offshore, coastal and terrestrial wind farms show that levels of active avoidance that may occur at short distances (termed the micro-avoidance rate) by gulls are consistently extremely high. Of the 16 studies reviewed in Appendix 3, the minimum calculated micro-avoidance rate is 99.25%, maximum 100%, median 100% and mean 99.97%. There is no evidence from the available studies that micro-avoidance rates of gulls differ significantly between offshore/coastal and terrestrial sites, or among gull species. In addition to these very high micro-avoidance rates, gulls also show moderate levels of active avoidance at long distances, up to several kilometres from a wind farm, (termed macro-avoidance) at around 50%, so combined with the minimum estimate of 99.25% micro-avoidance a total avoidance rate of 99.625% is obtained.

- **Terns**: Monitoring data from a variety of offshore and coastal wind farms show that micro-avoidance rates of terns are consistently extremely high. From the available data, micro-avoidance rates by terns are a minimum of 99.83%, maximum 100%, median 99.97% and mean 99.945%. Terns also show moderate macro-avoidance at around 50%. Combined with the minimum micro avoidance rate this gives a total avoidance rate for terns of 99.91%.
- **Gannets**: Observed avoidance rates of gannets are consistently extremely high with particularly high macro-avoidance, consistent with the recommendation of a precautionary estimate of 99.8% avoidance suggested by Whitfield and Urquhart (2013).
- **Sea ducks**: Avoidance rates of sea ducks (predominantly common eider) are consistently extremely high with high macro-avoidance and high micro-avoidance; Danish data suggest an avoidance rate of 99.98%.

4.4 The overall conclusion from the studies reviewed in Appendix 3 is that observed avoidance rates in all seabirds considered to be prone to collision with wind turbines are high and generally greater than 99.5%. It is important to note that, in many of the studies, the derived avoidance rates are based on empirical (observational) data. These studies therefore provide the data to fulfil the requirement set out in the SNH (2010) guidance that if potential change to the default 98% rate for a species is to be advocated that this should be based on a sound evidence base. Another key aspect is that there is strong consistency across all of the studies showing that high avoidance rates in seabirds are observed for a range of locations and situations, indicating that such rates are more than likely to apply in all situations that are typical of those represented by the studies to date.

5 Derivation of the default 98% avoidance rate and its applicability to seabirds in the marine environment

5.1 The default 98% avoidance rate for the majority of species advocated in the SNH (2010) guidance is based upon post-construction studies at terrestrial wind farms. In these studies the avoidance rate is derived by comparing the numbers of birds killed by collision (i.e. the mortality rate rather than direct observation) in relation to numbers flying close to turbines and at risk height. In deriving the avoidance rates for terrestrial species there are a number of factors which indicate that the overall rates are overly precautionary (see Appendix 1) for use in the offshore environment where there are significant differences with respect to the collection of data for use in the CRM and seabird behaviour. The following key points can be drawn out from the work presented in Appendix 1 and Appendix 3:

- At terrestrial sites the derived rates are primarily 'micro-avoidance' rates, since birds that undertake avoidance action at distance from terrestrial wind farms are not normally counted in post-construction surveys. Thus the SNH recommended avoidance rates essentially represent micro-avoidance rates, with the macro-avoidance component generally excluded, and therefore the derived rates will underestimate the total avoidance rate shown by birds. Such underestimation may be minimal for most terrestrial bird species as there is little evidence to suggest that terrestrial birds (apart perhaps from golden eagle and geese) show macro-avoidance (Devereux *et al*., 2008; Garvin *et al*., 2011; Pearce-Higgins *et al*., 2012; SNH 2013; Haworth and Fielding, in press).
- Surveys of avian flight activity at onshore wind farms are typically carried out using a series of vantage points selected so that no part of the wind farm is more than 2km from at least any one vantage point (SNH, 2013). However, over a distance of 2km, a relatively high proportion of birds flying through the area are unlikely to be detected as the probability of detecting a bird decreases as distance from the observer increases (Buckland *et al*., 2001; Madders & Whitfield, 2006; SNH 2013). Although it is possible to correct for imperfect detection through distance sampling, in practice, this does not appear to have been done in any of the studies in which derived avoidance rates have informed recommendations provided in SNH (2010).
- The flight behaviour of seabirds at proposed offshore wind farms is surveyed using techniques such as radar, high definition aerial photography and video, and boat transects. Digital photographic and video methods are likely to detect a very high proportion (close to 100%) of the birds present (Buckland *et al*., 2012). If, as is quite likely, bird detection rates over a 2000m range vantage point survey at

terrestrial sites are about 50% for many species (Diefenbach *et al*., 2003; Madders and Whitfield, 2006; Calladine *et al*., 2009; Warren and Baines, 2011), then a 98% precautionary avoidance rate for terrestrial birds would be equivalent to a 99% precautionary avoidance rate for offshore wind farms where virtually all birds will be detected.

5.2 On the basis of the review work presented in Appendix 1 and Appendix 3 it is clear that the default 98% avoidance rate is in itself precautionary with respect to use in the terrestrial environment. As the avoidance rate is largely derived from studies of interactions of terrestrial bird species at onshore wind farms, there are several aspects and assumptions that do not specifically apply to CRM in the offshore environment. The general lack of macro-avoidance exhibited by terrestrial species, in comparison to seabirds, and the level of detection error inherent in terrestrial surveys indicates that the 98% avoidance rate should be viewed as overly precautionary with respect to CRM for seabirds.

6 Selection of an appropriate avoidance rate to use in Options 3 and 4 of the extended Band Model

6.1 The SNCBs in their consultation responses to date on the use of Options 3 and 4 of the extended Band model have made it clear that in order for the outputs from these options to be considered it cannot be assumed that the standard 98% default avoidance rate should apply. In their relevant representation to the Planning Inspectorate on the proposed Dogger Bank Creyke Beck wind farm development, Natural England and the Joint Nature Conservation Committee (JNCC) make the following statement:

> "*The use of Option 3 to inform the impact assessment results in significantly lower predicted mortalities when compared with Option 1 results. JNCC and Natural England currently recommend the use of the "basic" Band model (i.e. Option 1 or 2 depending on whether site specific data is appropriate, see Band 2012), not the "extended" Band model used in Option 3. This advice is based on issues regarding some of the assumptions underpinning these options, and in particular from the uncertainty around the appropriateness of applying Avoidance Rates (ARs) derived using the 'basic' Band model to the 'extended' Band model*".

6.2 A very similar statement was provided by JNCC and Natural England in their relevant representation on Hornsea Project One:

> "*JNCC and Natural England currently recommend the use of the 'Basic' Band model (i.e. Options 1 or 2) (see Band 2012), not the 'Extended' Band model used in Option 3, and now Option 4. This advice is based on reservations regarding some of the assumptions underpinning these options, and in particular stems from the uncertainty around the appropriateness of applying Avoidance Rates (ARs) derived using the 'Basic' Band model to the 'Extended' Band model*."

6.3 The current 98% default avoidance rate derived from onshore studies (see Appendix 1) is unlikely to be realistic for seabirds in the marine environment. Terrestrial survey methods are likely to significantly underestimate bird flux (leading to a lower expected number of collisions and a derived avoidance rate that will also be an underestimate) and rates for terrestrial species are unlikely to incorporate any macro-avoidance behaviour. As seabirds show medium to high macro-avoidance behaviour, the application of a rate that effectively incorporates no macro-avoidance element is likely to be significantly over precautionary when applied to seabirds. This suggests that the default 98% avoidance rate currently applied in CRM for seabirds, and as used in the 'basic' model (i.e. Option 1 of the Band model) is not realistic and it can be argued that for seabirds the default rate should be greater than 98%.

6.4 As summarised in the previous section and detailed in Appendix 3, there is now significant evidence from observational studies that avoidance rates for seabirds in the coastal and offshore environment are high for all species studied. The available evidence suggests that a 99.5% avoidance rate would be precautionary for gulls (including black-legged kittiwake), northern gannet, terns and sea-ducks.

6.5 A comparison of the avoidance rates that would be required for both basic and extended models to predict similar rates has been undertaken. Appendix 2A and 2B provide the results of reverse calculations undertaken on the collision risk predictions using the extended model for four seabird species and indicate the avoidance rates required to produce similar collision rates to the basic model (Option 1). This work shows that the rates that would need to be applied to the extended model are much lower than those typically used in the basic model and significantly lower than the observed avoidance rates for all of the seabird species considered (see Appendix 3).

6.6 This exercise is essentially a comparison of the accuracy of the basic and extended versions of the model. It indicates the correction required to the basic verison to compensate for its inherent over-estimate of collision rates. This over-estimation arises because, compared to the extended version, the basic version coarsely approximates the number of birds at risk. Any differences in the avoidance rates calculated to equalise the number of collisions between options (see Appendix 2) are essentially a reflection of differences in the capacity of the individual model options to predict the number of collisions.

6.7 In order to equalise collision rate estimates between model options the avoidance rate needs to take account of both bird avoidance behaviour and a correction for model conservatism. A higher correction factor will be required to those options that coarsely approximate the number of birds at risk (i.e. a greater correction factor needs to be applied for use with options 1 and 2 of the model than for options 3 and 4). Defining the specific correction factor that needs to be applied to each of the Band model options (and in respect of each species under consideration) depends on the characteristics of the model rather than on the observed avoidance rate. Options 3 and 4 provide significantly more accurate estimates of collision than options 1 and 2 of the model as they represent a better 'model' of seabird behaviour (i.e. by taking into account flight height). As such, only limited correction (relative to the observed avoidance rate) is likely to be required in comparison to the basic model. Put another way, it is considered unlikely that the inaccuracies in the extended model would overestimate collision by a significant factor. Based on observed avoidance rates of 99.5%, a 'corrected' minimum rate of 98%, which would represent a fourfold increase in collision numbers over observed rates, is therefore considered suitably precautionary for use with the extended model. Given the greater inherent accuracy of the extended model, it is considered that the extended model together with an appropriate avoidance rate for this version of the model (i.e. a minimum of 98%) should be used to determine what avoidance rate (i.e. the necessary correction) should be applied to the basic model in order to deliver approximate parity in the predicted outcomes.

7 Conclusions

7.1 This review of the use of avoidance rates for seabirds in CRM for offshore wind farms has drawn together information and evidence from a number of sources. The main points that can be drawn from the studies and analysis presented here are as follows:

- The default 98% avoidance rate largely derived from studies of interactions of terrestrial bird species at onshore wind farms is based on a number of aspects and assumptions that do not specifically apply to the offshore environment. The general lack of macro-avoidance exhibited by terrestrial species, in comparison to seabirds, and the level of detection error inherent in terrestrial surveys indicates that the 98% avoidance rate should be viewed as overly precautionary with respect to CRM for seabirds.
- As the summary of the evidence base for the derivation of recommended avoidance rates (see Appendix 1) illustrates, in the studies that informed the SNH (2010) guidance, where avoidance rates have been derived from empirical data on mortality, reported values for avoidance have been in excess of 99% (Pendlebury, 2006; Whitfield & Madders, 2006; Whitfield, 2009). In these cases, estimates of the number of collisions expected in the absence of avoidance would need to be at least double to reduce the derived avoidance rate to the 98% default value.
- A review of available data from studies of avoidance rates in seabirds shows that both micro-avoidance and macro-avoidance rates are high and, when combined, the overall avoidance rate for all species considered to be potentially prone to collision risk is typically greater than 99.5%.
- To date there has been very limited acceptance of anything but the use of the 98% default avoidance rate with Option 1 for use in CRM for seabirds (see summary provided in Appendix 4). This situation is likely to have arisen for a number of reasons, chief of which are:
    - The precautionary nature and applicability of the onshore derived 98% avoidance rate has not been fully considered / understood in respect of its application for use in the offshore environment;
    - The lack of any specific and up to date review of the available data for seabird avoidance rates in the offshore environment;
    - There has been a certain amount of inertia on the part of both developers and statutory bodies to investigate the issue. A large element of this probably relates to the fact that the scale and nature of previous offshore wind farm developments has enabled precautionary avoidance rates to be applied without leading to any predicted detriment to designated seabird populations (i.e. a

conclusion of adverse effect on integrity would be unlikely to arise). Therefore the need to query further the use of such precautionary rates has occurred infrequently. It would also appear that in cases where high (non-standard) avoidance rates have been utilised, that unless it was apparent from the assessment work that a potential adverse effect on integrity could arise, the use of these rates has not been fully scrutinised.

- In those instances where greater than 98% avoidance rates have been utilised in CRM (see Appendix 4) the weight of evidence used to argue for a higher rate has varied. With respect to Sandwich tern, data from a limited number of studies has been sufficient to enable the competent authority to use a higher rate in their determination. In other situations, for example, the assessment of the impact of collision for lesser black-backed gull at the Galloper wind farm, the evidence presented in a number of studies was not accepted by the SNCBs and the competent authority as sufficient to warrant an alteration to the standard avoidance rate. In respect of this point regarding the evidence base, it is notable that the amount of data and consistency of the findings on gull avoidance rates presented in Appendix 3 is considerably greater than that which informed the decision to increase recommended avoidance rates for terrestrial species such as hen harrier and golden eagle (SNH, 2010) and geese (SNH, 2013).
- It is clear from the project assessment information summarised in Appendix 4 that, by and large, the avoidance rate evidence base has been considered insufficient to deal with deemed uncertainty and meet the levels of precaution employed by the SNCBs in the consenting process. To a degree this situation is largely a result of the outcomes of the issues highlighted above. However, it is also apparent that limited consideration has been given in previous submissions to the significant levels of precaution built into the default 98% rate and the applicability of some of the assumptions used in deriving this rate to seabirds in the offshore environment.
- Reverse calculation has been undertaken to demonstrate the avoidance rates that would be required when using the extended model to produce a similar number of collisions to that of the basic model. This shows that the rates that would need to be applied in the extended model CRM calculations would be significantly lower than observed avoidance rates for all of the seabird species considered in this review. In order to equalise collision rate estimates between model options a correction to the avoidance rate may be required. This correction factor will be greater for use with the basic model than the extended model as options 3 and 4 represent a better ‘model’ of seabird behaviour.
- Given the greater inherent accuracy of the extended model, it is considered that the extended model together with appropriate

avoidance rates should be used to set the avoidance rate (i.e. the necessary correction) for the basic model in order to approximate parity in predicted collision outcomes.

7.2 In conclusion, and taking into account the above points a minimum avoidance rate of 98% for use with the extended Band model, which would represent a fourfold increase in collision numbers over observed rates, is considered suitable for addressing aspects of uncertainty and precaution in the assessment process.

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Appendix 1 - Review of assumptions used in generating avoidance rates for onshore wind farms and applicability for conversion to avoidance rates for offshore wind farms

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Review of assumptions used in generating avoidance rates for onshore wind farms and applicability for conversion to avoidance rates for offshore wind farms

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Objectives

- Review of the evidence base for onshore avoidance rates, including identifying species for which avoidance rates have been calculated and a description of the methodologies used to derive them.
- A comparison of the ecological and behavioural characteristics of species for which avoidance rates have been derived for onshore wind farms and relating these to those of seabirds.
- A consideration of whether rates derived for terrestrial species incorporate avoidance within the rotor-swept area, and therefore whether use with the extended Band model would constitute double-counting.
- An assessment of other precautions built into avoidance rates for onshore species, for example detectability, and how these may affect the applicability of avoidance rates for birds offshore.

Background

In the onshore environment, existing Scottish Natural Heritage (SNH) guidance is that a default avoidance rate of 98% should be used in wind farm collision modelling for most species, with the exception of greylag goose, pink-footed goose, Greenland white-fronted goose, barnacle goose, golden eagle, hen harrier, white-tailed Eagle and kestrel (SNH 2010). Rates of 95% have been recommended for white-tailed eagle and kestrel, 99% for golden eagle and hen harrier and 99.8% for the four geese species (SNH 2010, SNH 2013a). Previous guidance, 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 (see Pendlebury 2006, Whitfield & Madders 2006a) suggested that this value was overly precautionary and a revised default rate of 98% was recommended. In the absence of specific guidance relating English sites, these guidelines have also been adopted for projects in England.

The importance of flight height distributions to the derivation of avoidance rates

These recommendations have been based on a relatively limited number of studies, covering just a subset of the species assessed as part of the guidance for onshore wind farms (Table 1). In these studies, avoidance rates have been derived from reported mortality rates (rather than direct observations of avoidance) following the formula given in SNH (2010), whereby observed mortality is divided by the mortality expected in the absence of avoidance based on the flux of birds through the rotor-swept area:

$$Avoidance\ Rate = 1 - \left(\frac{observed\ collisions}{collisions\ expected\ in\ the\ absence\ of\ avoidance}\right) \text{ [eq. 1]}$$

The resultant avoidance rates have then been used to infer likely avoidance rates for species for which insufficient data exist to allow such a calculation. Estimation of the number of collisions expected in the absence of avoidance requires details of the flux rates of the species through the focal site and for an assumption to be made as to the species' flight height distribution. In the studies reported in SNH (2010), avoidance rates have been derived assuming a homogenous flight height distribution (i.e. all birds are distributed equally within the rotor-swept area of the turbine) within the framework of the basic Band model (Band 2012). However, as birds are unlikely to be distributed evenly within the rotor-swept area of a turbine, this assumption is unlikely to realistic. Indeed, as seabird flight height distributions are skewed towards lower altitudes (Cook *et al.* 2012, Johnston *et al.* in press), such an assumption will lead to an overestimate of the total number of birds at risk, and therefore an overestimate of the total avoidance rate.

Band (2012) developed an extended model, capable of incorporating these heterogeneous distributions into the estimates of avian collision risk. Johnston *et al.* (in press) describe a methodology whereby such a distribution can be defined for seabird species. These heterogeneous distributions can be incorporated into the Band collision risk model under the extended Band model (Band 2012). Birds flying at collision risk height tend to be clustered towards the lower edge of the rotor swept-area, where both the probability of being hit by a blade and the proportion of the total area occupied by a blade are at their lowest, fewer collisions would be predicted under a model using this distribution, than under the model assuming a homogenous distribution. This would consequently lead to the derivation of lower estimates of avoidance rates as avoidance behaviour is effectively double-counted. For this reason, Band (2012) states that where the extended model is used, and avoidance rates have been derived from reported mortality rates, *"it is important that the calculations on which avoidance rates are based also start with a no-avoidance collision rate derived using the extended model*". However, if avoidance rates are derived from actual observations of avoidance behaviour (i.e. Krijgsveld *et al.* 2011) this will not be the case, and avoidance rates may be transferable between the basic and extended Band models.

Table 1 Summary of evidence base presented for avoidance rates presented in SNH (2010 & 2013a). Red highlights indicate rates derived from eq. 1, where flight activity data and mortality rates are combined to compare observed collision rates with those expected in the absence of avoidance, given the levels of flight activity recorded at a site. Orange highlights indicate where avoidance rates have been derived based on whether recorded collision rates were proportional to bird abundance at the relevant site.

Species	Avoidance Rate	Evidence base
Red-throated Diver	98%	Unpublished report describing behaviour and collision rates around turbines
Black-throated Diver	98%	
Whooper Swan	98%	Unpublished report describing flight behaviour and similarity with other species
Greylag Goose	99.8%	Initial review of Canada Goose avoidance rates at 5 onshore wind farms in the USA (Fernley *et al.* 2006, Pendlebury 2006). Subsequent investigations at a Bulgarian wind farm suggest a high avoidance rate for Red-breasted Geese and Greater White-fronted geese (Zhetindijev & Whitfield 2011), whilst review of collisions involving geese at European wind farms suggests that they are very rare (Rees 2012).
Pink-footed Goose	99.8%	
Greenland White-fronted Goose	99.8%	
Barnacle Goose	99.8%	
Red Kite	98%	Regression showing that number of Red Kite collisions was in line with what would be expected given the total number of birds at a site (Whitfield & Madders 2006)
Hen Harrier	99%	Based on data combining mortality rates and flight activity records at eight sites in the USA demonstrating that avoidance rates were likely to exceed 99% (Whitfield & Madders 2006a).
Goshawk	98%	
Golden Eagle	99%	Based on data combining mortality rates and flight activity records at four sites in the USA demonstrating that avoidance rates were likely to exceed 99% (Whitfield 2009).
White-tailed Eagle	95%	Study showing that a greater number of White-tailed Eagle collisions were recorded at a site than would have been expected given the total number of birds present (Bevanger *et al.* 2009)
Osprey	98%	
Merlin	98%	
Peregrine Falcon	98%	
Kestrel	95%	Regression showing that number of Kestrel collisions was greater than would be expected given the total number of birds at a site (Whitfield & Madders 2006)
Short-eared Owl	98%	
Black Grouse	98%	
Golden Plover	98%	
Dunlin	98%	
Curlew	98%	
Greenshank	98%	
Skua (all species)	98%	
Gull (all species)	98%	

Tern (all Species	98%	

Summary of the evidence base for current recommendations on avoidance rates

Pink-footed goose, greylag goose, Greenland white-fronted goose, barnacle goose

The evidence presented for avoidance rates in geese is based on a series of studies on Canada geese at five operational wind farms in the USA (Fernley *et al.* 2006, Pendlebury 2006, SNH 2013a). Whilst, avoidance rates were not derived using the Band Collision Risk Model, the resultant avoidance rates did not differ significantly from those that would have been derived from the Band Model (Pendlebury 2006). Geese were relatively abundant within the study area, with between 0.68 and 14.3 birds recorded per hour in circles with a diameter of 800 m (Pendlebury 2006). These studies all showed that collisions were an extremely rare event, with no corpses discovered during standardised searches. Instead, mortality estimates had to be based on incidental corpse discovery. The resultant avoidance rates were found to be between 99.77% and 100%. Subsequent analysis on data from a wind farm in Bulgaria have shown high avoidance rates for both Red-breasted and Greater White-fronted Geese (99.7%; Zehtindjiev & Whitfield 2011), and a review of data from around Europe has confirmed that collisions involving geese are extremely rare events (Rees 2012).

Golden eagle

The avoidance rate recommended in SNH (2010) for golden eagle is based on empirical data obtained from four sites in the USA, analysed using the Band Collision Risk Model and summarised by Whitfield (2009). Whilst mortality rates were relatively high at one site, Altamont Pass where they were estimated at 67 birds per annum, this in the context of a site with in excess of 5,000 turbines. When adjusted to reflect a mortality per turbine per year, this gives a value of 0.012 collisions per turbine per year, still high in comparison to the remaining sites, which ranged from 0.001-0.006 collisions per turbine per year, but still reflecting a relatively low risk.

Red kite, kestrel and white-tailed eagle

In order to assess collision risk in kestrel and red kite, Whitfield & Madders (2006b), compare recorded mortality rates to the abundance of birds around wind farms at a site in Spain. They use a linear regression to demonstrate the number of collisions that would be expected given the abundance of each species at the site. Their analysis demonstrates that the number of red kite collisions was in line with what would be expected given a 98% avoidance rate. In contrast a far higher number of kestrel collisions were recorded than would have been expected assuming a 99.8% avoidance rate. SNH (2010) therefore recommended that a rate of 98% is used for red kite and 95% is used for kestrel. Similar evidence is presented for white-tailed eagle where recorded collisions were disproportionately higher than would have been expected given the abundance of the species at a site in Norway (Bevanger *et al.* 2009). Such an approach makes no assumptions about the flight height distributions of the species concerned. Therefore, avoidance rates derived following this methodology are likely to be applicable to alternative collision risk models, including the extended Band model.

Hen harrier

The avoidance rate for hen harrier recommended in SNH (2010) is based on empirical mortality data and predictions of mortality from eight sites in the USA made using the Band Collision Risk Model and summarised in Whitfield & Madders (2006a). At six of the study sites, no collisions were reported (and thus avoidance was estimated to be 100%). At the other two sites, avoidance rates of

99.7% and 93.2% were derived, although in the latter case, it was suggested that the derived value was an underestimate as flight activity was underestimated (Whitfield & Madders 2006a).

Red-throated diver and whooper swan

SNH (2010) cites unpublished reports by Natural Research, which we have been unable to obtain, in support of avoidance rates of 98% for red-throated diver and whooper swan.

For the remaining species covered by the guidance – Black-throated diver, Goshawk, Merlin, Peregrine Falcon, Short-eared Owl, Black Grouse, Golden Plover, Dunlin, Curlew, Greenshank and Skuas – guidance is to use a default value of 98%, based, presumably, on evidence from similar species. It is also worth noting that, at least in the case of raptors, levels of recorded flight activity are likely to be considerably lower than those of seabirds. This is likely to be reflected in significant uncertainty surrounding final estimates of avoidance behaviour in raptors due to the low power of the data.

Flight behaviour

The following section considers whether the flight behaviour of offshore species might be expected to differ to that of the onshore species for which evidence was used as the basis for recommendations provided in SNH (2010) and SNH (2013a) and thus how applicable the current default avoidance rates are likely to be for seabirds.

As outlined above, the recommendations provided in SNH (2010) and SNH (2013a) are based on relatively limited data, and evidence to support the recommended rates was available for only 11 of the 25 species covered by the guidance. For four of these species, evidence includes assessment of typical flight behaviour or extrapolation from closely related species.

While such extrapolation may have merit for closely related species, studies of avian interactions with overhead power lines suggest that vulnerability to collision may be highly species-specific due to differences in flight behaviour (Janss 2000, Martin & Shaw 2010) and thus that caution should be exercised in making generalisations about avoidance rates between groups. It is highly debateable how applicable avoidance rates derived for geese and raptors are for seabird species for this reason.

Raptors are often amongst the species which are most prone to collision with wind turbines (i.e. Barrios & Rodriguez 2004, de Lucas *et al.* 2004, 2008, Farfan *et al.* 2009). In contrast, geese are thought to be amongst the species least prone to collisions, with high avoidance rates (SNH 2013a; see also evidence of observed behaviour in Plonczkier and Simms 2012). This may, in part, reflect differences in flight behaviour. In flight, geese tend to be commuting between feeding and roosting sites, or migrating and so their eyes are fixed on the horizon. In contrast, raptors may be hunting for prey with eyes focussed on the ground, which increases their risk of collision (Martin 2011). The same may be true for some seabird species.

Similarly, when hunting, species such as golden eagle tend to soar at considerable height, whilst hen harriers may hunt closer to the ground (Cramp 1980). This soaring behaviour and interactions with landscape topology may increase the risk of collision amongst species like eagles (Ferrer *et al.* 2012), characteristics likely to be rare amongst seabirds. Of the three species for which avoidance rates have been derived from real data, the flight behaviour and flight height distributions of seabirds may, therefore, most closely resemble those of the hen harrier.

Deriving avoidance rates with a heterogeneous flight height distribution for terrestrial species

Band (2012) emphasises that avoidance rates derived for the basic model are not applicable to the extended model. Avoidance rates suitable for the extended Band model could be derived by recalculating the number of collisions that would be predicted by incorporating a variable flight height distribution. In order to achieve this, it would need to be possible to access the original data used to derive the rates previously. These data include:

- Turbine parameters (hub height, rotor speed, rotor radius, etc.);
- Turbine operational periods;
- Proportion of birds at risk height;
- Species flux rates; and
- Avian mortality rates, including details of any corpse detection corrections.

One would also need details of the total numbers of birds at each site and, then, sufficient data to be able to statistically model a robust heterogeneous flight height distribution. In practice, the latter would require data describing how birds have been assigned to different flight heights. Whilst data describing the turbine parameters, mortality rates and flight heights are available for hen harrier, crucially, the cited report (Whitfield & Madders 2006a) gives no details about the total numbers of birds at each site. This means it is not possible to estimate the number of collisions expected in the absence of avoidance using a method that makes use of heterogeneous flight height distributions.

Accounting for a heterogeneous flight height distribution is likely to reduce the resultant avoidance rate derived. Deriving such distribution for the onshore species, whilst of value, would require considerable work to source and model the required data and is beyond the scope of this review.

Flight height distribution shape is species-specific (Cook *et al.* 2012, Johnston *et al.* 2013) and therefore, the magnitude of this reduction will also be species-specific. As outlined above, in the studies that informed the SNH (2010) guidance, where avoidance rates have been derived from empirical data on mortality, reported values for avoidance have been in excess of 99% (Pendlebury 2006, Whitfield & Madders 2006a, Whitfield 2009). In these cases, estimates of the number of collisions expected in the absence of avoidance would need to halve in order to reduce the derived avoidance rate below the 98% default value.

Other considerations concerning the derivation of reported avoidance rates

Surveys of avian flight activity at onshore wind farms are typically carried out from a series of vantage points selected so that no part of the wind farm is more than 2km from at least any one vantage point (SNH 2013b). When flight activity data are collected in this fashion, it is important that all birds within the survey area are accounted for. However, this is unlikely to be the case for two reasons. Firstly, as levels of flight activity increase, it becomes more difficult to accurately track all birds present within the survey area (Madders &Whitfield 2006). Secondly, as distance from the observer increases, the probability of detecting a bird decreases (Buckland *et al.* 2001). For example, Madders & Whitfield (2006) demonstrated that the detectability of golden eagles declined at distances greater than 750m, and that merlin could not be reliably detected at distances greater than this and are likely to be imperfectly detected at distances greater than this. Studies have found similar results for other species, including the short-eared owl (Calladine *et al.* 2010). Although it is possible to correct for imperfect detection through distance sampling, in practice, this does not appear to have been done in any of the studies in which derived avoidance rates have informed recommendations provided in SNH (2010), and is not routinely carried out as part of the assessments for onshore wind farms.

Following the formula for calculating avoidance rates given in SNH (2010) (eq. 1), if the number of birds passing through the rotor-swept area of a turbine, and therefore the expected number of collisions, is underestimated, the derived avoidance rate will also be an underestimate, a point acknowledged in Madders and Whitfield (2006). The default 98% avoidance rate recommended by SNH (2010) and informed by evidence dependent on these methods can thus be regarded as in fact encompassing two sources of precaution: in the actual rate at which birds avoid turbines, and also in the likelihood that bird flight activity will have been under recorded due to the limitations of the survey methods (MacArthur Green 2012).

An example of the potential impact of imperfect detection on calculated avoidance rates is presented below for merlin.

Total survey area assuming a 2km vantage point survey of a semi-circular area all of which is visible (following SNH 2013b):

$$0.5 \times \pi \times 2^2 = 6.28\ km^2 \quad \text{[eq. 2]}$$

Total area in which merlin can be detected, following Madders and Whitfield (2006) in which it is suggested that Merlin may not be detected beyond 0.75km:

$$0.5 \times \pi \times 0.75^2 = 0.88\ km^2 \quad \text{[eq. 3]}$$

Proportion of survey area in which merlin can be detected:

$$\frac{0.88}{6.28} = 0.14 \quad \text{[eq. 4]}$$

Estimates of actual avoidance rates (when calculated) are based on comparison of predicted mortality and actual mortality. Therefore, all that is needed to update the 'actual' avoidance rate estimates would be to divide them by the estimated detection rate.

In the hypothetical merlin example, a maximum detection rate of 0.14 was calculated (i.e. 14% of birds are seen, but note this is precautionary since it assumes all birds within 750m are detected whereas actual detection rates will decline with distance up to 750m), the flight activity would be increased (activity/0.14) thereby increasing the predicted collisions by the same amount. The ratio of actual mortality to predicted avoidance would thus also be reduced by the same amount.

In this example the 98% avoidance rate suggested by SNH for merlin (SNH 2010) would become:

$$1 - \left((1 - 0.98) \times 0.14\right) = 0.997 \quad \text{[eq. 5]}$$

As a consequence, avoidance rates derived for onshore wind farms, must also account for imperfect detection. In the offshore environment, it is likely that detection of flying birds will be at or close to 100%. In the case of boat-based surveys, only the 300m in front and to the side of the survey vessel is covered meaning all flying birds are likely to be detected (Camphuysen *et al.* 2004). Similarly, digital aerial surveys are also likely to detect all birds (Buckland *et al.* 2012). As there is no need to correct for imperfect detection within offshore survey data, using data derived from surveys of onshore wind farms is likely to significantly underestimate the true scale of avoidance behaviour.

Conclusions

Following review of studies for which avoidance rates have been derived from reported mortality rates, SNH (2010) provided revised guidance on the use of avoidance rates in collision risk modelling for onshore wind farms, recommending a default avoidance rate of 98%. In the absence of equivalent evidence-based guidance for offshore sites, this avoidance rate has been adopted for the modelling of collision risk at offshore wind farms. Uncertainty about the comparability of the flight behaviours of terrestrial and marine species means that this default value may not be applicable to offshore sites. Furthermore, the reasoning behind the acceptance of the 98% rate in the offshore environment is unclear, particularly given differences in data collection methodology which may mean that it is inappropriate to simply transfer the rate used in the onshore environment to the offshore environment.

For the three species (hen harrier, golden eagle and Canada goose) for which avoidance rates have been derived following equation 1, these rates have been shown to exceed 99%. However, even in these instances, derived avoidance rates are likely to be underestimates as there is no correction for imperfect detection during surveys. Avoidance rates are highly species specific, yet even amongst species, such as golden eagle, which may be more prone to collision they have been found to exceed 99%. These rates also capture imperfect detection of birds within onshore wind farms. Differences in survey methodology mean that this is unlikely to be an issue for birds within offshore wind farms.

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Appendix 2 - Reverse calculation of Option 3 numbers to show the avoidance rates that would be required to produce an equivalent collision rate to those derived from Option 1

Appendix 2A – Calculations for Dogger Bank Creyke Beck
Appendix 2B – Calculations for Hornsea Project One

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Reverse calculation of option 3 numbers to show the avoidance rates that would be required to produce an equivalent collision rate to those derived from option 1

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Option 3 of the Band collision risk model typically results in lower collision estimates in comparison to those obtained from option 1. We use a reverse calculation to demonstrate the avoidance rate that would be required using option 3 to produce a similar number of collisions to option 1. To do this, we divide the option 1 collision rate by the option 3 collision rate and then multiply this by 1 - the avoidance rate used in both models (eq. 1). Band (personal communication to A. Cook) suggests that this is a reasonable methodology for deriving a conversion factor for avoidance rates.

$$Option\ 3\ Avoidance\ Rate\ = 1 - \left(\frac{Option\ 1\ collision\ rate}{Option\ 3\ collision\ rate} \times (1 - Option\ 1\ Avoidance\ Rate)\right)$$

[eq. 1]

We assess this for four species, northern gannet, black-legged kittiwake, lesser black-backed gull and great black-backed gull, assuming a 98% avoidance rate, with an additional 99% avoidance rate for northern gannet. This analysis demonstrates that for the species listed, avoidance rates would need to be 93% for northern gannet (based on a 98% avoidance rate in option 1 or 96% based on 99%), 57% for black-legged kittiwake and 92% for lesser black-backed and great black-backed gulls, for the number of collisions predicted using option 3 to match those predicted using option 1 (Table 1). These results highlight that the final estimated collision rates are extremely sensitive to the assumptions made about the flight height distribution of the species concerned, particularly in the case of Black-legged Kittiwake. The avoidance rate required for the option 3 collision rate to match the option 1 collision rate for Black-legged Kittiwake appears wildly unrealistic, raising questions of the appropriateness of using a default 98% avoidance rate for Black-legged Kittiwake within option 1 of the Band model.

Table 1. Predicted collision rates for Creyke Beck A + B using options 1 and 3 of the Band Collision Risk Model and the avoidance rate that would be required for option 3 to produce an equivalent number of collisions to option 1.

	Option 1 Avoidance Rate	**Creyke Beck A + B Collision using Option 1**	**Creyke Beck A + B Collision using Option 3**	**Avoidance rate required for Option 3 to produce equivalent number of collisions to Option 1**
Northern Gannet	98%	397	121	93%
Northern Gannet	99%	199	60	96%
Black-legged Kittiwake	98%	4,678	217	57%
Lesser Black-backed Gull	98%	129	34	92%
Great Black-backed Gull	98%	214	53	92%

Avoidance Rate Analysis
Work Package 2: Hornsea Project 1 data

18 December 2013

Project No. UKN0093
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Version 1
Prepared by **HAZ**
Verified by **TNO**
Approved by **TNO**

Reverse calculation of collision rates from Option 4 of the Band collision risk model to show the avoidance rates that would be required to produce an equivalent collision rate to those derived from Option 1

Option 4 of the Band (2012) collision risk model typically results in lower collision estimates in comparison to those obtained from Option 1. The predicted collision rate, however, is the product of the model prediction and an avoidance rate. For Option 1 a set of default rates are used (typically 98%), the purpose of this exercise is to explore what avoidance rates would need to be applied to Option 4 model outputs to yield the same collision rate indicated by Option 1 together with a default avoidance rate.

A reverse calculation is used to demonstrate the avoidance rate that would be required for Option 4 to produce a similar number of collisions to Option 1.
The collision rate predicted using Option 1 with a default avoidance rate is equivalent to:

$$Collision\ rate_{Op1} = Collision\ rate_{Op1\ no\ avoidance} \times AR_{default}$$

The collision rate predicted using Option 4 with a modified avoidance rate is equivalent to:

$$Collision\ rate_{Op4} = Collision\ rate_{Op4\ no\ avoidance} \times AR_{Op\ 4}$$

The avoidance rate ($AR_{Op\ 4}$) that would be required to produce a collision rate derived from Option 4 ($Collision\ rate_{Op4}$) that is equivalent to the collision rate generated by Option 1 at a default avoidance rate($Collision\ rate_{Op1}$) can be calculated as follows:

$$AR_{Op\ 4} = 1 - \left(\frac{Collision\ rate_{Op1}}{Collision\ rate_{Op4}} \times (1 - AR_{default})\right)$$

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The avoidance rate ($AR_{Op\ 4}$) has been calculated for four species (table 1):

- northern gannet (at default avoidance rates of 98% and 99%)
- black-legged kittiwake (at a default avoidance rate of 98%)
- lesser black-backed gull (at a default avoidance rate of 98%)
- great black-backed gull (at a default avoidance rate of 98%)

Table 1. Predicted collision rates for Hornsea Project 1 using Options 1 and 4 of the Band (2012)collision risk model. The value ($AR_{Op\ 4}$) that would be required for the predictions from Option 1 and 4 to be equivalent is also shown. The collision rates are unpartitioned annual rates and include all birds (adult, immature and juvenile)

	Avoidance Rate (*AR* *default*)	**Hornsea P1 Option 1 (*Collision rate* *Op1*)**	**Hornsea P1 Option 4 (*Collision rate* *Op4*)**	**Avoidance rate for equivalence (*AR* *Op4*)**
Northern gannet	98%	119	54	95.6%
Northern gannet	99%	60	27	97.8%
Black-legged kittiwake	98%	225	31	85.5%
Lesser black-backed gull	98%	90	22	91.8%
Great black-backed gull	98%	377	127	94.1%

Appendix 3 – Review of avoidance rate estimates for seabirds

DECEMBER 2013

REVIEW OF AVOIDANCE RATE ESTIMATES FOR SEABIRDS

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CONTENTS

SUMMARY i
1. ACKNOWLEDGEMENTS 1
2. DEFINITIONS OF AVOIDANCE 1
3. THE CONCEPT AND USE OF AVOIDANCE RATES 2
4. EMPIRICAL EVIDENCE FOR AVOIDANCE RATES FROM SITE-BASED STUDIES AT WIND FARMS . 5
4.1 Blyth Harbour (coastal wind farm) 5
4.2 Terrestrial wind farms in The Netherlands 5
4.3 Egmond aan Zee offshore wind farm 5
4.4 Horns Rev offshore wind farm 6
4.5 Nysted offshore wind farm 6
4.6 Blyth offshore turbines 6
4.7 Kessingland Wind Farm (terrestrial) 7
4.8 Avonmouth Docks (coastal wind farm) 7
4.9 Belgian wind farms (terrestrial and coastal sites) 9
4.10 Oosterbierum ,The Netherlands (terrestrial) 10
4.11 Beatrice Offshore Turbines (Demonstrator Site) 10
4.12 Haverigg (terrestrial) 10
4.13 Hellrigg (terrestrial) 10
5. CONCLUSIONS 11
6. REFERENCES 12

SUMMARY

The 'default' 98% avoidance rate for birds recommended for use at terrestrial wind farms is not an appropriate value for offshore wind farms due to differences in the way survey data are collected and differences in the prevalence of 'macro-avoidance' which is much less for terrestrial bird species than for seabirds, but is not generally measured in terrestrial post-construction monitoring.

Post-construction monitoring data from a variety of offshore, coastal and terrestrial wind farms show that micro-avoidance rates of gulls are consistently extremely high. The 40 measurements of micro-avoidance rates by gulls (including one measurement for kittiwake) gave a minimum of 99.25%, maximum 100%, median 100% and mean 99.95%. Only one out of the 40 measurements was below 99.8% (a measurement for 'gulls' rather than a particular species). In addition to these high micro-avoidance rates, gulls also show moderate macro-avoidance at around 50%.

Post-construction monitoring data from a variety of offshore and coastal wind farms show that micro-avoidance rates of terns are consistently extremely high. The ten measurements of micro-avoidance rates by terns gave a minimum of 99.83%, maximum 100%, median 99.97% and mean 99.945%. In addition to these high micro-avoidance rates, terns also show moderate macro-avoidance at around 50%.

Post-construction monitoring data from offshore and coastal wind farms show that avoidance rates of gannets are consistently extremely high with particularly high macro-avoidance in that species, consistent with the recommendation of a precautionary estimate of 99.8% avoidance suggested by Whitfield and Urquhart (2013).

Post-construction monitoring data from offshore wind farms show that avoidance rates of sea ducks (predominantly common eider) are consistently extremely high with high macro-avoidance and high micro-avoidance; Danish data suggest an avoidance rate of 99.98%.

We conclude that it would be appropriate to use a 99.5% total avoidance rate as a precautionary default for seabirds given that there is strong evidence of macro-avoidance in many seabirds which is not incorporated into micro-avoidance measurements, and that mean micro-avoidance rates (whether weighted for sample size or not) are higher than 99.5% for all species and sites studied to date. We recommend that Band model avoidance corrections for gulls, terns, sea ducks, and gannets, should be computed from a precautionary 99.5% total avoidance rate, and that this rate should be considered appropriate as a precautionary default estimate for seabirds in general.

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2. DEFINITIONS OF AVOIDANCE

Wind turbines represent a hazard to birds. Risk of collision mortality depends on the flight height of birds which may vary with environmental conditions (Shamoun-Baranes et al. 2006; Kahlert et al. 2012; Mateos-Rodriguez and Liechti 2012), their size and flight speed (Band et al. 2007; Perrow et al. 2011), and whether or not they change their flight trajectory to avoid collision (Chamberlain et al. 2006). Some birds flying directly towards rotating blades will miss the blades by chance and pass through unscathed. This makes it difficult to distinguish between passive avoidance and change to flight to avoid a collision that would otherwise have occurred.

Collision rates of birds with turbines can be measured by counting carcasses of birds killed by wind turbines. When combined with counts of numbers of birds 'at risk' this provides a collision mortality rate. Carcass count data can then be used to assess population level impacts through modelling of the additional mortality rate imposed on bird populations (Peron et al. 2013). Avoidance rate can be calculated as 1-collision rate (and thus incorporates both passive avoidance and active avoidance). However, active avoidance may occur at short distances (termed micro-avoidance) or at long distances up to several kilometres from a wind farm (termed macro-avoidance). When numbers of birds 'at risk' are counted at existing wind farms, the counts often ignore macro-avoidance since birds 'at risk' are counted when close to turbines. Hence, a true avoidance rate would require assessment of macro-avoidance as well as micro-avoidance. That could be done by comparing numbers coming close to wind turbine sites before and after wind farm construction. A reduction in numbers after construction, if corrected for any other long-term trends by a Before-After-Control-Impact (BACI) design, would indicate the extent of macro-avoidance. However, this approach has not generally been used.

The standard method to estimate collision risk to bird populations is based on pre-construction counts of bird activity at a proposed wind farm site and the input of such data into a model to assess numbers likely to be killed by collisions. The assessments are normally made using the Band model (Band et al. 2007), although other similar models can be used. The Band model calculates the proportion of birds flying at rotor height that would be expected to pass through a turbine unscathed and the proportion expected to collide if no evasive action was taken. In practice, birds tend to take evasive action, and the numbers likely to be killed are mainly determined by the extent of evasive action rather than by features of turbine design or species' flight speed or bird size (Chamberlain et al. 2006). So understanding avoidance rates of birds is key to assessing numbers likely to be killed by collisions.

To use the Band model, a correction factor has to be applied to account for the extent to which birds avoid turbines. Unfortunately, this correction factor has often also been called an 'avoidance rate', but in fact it should be used to determine an 'avoidance correction' to the Band model to account for avoidance, since new formulations of the Band model have been developed that take account of the particular flight height distribution of seabirds, and the correction factor required to account for avoidance will depend on which model is being used. In each case a correction factor will be required, based on the species-specific avoidance rate, but the correction factor may differ depending on the version of the Band model.

Before data on bird behaviour at wind farms were available, SNH recommended use of a precautionary avoidance rate estimate of 95%, but with accumulation of data at terrestrial wind farms this has been revised to 98% for most species (SNH 2010). With development of offshore wind farms, there is a need to consider whether avoidance rates of seabirds, and appropriate avoidance correction factors for application of the Band models, are the same as, or different from those of terrestrial birds. Many factors differ between seabirds and most terrestrial birds: many seabirds (such as gulls for example) are adapted to highly competitive aerial flock foraging where agility is a key to foraging success, so it may be anticipated that seabirds will be especially capable of aerial agility. Marine environments generally lack the thermals and deflected air currents off slopes that permit soaring flight in many large terrestrial birds which is a major factor influencing collision risk of large raptors and other soaring birds (Ferrer et al. 2012). Whereas large terrestrial birds minimize costs of flight by taking advantage of terrain and thermals to soar, seabirds minimize costs of flight during migration by travelling slowly, flying close to the sea surface to gain from the ground effect, and refuelling during migration (Klaassen et al. 2012).

3. THE CONCEPT AND USE OF AVOIDANCE RATES

Predicting numbers of birds that might be killed by collision with wind farm turbines requires estimation of numbers of birds flying through the area (pre-construction) within the height window in which collision with rotors might occur, combined with assessment of how many of these will avoid the blades, either passively or by behavioural response to the collision hazard. Such assessments are mostly made using the Band Model (Band et al. 2007), also known as the SNH collision risk model (SNH 2010), although other models of collision risk also exist (Whitfield and

Urquhart 2013), and the original Band model is often now being superceded for offshore wind farm assessments by new Band models that take account of seabird flight height distribution (Band 2012).

SNH (2010) used accumulating evidence from post-construction studies at terrestrial wind farms to recommend use of a default 98% avoidance rate for most terrestrial bird species, with 99% for a few species where data indicated lower risk, and 95% for a few species where data indicated higher risk. These 'avoidance rates' were derived from post-construction studies of numbers of birds killed by collision in relation to numbers flying close to turbines and at risk height, for the set of species for which adequate data existed to permit such calculations.

These rates are primarily 'micro-avoidance' rates, since birds that avoid the wind farm entirely are not normally counted in post-construction surveys. To assess how many birds avoid the wind farm so strongly that they are not counted post-construction (a form of avoidance termed 'macro-avoidance') it would be necessary to compare bird numbers before and after construction using a BACI design to correct for trends over time caused by other factors. None of the SNH estimates of avoidance rate do that, but are based only on post-construction data. Thus the SNH recommended avoidance rates are micro-avoidance rates ignoring [some] macro-avoidance, and therefore underestimate the total avoidance rate shown by birds. Such underestimation may be minimal for most terrestrial bird species as there is little evidence to suggest that terrestrial birds (apart perhaps from golden eagle and geese) show macro-avoidance, but studies of seabirds at offshore wind farms show that some seabirds alter their flight path when as much as 5 km from a wind farm in order to avoid flying close to the wind farm (Christensen and Hounisen 2005; Desholm and Kahlert 2005; Fox et al. 2006; Blew et al. 2008; Krijgsveld et al. 2011; Cook et al. 2012).

The 98% avoidance rate recommended by SNH for most terrestrial birds is not appropriate as a default for seabirds at offshore wind farms for at least two reasons:

a) The 98% rate is selected to be precautionary for terrestrial wind farms because the standard method of studying bird flight at terrestrial wind farms is by Vantage Point (VP) surveys of bird activity at distances up to 2000 m from the observer (SNH 2013). Over such large distances, a moderately high proportion of birds flying through the area will not be detected (SNH 2013). Detection probability declines with distance, and also varies with bird species, weather conditions, and habitat type (SNH 2013). The VP method also requires the observer to follow flights of a focal bird, or birds, of a target species once detected until the bird is lost from the area; this means that any other target species flying through the area while the focal bird is still being tracked will not be recorded, so further contributes to the potential for under-recording of bird numbers and activity. In contrast, seabirds are studied at proposed offshore wind farms using techniques such as radar, high definition aerial photography and video, and boat transects. Digital photographic and video methods are likely to detect a very high proportion (close to 100%) of the birds present, so that there is no need to adjust avoidance rate estimates to allow for birds that have not been detected, while boat surveys extend to only 300 m from the vessel so will be expected to miss a much smaller proportion of birds than would be the case onshore, and record presence without tracking focal individuals over time, so avoid under-representation of birds. If, as is quite likely, bird detection rates over a 2000 m range VP study at terrestrial wind farms are about

50% for many species (Brown and Shepherd 1993; Diefenbach et al. 2003; Madders and Whitfield 2006; Calladine et al. 2009; Warren and Baines 2011), but all are detected at offshore wind farms, then a 98% precautionary avoidance rate for terrestrial birds would be exactly equivalent to a 99% precautionary avoidance rate for offshore wind farms.

b) Macro-avoidance by seabirds is high (Cook et al. 2012), whereas it is not shown by most terrestrial birds (Garvin et al. 2011; Pearce-Higgins et al. 2012; SNH 2013; Haworth and Fielding 2014). Due to the high level of macro-avoidance shown by many species of seabirds, it is inappropriate to use the same default avoidance rate set for most terrestrial bird species.

Based largely on the difference in macro-avoidance between seabirds and terrestrial birds, Whitfield and Urquhart (2013) suggest that a default avoidance rate for seabirds should be at least 99%, and higher for some species where there is evidence; for example they suggest a more appropriate avoidance rate for gannet would be 99.8%, and urge further research on the derivation of avoidance rates for gulls. Their review reiterates conclusions reached by Maclean et al. (2009) who suggested that a more appropriate *default* avoidance rate for seabirds should be 99%, but the rate should be higher still for auks, gulls and gannets (99.5%), and fulmars and shearwaters (99.9%). The very high rate suggested for fulmars and shearwaters was in recognition of the fact that these birds generally fly very low over the sea and therefore are rarely at risk of collision with rotors. The variations in flight height distributions of seabirds (Cook et al. 2012) indicate the need for different species-specific avoidance corrections to be applied for different Band models based on these flight height distributions, since part of the avoidance corrected for by 'avoidance rate corrections' in the Band models is to allow for passive avoidance of birds caused by their flight not intersecting with rotors for purely mechanistic reasons. Although there are some seabirds that habitually fly high (e.g. marbled murrelets, Stumpf et al. 2011), most species in the UK and overseas tend to fly predominantly below rotor height.

It is possible to assess bird collision risk based on expert opinion, as done for example in assessing risk of bird strikes by aircraft (Shamoun-Baranes et al. 2008), but here we consider evidence and avoid use of expert opinion. Evidence was obtained from studies at wind farms assessing mortality of seabirds due to collisions in relation to numbers of birds at risk, and assessing the extent of macro-avoidance at offshore wind farms studied using a combination of radar and direct observation. Studies of gulls at terrestrial and coastal wind farms are included as well as studies at offshore wind farms since gull avoidance rates appear not to have been reviewed in detail up to now. Behaviour of gulls may differ between terrestrial and offshore wind farms, so the estimates from terrestrial sites need to be considered with caution. For example, gulls may use thermals over terrain for soaring to reduce energy costs of travel (Shamoun-Baranes and van Loon 2006), which they do not at sea. This could increase their collision risk at terrestrial wind farms relative to their risk at offshore wind farms due to a wider flight height distribution over land. At the population level, there may also be a need to consider sex specific and age-related or status-related behaviour of birds that could alter risk of different components of bird populations (e.g. Stienen et al. 2008).

4. EMPIRICAL EVIDENCE FOR AVOIDANCE RATES FROM SITE-BASED STUDIES AT WIND FARMS

The following sections present evidence from sites where avoidance has been studied. We include all of the examples we have been able to identify where seabird avoidance rates have been measured empirically and with moderate to large sample sizes. There are no examples of which we are aware that have been left out of this review.

4.1 Blyth Harbour (coastal wind farm)

Newton and Little (2009) suggested that Blyth Harbour Wind Farm (nine 0.3MW WindMaster turbines at a coastal site) might kill between 16.5 and 21.5 birds per turbine per year (mainly large gulls). This estimate was derived from survey of dead birds on the shoreline, of which 3% were estimated to be killed by collision with wind turbines. The total numbers were then multiplied up by a correction factor to account for the fact that not all birds killed would be deposited onto the shoreline. Direct observations at Blyth Harbour estimated 45,104 gull flights per year close to the turbines, with 5,367 of these within the rotor swept area. However, in contrast to the suggested numbers of Newton and Little (2009), an estimated 0.8 gull collisions per turbine per year were recorded, giving a corrected total of 1.48 per turbine per year. This represents a micro-avoidance rate of 99.25% (RPS 2011), despite the turbines at this site being relatively small and therefore likely to be a greater hazard (Krijgsveld et al. 2009).

4.2 Terrestrial wind farms in The Netherlands

Krijgsveld et al. (2009) used a combination of radar and carcass searches to estimate a collision risk of 0.14% for birds (including large numbers of gulls) flying past 1.65 MW turbines at three onshore wind farms in The Netherlands, a risk which the authors stated was three-fold lower than for smaller turbines in the same region (implying a micro-avoidance rate of 99.86%). This decrease in relative collision risk with increasing turbine size indicates that turbine size is one factor that needs to be taken into account when looking at detailed values of avoidance rate. Krijgsveld et al. (2009) suggest that the decreased risk can be explained by three factors: increased height of turbines presents a greater risk-free height band low over the ground which is where most bird flight was occurring; increased spacing between turbines may allow birds to fly between rows more easily; lower rotor speed of larger turbines may reduce collision risk.

4.3 Egmond aan Zee offshore wind farm

Radar studies combined with direct observation to check on species identification (Krijgsveld et al. 2011) provided estimates of macro-avoidance of Egmond aan Zee OWF (seabirds changing flight direction to avoid entering the wind farm area). Macro-avoidance was around 20% for cormorants, 30% for gulls and terns, 45% for alcids, 50% for divers, grebes, fulmars and other petrels, and seaducks, and 70% for gannets. However, this study did not measure micro-avoidance rates.

4.4 Horns Rev offshore wind farm

Radar studies indicated that some 'seabirds' (a range of species mainly including sea ducks, gannets, gulls, terns and cormorants) changed flight direction when between 10 and 2 km away from the wind farm but the extent of this macro-avoidance was not quantified due to difficulty in detecting birds at a distance of 10 km from the site. Of those still heading towards the site when 1.5 to 2 km distant, 71-86% changed track to avoid entering the wind farm. Therefore, 'macro-avoidance' was at least 71-86% and probably considerably higher (Fox et al. 2006). From the same data, Petersen et al. (2006) estimated a macro-avoidance rate of 100% for gannets (n=268), and a macro-avoidance rate of about 70% for gulls (mostly great black-backed gulls and herring gulls) and for terns (common, Arctic and Sandwich). These estimates tend to be slightly higher than estimates for the same species at Egmond aan Zee OWF but it is unclear whether this is due to site-specific differences in macro-avoidance or to differences in methodology (possibly including birds at greater distances than tracked in the Dutch study). Petersen et al. (2006) did not estimate micro-avoidance rates for gannets, gulls and terns as no gannets that were tracked by radar entered the wind farm, and sample sizes of gulls and terns observed entering the wind farm were small; however, Thermal Animal Detection System (TADS) recordings (infrared video) totalling 123.6 days did not record any collisions by any seabirds. Blew et al. (2008) present direct observations and radar studies in spring and autumn of 2005 and 2006 at the same site. Highest numbers of seabirds were sea ducks, gulls, cormorants, and terns, with small numbers of gannets, fulmars and auks. Most flying seabirds avoided entering the wind farm, indicating high macro-avoidance. Although the study presented data on flight heights and behaviour, the authors did not estimate micro-avoidance or collision rates.

4.5 Nysted offshore wind farm

Radar studies (Petersen et al. 2006) showed that 91-92% of 'seabirds' (mostly common eiders) avoided entering the wind farm by changing their flight direction as they approached the site ('macro-avoidance'). Use of a thermal camera (TADS) sampling bird flights close to one turbine over two years recorded 100% micro-avoidance for that small sample of flights (mostly of eiders). Petersen et al. (2006) reported an avoidance rate of 99.98% for sea ducks (almost all of which were common eiders) based on radar studies combined with direct observations to identify species. Blew et al. (2008) present direct observations and radar studies in spring and autumn of 2005 and 2006 at the same site. Highest numbers of seabirds were eiders, cormorants, and gulls. Most flying seabirds avoided entering the wind farm, indicating high rates of macro-avoidance, although cormorants tended to congregate within the wind farm to forage communally despite also showing macro-avoidance in flight. Although the study presented data on flight heights and behaviour, the authors did not estimate micro-avoidance or collision rates.

4.6 Blyth offshore turbines

Rothery et al. (2009), working at Blyth (2 turbines offshore, 2MW each, hub height 59.4m, rotor diameter 66m), reported on 352 hours of Vantage Point direct observations during 1998-2003 of seabirds passing close to the turbines (close being defined as 'at risk' and therefore not considering macro-avoidance). All species watched showed 100% micro-avoidance (no collisions) as shown in Table 1.

Table 1. Data from Rothery et al. (2009) of the micro-avoidance rates of seabirds passing close to offshore wind turbines near Blyth, Northumberland.

Species	Total number passing close to turbines	Percent flying at rotor height	Total number at rotor height	Observed micro-avoidance rate (%)
Gannet	432	13	54	100
Black-headed gull	978	4	42	100
Herring gull	1408	33	460	100
Great black-backed gull	564	44	249	100
Kittiwake	1350	11	146	100
Sandwich tern	2135	3	69	100

4.7 *Kessingland Wind Farm (terrestrial)*

Post-construction monitoring of non-breeding season birds at two turbines (Kessingland Wind Farm) was reported by Wild Frontier Ecology (2013). Large numbers of black-headed, common, herring, and lesser black-backed gulls were observed flying at risk height past these turbines, and carcass collections were carried out through winter study periods over two years post-construction. No comparison was made with numbers recorded before construction so macro-avoidance could not be assessed. Total numbers of gulls at risk were between 450 (common gull) and almost 2000 (herring gull). Micro-avoidance rates were 99.92% for common gull, 99.93% for herring gull, 99.94% for black-headed gull, and 100% for lesser black-backed gull (Wild Frontier Ecology 2013).

Table 2. Data from Wild Frontier Ecology (2013) indicating the avoidance rates of gulls passing close to wind turbines at Kessingland Wind Farm in the first two non-breeding seasons post-construction 2011/12 and 2012/13.

Species	Total number passing turbines at rotor height	Observed micro-avoidance rate (%)
Black-headed gull	1135	99.94
Common gull	454	99.92
Herring gull	1920	99.93
Lesser black-backed gull	480	100.00

4.8 *Avonmouth Docks (coastal wind farm)*

The Landmark Practice (2010) monitored bird activity at Avonmouth Docks wind farm (Ecotricity; 3 Enercon E82 turbines). They carried out 264 carcass searches (approximately one search every three days over the first two years post-construction, 2007/08 and 2008/09) and a total of 340 hours of collision watch surveys (monthly surveys over the first two years post-construction, 2007/08 and 2008/09). No estimates were made of carcass removal rates due to scavengers or of carcass detection efficiency, but it was considered that carcasses were unlikely to have been overlooked in view of the industrial nature of the area with little scope for carcasses to be hidden, and that even if carcasses were taken by scavengers, trace evidence such as patches of feathers would be seen (The Landmark Practice 2010). Numbers of gulls passing close to turbines were about 50% lower than before construction, suggesting some moderate level of macro-avoidance which might be as much as 50%, but the authors cautioned that other changes in the environment may have contributed to this decrease and no control site was monitored. No collisions were detected either by direct observation or by carcass searching, despite very large numbers of gulls (between 20,000 and 30,000 each year) passing through the site close to turbines at rotor height, so that micro-avoidance was 100% for all gull species in both years (Table 3).

Table 3. Data from The Landmark Practice (2010) indicating the micro-avoidance rates of seabirds passing close to wind turbines at Avonmouth Docks in 2007/08 and 2008/09.

Species	Mean hourly number passing turbines 2007/08	Mean hourly number passing turbines 2008/09	Percent at rotor height 2007/08	Percent at rotor height 2008/09	Number at rotor height in 2007/08	Number at rotor height in 2008/09	Micro-avoidance rate based on carcass searches (%)
Black-headed gull	4.4	7.1	68	35	13,105	10,884	100
Common gull	0.1	0.0	(68)	-	298	0	100
Lesser black-backed gull	3.4	0.6	(19)	(18)	2,829	473	100
Herring gull	6.8	13.0	19	18	5,659	10,249	100
Great black-backed gull	0.1	0.0	(19)	-	83	0	100
Large gull sp.	8.1	1.6	(19)	(18)	6,741	1,261	100
All gulls	22.9	22.3			28,715	22,867	100

*Number in year computed as hourly rate x 12 hours daily activity x 365 days

The Landmark Practice (2011 and 2013) reported on two further years of monitoring at Avonmouth, in 2009/10 and in 2011/12. Monitoring involved carcass searches and vantage point surveys (108 hours in 2009/10 and 108 hours in 2011/12). As in the earlier two years, no collisions were detected either by direct observation or by carcass searching, despite very large numbers of gulls (over 39,000 in 2009/10 and over 55,000 in 2011/12) passing through the site close to turbines and at rotor height, indicating a micro-avoidance rate of 100% in these two years (Table 4).

Table 4. Data from The Landmark Practice (2011 and 2013) indicating the micro-avoidance rates of seabirds passing close to wind turbines at Avonmouth Docks in 2009/10 and 2011/12.

Species	Mean hourly number passing turbines 2009/10	Mean hourly number passing turbines 2011/12	Percent at rotor height 2009/10	Percent at rotor height 2011/12	Number at rotor height in 2009/10	Number at rotor height in 2011/12	Micro-avoidance rate based on carcass searches (%)
Black-headed gull	2.9	12.8	67	25	8,510	14,016	100
Lesser black-backed gull	1.3	4.3	(33)	(21)	1,879	3,955	100
Herring gull	18.8	38.2	33	21	27,174	35,136	100

Great black-backed gull	0.0	0.1	-	(21)	0	92	100
Large gull sp.	1.1	2.3	(33)	(21)	1,590	2,116	100
All gulls	24.1	57.7			39,153	55,315	100

*Number in year computed as hourly rate x 12 hours daily activity x 365 days

4.9 Belgian wind farms (terrestrial and coastal sites)

Detailed studies have been carried out of bird collisions at terrestrial and coastal wind farms in Belgium over many years (Everaert 2003, 2008; Everaert et al. 2001, 2002; Everaert and Kuijken 2002, 2007; Everaert and Stienen 2007). Estimates of avoidance rates of gulls and terns at these sites are listed in Table 5. Micro-avoidance rates must be treated with some caution (although there is no reason to anticipate bias in one direction or the other) for these sites however, as correction factors for carcass detection efficiency and corpse disappearance rates were taken as average values from earlier work in The Netherlands rather than from studies at these same sites.

Table 5. Estimates of micro-avoidance rates of gulls and terns at terrestrial and coastal wind farms in Belgium, based on numbers of collision casualties (corrected for detection efficiency and corpse disappearance rates) and predicted casualties based on gull and tern numbers and flight heights at each site.

Site	Year	Species	Micro-avoidance rate (%)	Reference
De Put, Nieuwkapelle (2 x 0.8MW, 75m tower)	2006	Black-headed gull and common gull	99.90	Everaert & Kuijken (2007)
De Put, Nieuwkapelle (2 x 0.8MW, 75m tower)	2006	Lesser black-backed gull and herring gull	100.00	Everaert & Kuijken (2007)
Boudewijn canal, Brugge (14 x 0.6MW, 55m tower)	2001	Black-headed gull	100.00	Everaert & Kuijken (2007)
Boudewijn canal, Brugge (14 x 0.6MW, 55m tower)	2001	Herring gull	99.87	Everaert & Kuijken (2007)
Boudewijn canal, Brugge (14 x 0.6MW, 55m tower)	2005	Black-headed gull	99.97	Everaert & Kuijken (2007)
Boudewijn canal, Brugge (14 x 0.6MW, 55m tower)	2005	Herring gull	99.88	Everaert & Kuijken (2007)
Kleine Pathoekeweg, Brugge (7 x 1.8MW, 85m tower)	2005	Black-headed gull	99.97	Everaert & Kuijken (2007)
Kleine Pathoekeweg, Brugge (7 x 1.8MW, 85m tower)	2005	Lesser black-backed gull and herring gull	99.86	Everaert & Kuijken (2007)
Kluizendok, Gent (11 x 2MW, 98m tower)	2005-2007	Black-headed gull	99.96	Everaert (2008)
Kluizendok, Gent (11 x 2MW, 98m tower)	2005-2007	Lesser black-backed gull and herring gull	100.00	Everaert (2008)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2001	Lesser black-backed gull and herring gull	99.95	Everaert & Kuijken (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2001	Little tern	99.99	Everaert (2008)
Eastern port, Zeebrugge	2001	Common tern	99.83	Everaert (2008)

Site	Year	Species	Micro-avoidance rate (%)	Reference
(24 x 0.4 MW, 23-55m towers)				
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2001	Sandwich tern	100.00	Everaert (2008)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2004	Lesser black-backed gull and herring gull	100.00	Everaert & Kuijken (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2004	Little tern	100.00	Everaert & Kuijken (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2004	Common tern	99.88	Everaert & Kuijken (2007) ; Everaert & Stienen (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2004	Sandwich tern	99.91	Everaert & Kuijken (2007) ; Everaert & Stienen (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2005	Lesser black-backed gull and herring gull	100.00	Everaert & Kuijken (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2005	Little tern	100.00	Everaert & Kuijken (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2005	Common tern	99.89	Everaert & Kuijken (2007); Everaert & Stienen (2007)
Eastern port, Zeebrugge (24 x 0.4 MW, 23-55m towers)	2005	Sandwich tern	99.95	Everaert & Kuijken (2007) ; Everaert & Stienen (2007)

4.10 Oosterbierum ,The Netherlands (terrestrial)

Winkelman (1992) estimated a micro-avoidance rate of 99.82% for gulls at Oosterbierum, Friesland, The Netherlands.

4.11 Beatrice Offshore Turbines (Demonstrator Site)

Observations of the two turbines recorded 6,434 gulls flying close to the turbines, with 4,321 at rotor height. None of these birds collided with turbines, indicating 100% micro-avoidance (RPS 2010).

4.12 Haverigg (terrestrial)

Observations recorded 10,151 large gulls flying close to the turbines, with 252 at rotor height. None of these birds collided with turbines, indicating 100% micro-avoidance (RPS 2011).

4.13 Hellrigg (terrestrial)

Post-construction monitoring at Hellrigg Wind Farm included vantage point counts of bird numbers flying close to the turbines and carcass sampling over periods of about 100 days in December-March in 2011-12 and 2012-13 (Ecology Consulting 2012, 2013). These studies were primarily focused on geese, but included thorough sampling of carcasses of all bird species and counts of numbers of a range of Target bird species including gulls. Small numbers of gulls were counted in 2011-12 but much larger numbers (primarily flying to and from roost sites) were counted in 2012-13. Although the carcass monitoring recorded 48 birds of 9 species in 2011-12 (Ecology Consulting 2012), only one of these was a gull (a herring gull). Although the carcass monitoring recorded 17 birds of 4 species in 2012-13 (Ecology Consulting 2013), no gulls were included. Carcass monitoring at Hellrigg was carried out once per week following standard method recommended by SNH (2009). Individual carcasses remained detectable for many weeks with a mean time to disappearance of over 3 weeks (Ecology Consulting 2013). Almost all marked carcasses found were detected again at the search one week later, indicating high search efficiency as well as carcasses remaining evident, and indicating that for this site there was unlikely to be any problem with collision victims being undetected (Ecology Consulting 2013).

Table 6. Data from Ecology Consulting (2012 and 2013) indicating the micro-avoidance rates of seabirds passing close to wind turbines at Hellrigg Wind Farm in mid-December to mid-March 2011/12 and 2012/13.

Species	Mean number per hour passing turbines 2011/12	Mean number per hour passing turbines 2012/13	Percent at rotor height 2011/12	Percent at rotor height 2013/13	Number at rotor height in 2011/12	Number at rotor height in 2012/13	Micro-avoidance rate based on carcass searches (%)
Black-headed gull	5.1	131.5	25	81	1,148	95,864	100.00
Common gull	8.9	507.2	50	88	4,005	401,702	100.00
Lesser black-backed gull	0	0.4	-	88	0	317	100.00
Herring gull	3.9	72.5	44	94	1,544	61,335	99.99
Great black-backed gull	0.1	0.5	100	93	108	418	100.00
All gulls					6,805	559,636	99.9998

5. CONCLUSIONS

- **Gulls:** Post-construction monitoring data from a variety of offshore, coastal and terrestrial wind farms show that micro-avoidance rates of gulls are consistently extremely high. The 40 measurements of micro-avoidance rates by gulls listed above (including one measurement for kittiwake) gave a minimum of 99.25%, maximum 100%, median 100% and mean 99.97%. This mean would not alter noticeably if computed using the sample size to weight the means by amount of data. There is no evidence that micro-avoidance rates of gulls differ significantly between offshore/coastal and terrestrial sites, or among gull species. Only one out of the 40 measurements was below 99.8%, a measurement of 99.25% for 'gulls' (at Blyth Harbour which is also the site with the smallest turbines and therefore the highest predicted risk, and so the least suitable model for a modern offshore wind farm). We also note that the amount of evidence, and consistency of the evidence, for gull avoidance rates is very considerably greater than the amount of evidence that was considered appropriate to allow decisions to increase recommended avoidance rates for terrestrial species such as hen harrier and golden eagle (SNH 2010).

- In addition to these very high micro-avoidance rates, gulls also show moderate macro-avoidance at around 50%, so the *minimum* estimate of 99.25% micro-avoidance equates to 99.625% total avoidance if this estimate of macro-avoidance is taken into account.
- **Terns:** Post-construction monitoring data from a variety of offshore and coastal wind farms show that micro-avoidance rates of terns are consistently extremely high. The ten measurements of micro-avoidance rates by terns gave a minimum of 99.83%, maximum 100%, median 99.97% and mean 99.945%.
- In addition to these very high micro-avoidance rates, terns also show moderate macro-avoidance at around 50%. Combined with the *minimum* micro avoidance rate this would give a total avoidance rate for terns of 99.91%.
- **Gannets:** Post-construction monitoring data from offshore and coastal wind farms show that avoidance rates of gannets are consistently extremely high with particularly high macro-avoidance in that species, consistent with the recommendation of a precautionary estimate of 99.8% avoidance suggested by Whitfield and Urquhart (2013).
- **Sea ducks:** Post-construction monitoring data from offshore wind farms show that avoidance rates of sea ducks (predominantly common eider) are consistently extremely high with high macro-avoidance and high micro-avoidance; Danish data suggest an avoidance rate of 99.98%.

We conclude that it would be appropriate to use a 99.5% total avoidance rate as a precautionary default for seabirds given the data summarised above, but that appropriate avoidance corrections for Band models would have to be computed from this depending on which version of the Band model was being used.

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Appendix 4 – Review of avoidance rates used in the assessment of consented offshore wind farms

DECEMBER 2013

Review of Avoidance Rates for Consented Offshore Wind Farms

Forewind

18 December 2013

Final Report

9X1252

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CONTENTS

Page

1 INTRODUCTION 1
1.1 Purpose of this Report 1
1.2 Projects considered 1

2 ANALYSIS OF AVOIDANCE RATE USE 5
2.1 Introduction 5
2.2 Dudgeon Offshore Wind Farm and Race Bank Wind Farm 5
2.3 Galloper Offshore Wind Farm 5
2.4 Greater Gabbard Offshore Wind Farm 10
2.5 Teesside Offshore Wind Farm 11
2.6 Triton Knoll Offshore Wind Farm 11
2.7 Westermost Rough Offshore Wind Farm 13
2.8 Sheringham Shoal Offshore Wind Farm 13

3 SUMMARY AND CONCLUSIONS 14
3.1 Summary of avoidance rate use for selected seabird species 14

4 REFERENCES 16

TABLES

Table 1.1: Projects considered in the review and data availability 2

Table 1.2: Applications where AA was undertaken by the Competent Authority and the species and European Sites assessed 3

Table 2.1: Collision risk model used, and species avoidance rate, for each consented project reviewed 6

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1 INTRODUCTION

1.1 Purpose of this Report

1.1.1 This report provides a review of consent decisions from Round 1 and 2 wind farm developments in order to determine the approach taken during the consenting and or assessment process in respect of the use of avoidance rates in collision risk modelling (CRM). In particular, focus is given to those projects where deviation from the generally accepted 98% default avoidance rate (SNH 2010) occurred.

1.1.2 Where information is available, the evidence base used to justify the adopted avoidance rate is presented as well as commentary on any debate surrounding the acceptance (or not) of proposed avoidance rate and the eventual outcome of the decision making / assessment process. Specific attention in this review is drawn to avoidance rates applicable to seabird species of particular concern with regard to collisions at a cumulative North Sea level, notably:

- Northern gannet;
- Black-legged kittiwake;
- Great black-backed gull; and
- Lesser black-backed gull.

1.1.3 Information on the avoidance rates used in CRM for Sandwich tern is also presented as the avoidance rate used in CRM for this species has been scrutinised via the consenting process for a number of offshore projects. As a result, there may be some important principles relating to the use of avoidance rates in the offshore environment that can be derived.

1.1.4 It should be noted that this review considers 'avoidance rates' in the wider sense, i.e. with respect to the overarching avoidance rate applied to modelled collision risk, which can include micro-, and macro- avoidance.

1.1.5 The information used in the preparation of this review includes the relevant projects' Environmental Statements (ES) and supporting technical appendices, the Examining Authority's (ExA) shadow Habitats Regulations Assessment (HRA) / Report on the Implications for European Sites (RIES), or the AA undertaken by the relevant Competent Authority. It should be noted that the information contained within this review is based on readily available reports, most of which were submitted as part of the consenting process, but subsequent revisions, addendums, or changes to projects during the determination process and post-consent are less publicly accessible.

1.2 Projects considered

1.2.1 **Table 1.1** presents a list of the projects considered in this review along with an indication of project status and the availability of project documentation obtained and used in this review.

Table 1.1: Projects considered in the review and data availability

Project Title	Project status	Documentation status
Dudgeon Offshore Wind Farm	Consent granted in 2012.	ES and appendices are available, including 2009 updates. MMO AA carried out in 2012 is available.
European Offshore Wind Development Centre	Consent granted March 2013, held pending appeals.	All final ES documents and addendum (submitted July 2012) including information for HRA are available. AA undertaken by the Competent Authority is not available.
Galloper Offshore Wind Farm	Consent granted in May 2013.	ES and HRA are available. DECC AA (May 2013) is available.
Greater Gabbard Offshore Wind Farm	Consent granted in February 2007. Fully commissioned in August 2013.	Final ES is available. Project AA undertaken by DTi, but not available. Joint AA carried out by DECC (2012) for Outer Thames Estuary SPA.
Humber Gateway Offshore Wind Farm	Consented in February 2011 and under construction.	ES documents and appendices are not publicly accessible. AA carried out by DECC (July 2009) is available.
Lincs Offshore Wind Farm	Consent granted in October 2008. Fully commissioned in September 2013.	ES and appendices not available (only LID6 ES is available). AA carried out by BERR (2008) is available.
Race Bank Offshore Wind Farm	Consent granted in July 2012. No progress on construction.	ES and appendices not available. DECC AA carried out in 2012 is available.
Sheringham Shoal Offshore Wind Farm	Consent granted in June 2009. Fully commissioned in September 2012.	ES and HRA submitted are available. AA carried out by BERR (2009) is available.
Teesside Offshore Wind Farm	Consent granted in September 2007. Fully commissioned in August 2013.	Only ES chapters are available (supporting technical appendices are not available) and no HRA was prepared. AA carried out by DTI (2007) is available.
Thanet Offshore Wind Farm	Consent granted in December 2006. Fully commissioned in September 2010.	ES, supporting appendices and Information for AA are available. The AA undertaken by BERR (2006) is not available.
Triton Knoll Offshore Wind Farm	Consent granted in July 2013.	Final ES, supporting appendices and information for AA are available. DECC AA (July 2013) is available.
Westermost Rough Offshore Wind Farm	Consent granted in November 2011. Construction to commence in 2014.	ES and Information for AA are not available. Judgement of LSE determined by DECC (June 2011) is available.

1.2.2 **Table 1.2** presents the list of applications that have, during examination and subsequent determination, had an AA undertaken, in date order. The table identifies the species and the European sites considered in the assessment, though noting that habitats or any species other than birds have not been included in the list.

Table 1.2: Applications where AA was undertaken by the Competent Authority and the species and European Sites assessed

Project	Date / ExA	Species	European site
Teesside	June 2007 (DTI)	Sandwich tern Redshank Cormorant Oystercatcher Bar-tailed godwit	Teesmouth and Cleveland Coast SPA
Lincs	June 2008 (BERR)	Pink-footed goose	North Norfolk Coast SPA
Sheringham Shoal	July 2008 (BERR)	Sandwich tern Common tern	North Norfolk Coast SPA
Humber Gateway	July 2009 (DECC)	Pink-footed goose	North Norfolk Coast SPA
		Common guillemot	Flamborough Head and Bempton Cliffs SPA
Docking Shoal, Race Bank, and Dudgeon	June 2012 (DECC)	Sandwich tern	North Norfolk Coast SPA
Kentish Flats Extension	February 2013 (DECC)	Red-throated diver	Outer Thames Estuary SPA
Galloper	May 2013 (DECC)	Lesser black-backed gull	Alde-Ore Estuary SPA
Triton Knoll	July 2013 (DECC)	Sandwich tern	North Norfolk Coast SPA
		Northern gannet Black-legged kittiwake	Flamborough Head and Bempton Cliffs SPA

1.2.3 The documents considered in this review are those listed in **Table 1.2** where collision risks on Sandwich tern, black-legged kittiwake, great black-backed gull, lesser black-backed gull, and northern gannet were assessed in the relevant AA. This review therefore focuses on the following projects:

- Dudgeon Offshore Wind Farm;
- Race Bank Offshore Wind Farm;
- Sheringham Shoal Offshore Wind Farm;
- Teesside Offshore Wind Farm;
- Galloper Offshore Wind Farm; and
- Triton Knoll Offshore Wind Farm.

1.2.4 A Judgement on LSE was carried out for Westermost Rough Offshore Wind Farm by DECC in 2011. This concluded no LSE and no further assessment was undertaken, however, there is some additional information within the Judgement document which is indirectly of use and this has also therefore been considered in this review.

1.2.5 As noted in **paragraph 1.1.5**, the review of the above is limited by the information readily accessible (i.e. where archived records are still publicly available). Whilst the AA / RIES have been obtained and are available for many consented projects, the projects' ES and other documents (that may have been presented during examinations and hearings) are not necessarily readily available.

2 ANALYSIS OF AVOIDANCE RATE USE

2.1 Introduction

2.1.1 **Table 2.1** presents the information extracted from the consented offshore wind farm projects' ESs or from any other sources (such as subsequent projects' Information for Appropriate Assessment (IfAA) with respect to the relevant seabird species. For many of the projects listed in **Table 2.1** there is limited justification for the use of the specific avoidance rates used in the CRM and the assessment process.

2.1.2 The following sections provide a summary of the avoidance rates used in the CRM for use in impact assessment work for those projects for which relevant information could be sourced.

2.2 Dudgeon Offshore Wind Farm and Race Bank Wind Farm

Sandwich tern

2.2.1 DECC undertook an Appropriate Assessment for the Docking Shoal, Race Bank and Dudgeon Offshore Wind Farm Projects in December 2011 and updated this in June 2012. In addition, MMO carried out an Appropriate Assessment in July 2012, which responded to some of the issues raised by Natural England and JNCC to the DECC AA. There was no consideration or assessment with respect to the four key seabird species considered in this review within either of the AAs, and the AA focused on the Sandwich tern population at the North Norfolk Coast SPA.

2.2.2 In the Dudgeon ES, the use of a 99.6% avoidance rate was justified on two studies undertaken for the Zeebrugge wind farm project, notably Everaert & Stienen (2006) and Steinen *et al*. (2008).

2.2.3 In the AA by DECC (June 2012), reference was made to the studies at Zeebrugge (Everaert & Stienen, 2006), Horns Rev (Petersen *et al*., 2006), Egmond aan Zee (Lindeboom *et al*., 2011), Thornton Bank (Vanermen & Stienen, 2009), and Blyth (Rothery *et al*., 2009) in relation to avoidance rates. JNCC & Natural England (2011) reviewed the Zeebrugge rate and concluded that 98.83% was most appropriate, though initially a 99.6% avoidance rate (Dudgeon) was applied.

Table 2.1: Collision risk model used, and species avoidance rate, for each consented project reviewed

Project	CRM used	Avoidance rate used/reported (%)					Considered in CA/ExA AA/RIES
		Black-legged kittiwake	Great black-backed gull	Lesser black-backed gull	Northern gannet	Sandwich tern	
Dudgeon Offshore Wind Farm	States Band (2000) CRM according to the Folkerts method was used	Not assessed	Not assessed	99%a	97%[a]	99.6%[a]	Yes – for Sandwich tern only, as part of overall AA for Dudgeon, Race Bank and Docking Shoal.
European Offshore Wind Development Centre	States Band model but no other detail	98%	98%	Not assessed	98%	98%	Yes for black-legged kittiwake and northern gannet (developer HRA only)
Galloper Offshore Wind Farm	States the standardised onshore CRM (Band *et al.*, 2007) was used – AA states 'directional approach'	99%[b]	99%[b]	99%[b]	98%	Not assessed	Yes for lesser black-backed gull – ExA reduced to 98% based on SNCB recommendation
Greater Gabbard Offshore Wind Farm	States Band (2000) CRM was used	No CRM presented	No CRM presented	99.82%[c]	No CRM presented	Not assessed	No
Humber Gateway Offshore Wind Farm	Detail not available	ES not available	ES not available	ES not available	ES not available	Not assessed	No
Kentish Flats Offshore Wind Farm	Detail not available	Not assessed	Not assessed	Not assessed	ES not available	Not assessed	No
Lincs Offshore Wind Farm	Detail not available	ES not available	ES not available	ES not available	ES not available	Not assessed	No
London Array 1 & II	Detail not available	Not assessed	Not assessed	Not assessed	ES not available	Not assessed	No
Race Bank Offshore Wind Farm	The AA stated that the Band (2000) CRM according to the Folkerts method was used	ES not available	ES not available	ES not available	ES not available	ES not available	Yes – for Sandwich tern only, as part of overall AA for Dudgeon, Race Bank and Docking Shoal.

Project	CRM used	Avoidance rate used/reported (%)					Considered in CA/ExA AA/RIES
		Black-legged kittiwake	Great black-backed gull	Lesser black-backed gull	Northern gannet	Sandwich tern	
Sheringham Shoal Offshore Wind Farm	States Band (2000) CRM was used	98%	98%	98%	98%	98%	Yes, for Sandwich tern as part of AA undertaken by BERR, for which an avoidance rate of 99.6% was applied.
Teesside Offshore Wind Farm	States Band (2001) CRM was used	99.62%[d]	99.62%[d]	99.62%[d]	99.62%[d]	99.62%[d]	No
Thanet Offshore Wind Farm	States Band *et al*. (in press) model was used	99%[e]	99%[e]	99%[e]	99%[f]	Not clearly stated	No
Triton Knoll Offshore Wind Farm	States Band (2000) CRM was used, but then implies that the Folkerts method which was refined further	98%	98%	98%	98%	98.83%[g]	Yes: 98% used for black-legged kittiwake, and 99% was identified as precautionary for northern gannet by the ExA.
Westermost Rough Offshore Wind Farm	Detail not available	ES not available	ES not available	ES not available	ES not available	Not assessed	Yes for all species - included as an Annex to the DECC judgement of no LSE.

a. Avoidance rate source referred to Maclean *et al.* (2009).
b. Various studies referenced including Krijgsveld *et al.* (2010) and Christensen *et al*. (2004) for northern gannet, and Winkelman (1992), Everaert (2003, 2008, 2011), Everaert *et al*. (2002), Everaert & Stienen (2007), and Camphuysen (2011) for gulls.
c. Values derived from medium risk and referenced Gill *et al*. (2002) and Chamberlain *et al*. (2005), with general reference to collisions being uncommon from studies such as Langston & Pullan (2003), Percival (2005), Pettersson (2005), and avoidance described by Desholm & Kalhert (2005).
d. Calculations based on Still *et al*. (1996) and Painter *et al*. (1999).
e. Refer to calculations made by Still *et al*. (1996) and studies by Everaert *et al*. (2002) and Langston & Pullan (2003).
f. Not specifically justified so it is assumed that those references for gulls were implied (see [e] above).
g. Taken from Everaert & Stienen (2007) and re-worked by Natural England (no reference to this latter one provided).

2.1 Galloper Offshore Wind Farm

Northern gannet

2.1.1 Reference is made in the ES to the studies of Krijgsveld *et al*. (2010) and Christensen *et al*. (2004) which indicate high levels macro-avoidance. The point is made that although there is no information on micro avoidance rates in the literature, the combined avoidance rate (i.e. macro + micro) is likely to be high (over 99%), especially for birds on migration through the site. Nevertheless, without qualitative data, the impact assessment considered both 98% and 99% avoidance rates.

2.1.2 In their advice letter to the Examining Authority (8th October 2012), Natural England provide the following comment in respect of the application of avoidance rates for northern gannet: "*Current guidance by Scottish Natural Heritage ("SNH") suggests a default 98% avoidance rate should be used in generating collision mortality figures (this implies that 98% of birds in an area will avoid collisions with turbines, with 2% of birds being killed). However, whilst this 98% is the currently accepted figure, there is a recent empirical study (Krijgsveld et al 2011) that documents greater avoidance of windfarms by Gannets than many other species and estimates an overall avoidance rate of 99.1% for this species. On this basis, in the current case an avoidance rate of 99% may be appropriate, pending further consideration of the SNH guidance. Currently the applicant estimates a mortality of 91 – 112 Gannets per annum using a 98% avoidance rate. If the greater 99% avoidance rate were used the mortality could be 46 – 56 birds per annum*."

2.1.3 In the record of the HRA undertaken by DECC (DECC 2013a) the following statement and conclusion regarding the potential impact of the project on the northern gannet population of the Flamborough Head and Bempton Cliffs SPA was provided: appropriate avoidance rate for use in calculating collision mortality figures is made:

2.1.4 "*A population viability analysis (PVA) for the Flamborough Head and Bempton Cliffs SPA was undertaken by the Wildfowl and Wetlands Trust Consultancy in 2012 suggesting an additional mortality of up to 113 gannets per annum as a result of the project alone. NE considers that this would not pose a risk of population decline, especially given the greater than average growth rate of this gannet colony. A more simplistic Potential Biological Removal (PBR) model was used to estimate population-level effects, based on in combination collisions of between 242 and 351 gannets per annum, calculated using a precautionary 98% avoidance rate. Using standard gannet demographic parameters, NE estimates that these collision levels would appear to be sustainable at all but the most precautionary values of the recovery factor. NE therefore advises that, on balance, and based on the assessments presented, a likely significant effect can be excluded on the Flamborough Head and Bempton Cliffs SPA, both from GWF alone and in combination with other plans and projects*."

2.1.5 The statement made in the HRA indicates that no further consideration was given to the use / acceptability of a 99% avoidance rate for gannet as using a 98% rate it was apparent from the PVA work that a likely significant effect could be excluded.

Gulls (including black-legged kittiwake)

2.1.6 A number of studies are cited in the ES that provide evidence for micro- and macro-avoidance rates for gulls. These are:

- Blyth Harbour Wind Farm, Northumberland (Lawrence *et al*., 2007);
- Oosterbierum in The Netherlands - Winkelman (1992); and
- Wind farms in Flanders (Everaert, 2006, 2008, 2011; Everaert *et al*., 2002; Everaert & Stienen, 2007).

2.1.7 On the basis of additional information on gull behaviour, including nocturnal activity (Camphuysen (2011)) and macro-avoidance rates (Krigsveld *et al*. (2010)), the overall avoidance rate for gulls was judged to be at least 99.0% (this rate was used in the environmental assessment), and potentially higher in the offshore environment, particularly in a large multi-row wind farm such as Galloper.

2.1.8 The AA carried out by DECC (May 2013) only considered the impact of the proposed wind farm development on the lesser black-backed gull population of the Alde-Ore Estuary SPA. Natural England and the ExA agreed that no LSE would arise with respect to other bird populations at this site and all other European sites screened into the assessment.

2.1.9 The avoidance rate used for the Galloper CRM was 99% on the basis of a COWRIE report (MacLean *et al*., 2009) in which gulls are ascribed an avoidance rate of 99.5% and also monitoring work at Blyth Harbour wind farm in Northumberland which showed that micro avoidance rates alone for large gulls are likely to be above 99% (Lawrence *et al*., 2007). In respect of this assessment work and the use of the 99% avoidance rate, the following statements were made in the written representation by Natural England (Appendix D – Expert Report on Ornithology by Richard Caldow – 16th July 2012):

"*The Applicant presents a review of the literature (Appendix 3 to OTR) and concludes that there is sufficient evidence to support an avoidance rate for gulls of 99% or more. To an extent, this is based on dismissal of studies that have generated lower values of micro-avoidance. Table A.3.8 lists 20 values of micro-avoidance by gulls and of these, 11 are less than or equal to 98%. Paras 1.136 – 1.142 of this Appendix 3 to OTR detail a number of reasons why these values may be lower than would be appropriate in a large offshore windfarm. However, clearly there is still considerable uncertainty as to what the "correct" value is. Natural England is not of the view that the overall avoidance rate of gulls at large offshore windfarms has been proved beyond all doubt to be precisely 98%. However, it must be recognised that reliance on any particular value of avoidance rate carries with it a risk to decision making. The value chosen: i) may not be close to the "true" value and ii) will not acknowledge the range of uncertainty that would exist even around that "true" value were it known*.

Use of avoidance rates that are relatively high risks underestimating the number of gull collisions. This in turn poses a risk that the magnitude of the increase in risk to the protected Lesser-black-backed gull population of the Alde Ore Estuary SPA will be underestimated. Conversely, the selection of a low avoidance rate risks overestimating the number of gull collisions and the magnitude of the increase in risk to the protected Lesser-black-backed gull population of the Alde Ore Estuary SPA will be overestimated. However, adopting a value informed by the lower end of the suite of values that can be derived from the empirical data would be consistent with the adoption of a precautionary approach to the assessment of an impact on an SPA interest feature in circumstances where there is uncertainty regarding the "true" avoidance rate value. Current SNH guidance recommends that a default (and precautionary) figure of 98% should be employed for all gulls and terns. As can be seen from Table 7.16 – 7.19 in the HRA, *assuming an AR of 98% predicts twice the number of collisions as does assuming a value of 99%, and four times as many as when an AR of 99.5% is assumed*."

2.1.10 In the AA carried out by DECC (May 2013) the following conclusions were made regarding the applicable avoidance rate for use in CRM for lesser black-backed gull:

"*NE suggest that a 98% avoidance rate is suitably precautionary for LBBG, given the uncertainty regarding bird behaviour when encountering a windfarm. This is largely on the basis of work undertaken by Krijgsveld et al. (2010, 2011) and Poot et al (2011) for the Egmund aan Zee wind farm – the first large-scale offshore wind farm built off the Dutch North Sea coast. This is also the default avoidance rate suggested by Scottish National Heritage (SNH) in its guidance note on avoidance rates (SNH, 2010) where there is a lack of suitable data to determine species-specific avoidance rates. NE considers that this is a realistic basis on which to make an assessment that incorporates a degree of precaution and is consistent with the available empirical evidence*.

The Applicant has conducted a literature review in its HRA and highlights, in particular, a COWRIE report (MacLean et al. 2009) in which gulls are ascribed an avoidance rate of 99.5% and also monitoring work at Blyth Harbour wind farm in Northumberland which showed that micro avoidance rates alone for large gulls are likely to be above 99% (Lawrence et al. 2007). The HRA literature review notes that some studies, such as those for wind farms in Flanders (e.g. Everaert, 2011; Everaert & Kuijken, 2007) indicate avoidance rates from 98.69% down to 91.53%. However, methods of calculations between studies are different and the location and layouts of wind farms are also different to GWF with respect to gull colonies. For example, there is a local migration route of gulls towards a roost site in one example (Brugge), whilst another wind farm studied lies near to a breeding colony (Zeebrugge). The Applicant suggests that turbines closer to nesting colonies would be subject to more short nocturnal trips and, hence, collision chance per turbine would be likely to be higher for such smaller, linear wind farms located close to colonies than for a large multi-row wind farm further offshore, such as GWF. As a result of its literature review, and taking into account the similarities/differences between the proposed GWF and other wind farms studied, the Applicant considers that the avoidance rate for LBBGs is likely to be at least 99% and possibly higher in the offshore environment, particularly for large multi-row wind farms, such as GWF.

The ExA recommends that, on balance, the 98% figure be used and that this would give an adequate level of precaution, because of the lack of species-specific evidence that can be used to confirm an avoidance rate with certainty."

2.2 Greater Gabbard Offshore Wind Farm

Lesser black-backed gull

2.2.1 In the Greater Gabbard EIA, three avoidance rates (high, medium and low) are presented. For the CRM the medium rate (99.82%) is used in the assessment. This rate is derived from the mortality rates for gulls presented in Winkelman (1997).

2.2.2 There is reference to an AA undertaken by DTi in the decision letter for the project in which it is stated that AA was undertaken with reference to the impact on the lesser black-backed gull population of the Alde-Ore Estuary SPA and the red-throated diver population of the Outer Thames Estuary pSPA. However, no record of this AA can be located. The decision letter states:

"*In light of the advice offered by the JNCC and NE, the DTI's environmental staff undertook an Appropriate Assessment ("AA") on behalf of the Secretary of State that considered the potential impacts of the Development on each of the sites mentioned before (Outer Thames Estuary pSPA and the Alde-Ore Estuary SPA). The conclusion of the AA was that the Development would not, either alone or in combination with other plans or projects within the Thames Estuary, adversely affect the conservation objectives of the integrity of the pSPA or the SPA. Both the JNCC and NE concur with the outcome of the AA and agree that the potential impact on birds is not sufficient to withhold consent*."

2.2.3 Subsequent to the individual project AA, DECC carried out an Appropriate Assessment in July 2013 of the combined London Array Phase I, London Array Phase II and the Greater Gabbard Offshore Wind Farms on the Outer Thames Estuary SPA features. The AA only considered the red-throated diver population.

2.3 Teesside Offshore Wind Farm

2.3.1 The ES generically notes that Percival (2000) indicates that avoidance rates are typically in excess of 99%, though no specific reference to which species is made. Overall, they used the Blyth Harbour Offshore Wind Farm results (Still *et al*., 1996; Painter *et al*., 1999) to justify the avoidance rates, which were based on the calculated number of collisions from the SNH collision model without avoidance (6,453) divided by the number of collisions per year (corrected for search efficiency) which averaged 24.7 birds per year, which resulted in the avoidance rate of 99.62%.

2.3.2 The ES presented the results of monitoring of the Nysted wind farm (using TADS) as justification for the higher avoidance rate. At Nysted, over 2,400 hours failed to detect a single collision, and the radar studies showed extensive avoidance reaction from migrants and waterfowl. Monitoring of Horns Rev also showed avoidance behaviour of (amongst other species) gulls (Petersen *et al*., 2006).

2.3.3 DTI carried out an Appropriate Assessment in June 2007. The assessment considered only the Teesmouth and Cleveland Coast SPA and in particular Sandwich tern and waterfowl (no seabirds). There was no consideration or assessment with respect to the four key seabird species within the DTI AA.

2.3.4 With regard to Sandwich tern, the ES stated that 99.2% was necessary to demonstrate no significant effect, and that avoidance rates were likely to be higher (with reference to Nysted (Petersen *et al*., 2006) and Flanders (Everaert, 2003)) and others. The Competent Authority (DTI, 2007) accepted the assessment put forward for Sandwich tern and determined No Adverse Effect on Integrity (NAEOI).

2.4 Triton Knoll Offshore Wind Farm

2.4.1 Collision risk modelling using a default avoidance rate of 98% was undertaken for all seabird species apart from Sandwich tern where 98.83% was utilised. The derived collision mortality figures were used in the environmental assessment and the information for HRA report.

2.4.2 An AA / RIES was carried out for the Flamborough Head and Bempton Cliffs SPA (northern gannet and black-legged kittiwake) and the North Norfolk Coast SPA (Sandwich tern), as well as other SPAs (DECC, 2013b).

Black-legged kittiwake

2.4.3 With regard to black-legged kittiwake, no discussion or comment was provided by the SNCBs and DECC as to the utilisation of the default 98% avoidance rate, other than to state that it was acceptable.

Northern gannet

2.4.4 While TKOWFL applied (and reported within the ES and HRA) an avoidance rate of 98% for northern gannet, further comment on the use of this rate was provided by Natural England (Appendix 2 of the Statement of Common Ground between TKOWFL and Natural England and the JNCC), as set out below:

"*From Current guidance by Scottish Natural Heritage ("SNH") suggests a default 98% avoidance rate should be used in generating collision mortality figures (this implies that 98% of birds in an area will avoid collisions with turbines, with 2% of birds being killed). However, whilst this 98% is the currently accepted figure, there is a recent empirical study (Krijgsveld et al 2011) that documents greater avoidance of windfarms by Gannets than many other species and estimates an overall avoidance rate of 99.1% for this species. On this basis, in the current case an avoidance rate of 99% may be appropriate, pending further consideration of the SNH guidance. Currently the applicant estimates a cumulative mortality of 357 Gannets per annum using a 98% avoidance rate. If the greater 99% avoidance rate were used the mortality could be 179 birds per annum*".

2.4.5 In the record of the HRA undertaken by DECC for TKOWF (DECC, 2013b), the following statement and conclusion regarding the appropriate avoidance rate for use in calculating collision mortality figures is made:

"*TKOWFL applied an avoidance rate of 98% for Gannet. However the SNCBs advise that whilst this 98% is the currently accepted figure, there is a recent empirical study (Krijgsveld et al 2011) that documents greater avoidance of windfarms by Gannets than many other species and estimates an overall avoidance rate of 99.1% for this species. Consequently SNCBs stated that in their view, in the current case, an avoidance rate of 99% may be appropriate, pending further consideration of the Scottish Natural Heritage guidance (Ornithology SoCG: Appendix 2). The Secretary of State agrees with the SNCBs, and concludes that an avoidance rate of 99% for Gannets may be sufficiently precautionary for this species, based on the most recent evidence, although he notes that there would not be an adverse impact even with a 98% avoidance rate in this instance*".

2.4.6 The clear conclusion is that the Secretary of State determined that the level of evidence (i.e. the empirical data and conclusions reached in Krijgsveld *et al*. (2011) was sufficient to enable a 99% avoidance rate to be applied in the case of the TKOWF.

2.4.7 Subsequent to the decision reached on TKOWF, further consideration of the use of the 99% avoidance rate for gannet has been given during the examination process for the

East Anglia ONE wind farm development. The following text is reproduced from Annex D of the written representation from Natural England (Natural England, 2013):

"*SNCBs are currently considering revisions to avoidance rates and that advice on avoidance rates for gannets may change in the light of ongoing evidence reviews and future studies. In the meantime, NE considers figures based on both 98% and 99% as being worth consideration, and takes into account the likely degree of precaution offered by both in reaching its conclusions*".

Sandwich tern

2.4.8 TKOWFL utilised a 98.83% avoidance rate in the collision risk modelling based on data from the wind farm at Zeebrugge (Everaert & Stienen, 2007). However, the SNCBs argued that a rate of 98% should be applied due to the fact that the rate proposed was only based on one study at a site which might not be representative of the conditions likely to prevail at the TKOWF site. The Competent Authority determined that the application of a 98.83% avoidance rate should be retained as there was no demonstrated unreasonableness in the Greater Wash AA (see Dudgeon Wind Farm, above) decision or of any new scientific evidence to suggest that a different decision should be reached.

2.5 Westermost Rough Offshore Wind Farm

2.5.1 DECC produced a Judgement of LSE (JoLSE) with respect to the Westermost Rough Offshore Wind Farm in June 2011. Whilst the key focus of the JoLSE appeared to be guillemot, seals and habitats, and the judgement only considered the Humber Estuary European sites (SAC, SPA and Ramsar) consideration was given to the collision risk for seabirds. In particular the judgement states in paragraph 3.2 bullet 4:

"*Natural England (2011b) acknowledged that on the basis of the information provided to date, the contribution of collision mortality at WMR to the cumulative total is minor for all species but advised that the effects of Docking Shoal, Race Bank and Dudgeon be considered in combination (Annex 2). WMR makes a minimal contribution to estimated seabird collision rates in combination with other windfarms of the east coast of Britain*".

2.5.2 The Annex 2 referred to and presented in the Judgement of LSE, presents the estimated annual collision rates of seabirds at operational, consented and proposed (in planning) wind farms along the east coast. The judgement of no LSE was therefore issued on the basis of the avoidance rates presented in that Annex, which were 99% or higher with the exception of common tern. The avoidance rates were justified through reference to Maclean *et al*. (2009).

2.6 Sheringham Shoal Offshore Wind Farm

2.6.1 BERR carried out an Appropriate Assessment in July 2008. There was no consideration or assessment with respect to the four seabird species considered in this review within the BERR AA and only Sandwich tern and common tern with respect to the North Norfolk SPA were considered.

2.6.2 Assessment of collision risk was undertaken in the ES using an avoidance rate of 98%. However, aspects of the collision modelling were updated and, although not available, it would appear that evidence from the studies at Zeebrugge (Everaert & Stienen (2006) and Everaert & Kuijken (2007) were used in defining a 99.6% rate. Natural England argued for an avoidance rate of 98% for Sandwich tern based on differences between the Zeebrugge wind farm and the Sheringham Shoal Offshore Wind Farm (e.g. coastal location vs offshore, as put forward in their letter to BERR dated 22 May 2007). However, the 99.6% used by the applicant was accepted by the Competent Authority based on the findings of Everaert & Stienen (2006) and Everaert & Kuijken (2007).

3 SUMMARY

Northern gannet

3.1.1 For northern gannet there is some evidence (Krijgsveld *et al*., 2011) to suggest that the 98% avoidance rate is too precautionary and may be closer to 99%. For both the Galloper Offshore Wind Farm and Triton Knoll Offshore Wind Farm, Natural England indicated in their written representations to the ExA that "*in the current case an avoidance rate of 99% may be appropriate, pending further consideration of the SNH guidance*". In the case of Galloper, the Competent Authority (DECC, 2013a) in their HRA appear to accept and base their conclusions of no LSE on the basis of a 98% avoidance rate. For Triton Knoll, DECC (DECC, 2013b) conclude that "*an avoidance rate of 99% for Gannets may be sufficiently precautionary for this species, based on the most recent evidence*".

3.1.2 The current situation with regard to the appropriate avoidance rate for use in CRM for gannet is therefore not clear. Based on both the Galloper and Triton Knoll decisions it would appear that an avoidance rate of 99% is acceptable. However, its application is likely to be tested on a case by case basis, rather than across all projects. It should be noted that recent review work (Whitfield and Urqhart, 2013) advocates a 99.5% avoidance rate for gannet (see Appendix 3 for further information).

Kittiwake

3.1.3 Earlier offshore wind farm applications used a 98% avoidance rate, and this rate continues to be used. However, it should be noted that for the Westermost Rough Offshore Wind Farm, the AA carried out by DECC in 2011 presented the number of black-legged kittiwake affected by collisions for a range of offshore projects. This report presented a Judgement of no LSE and included a paragraph referring to the Annex and in-combination figures which used a 99% avoidance rate for black-legged kittiwake.

Great black-backed gull

3.1.4 Earlier offshore wind farm applications mainly used a 98% avoidance rate, though some such as Galloper, Teesside, and Westermost Rough reported with higher avoidance rates (99% or 99.5% - based on Maclean *et al*. (2009) and other studies). However none of the applications that applied the higher avoidance rates were taken through to AA with respect to this species and no determination or arguments were presented to justify and conclude on the use of higher avoidance rates. However, it should be noted that for the Westermost Rough Offshore Wind Farm, the AA carried out by DECC in 2011 presented the number of great black-backed gull affected by collisions for a range of offshore projects. This report presented a Judgement of no LSE and included a paragraph referring to the Annex and in-combination figures which used a 99.5% avoidance rate for great black-backed gull.

Lesser black backed gull

3.1.5 Earlier offshore wind farm applications mainly used a 98% avoidance rate for lesser black-backed gull. For Greater Gabbard an avoidance rate of 99.82% was used based on data in Winkelman (1992). A conclusion of no adverse effect on the integrity of the Alde Ore Estuary SPA was given in the AA undertaken by DTI, which suggests that the collision risk output (and therefore the avoidance rate used) was accepted by the Competent Authority.

3.1.6 The Westermost Rough Offshore Wind Farm AA/RIES carried out by DECC in 2011 presented the number of lesser black-backed gull affected by collisions for a range of offshore projects. This report presented a Judgement of no LSE and included a paragraph referring to the Annex and in-combination figures which used a 99% avoidance rate for lesser black-backed gull.

3.1.7 In the case of the Galloper Offshore Wind Farm, GOWL used a 99% avoidance rate in the CRM and justified the use of this rate on the basis of a number of studies. Natural England in their representations to the ExA argued that the evidence was not sufficient to support the use of a 99% rate and that from a precautionary perspective 98% should be utilised. For the AA undertaken by DECC (DECC, 2013a), it was determined, on the basis of advice from Natural England, that an avoidance rate of 98% should be utilised in the CRM because of the lack of species-specific evidence that could be used to confirm an avoidance rate with certainty.

Sandwich tern

3.1.8 Scrutiny of the appropriate avoidance rate to be used for Sandwich tern has been undertaken with respect to the Docking Shoal, Dudgeon, and Race Bank Offshore Wind Farm projects, via a combined HRA (DECC, 2012). Avoidance rates greater than 98% were also utilised for the Sheringham Shoal Offshore Wind Farm (BERR, 2008), the Teesside Offshore Wind Farm (DTI, 2007), and Triton Knoll (DECC, 2013).

3.1.9 In the case of Teesside Offshore Wind Farm, there appears to have been no specific scrutiny of the avoidance rates used and the assessment work undertaken in respect of the collision impact of the wind farms on Sandwich tern were accepted by the Competent Authority (and consenting authority) in both cases.

3.1.10 For the Docking Shoal, Dudgeon, and Race Bank Offshore Wind Farm, JNCC & Natural England (2011) reviewed the Zeebrugge avoidance rate and concluded that 98.83% was most appropriate rate, and this was accepted by the Competent Authority (and consenting authority). Subsequently, whilst recommendations by Natural England to lower the avoidance rate arose for Triton Knoll, again the Competent Authority (and consenting authority) found the higher rate (98.83%) suitably precautionary.

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