From: James Dawkins [mailto:James.Dawkins@rspb.org.uk]
Sent: 08 February 2019 20:11
To: Hornsea Project Three
Subject: The RSPB's submission for Deadline 6
Importance: High

I attach the RSPB's submissions for Deadline 6.

There are two files:
The RSPB's main submission
A document from the Norfolk Vanguard examination, Appendix 3.2 – Collision Risk Modelling: update and clarification, which we cite in our main response.

Please could you acknowledge safe delivery.

Kind regards,
James

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Norfolk Vanguard Offshore Wind Farm

The Applicant Responses to First Written Questions

Appendix 3.2 - Collision Risk Modelling: update and clarification

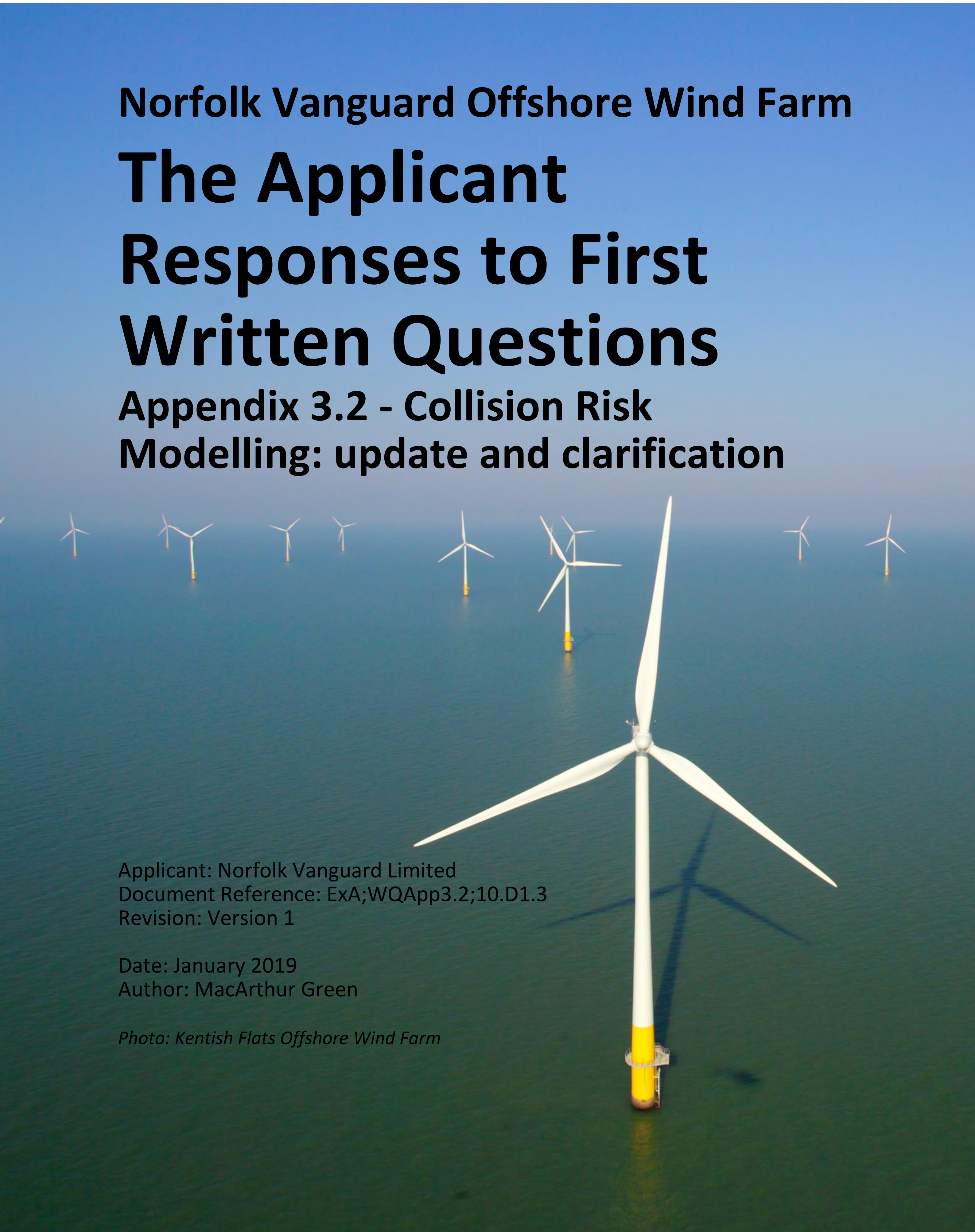

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Photo: Kentish Flats Offshore Wind Farm

Date	Issue No.	Remarks / Reason for Issue	Author	Checked	Approved
12/12/2018	01D	First draft for Norfolk Vanguard Ltd review	MT	JKL / RWF	EV
07/01/2019	02D	Final	MT	RWF	EV

Executive Summary

This note provides an update to the collision risk modelling (CRM) presented in the Norfolk Vanguard ES, and addresses comments received from Natural England (NE) in their relevant representation.

The aspects covered include derivation of seabird densities used an input to the CRM, complete tables of input parameters (to enable NE to check the results obtained), comparison of the CRM estimate for Norfolk Vanguard with those obtained using the Band (2012) spreadsheet and the Marine Scotland Science (MSS) commissioned stochastic version of the Band model, assessment of potential effects of collisions at Norfolk Vanguard on herring gull and presentation of the annual outputs calculated using alternative summary metrics.

The note only provides collision estimates for the Norfolk Vanguard project alone; cumulative and in-combination estimates will be provided in separate notes.

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Tables

Glossary

BDMPS	Biologically Defined Minimum Population Scale
CRM	Collision Risk Model
SPA	Special Protection Area
NE	Natural England
PVA	Population Viability Analysis
MSS	Marine Scotland Science
PCH	Potential Collision Height

1 INTRODUCTION

1. This note provides an update to the Norfolk Vanguard collision risk modelling (CRM) assessment (Vattenfall 2018) which addresses comments from Natural England (NE) in their Relevant Representation for the Norfolk Vanguard application and updates to the project design.

2. The detailed comments provided by NE and where they have been addressed are provided in Table 1.

Table 1 Comments on the collision risk modelling provided by Natural England (2018) in their relevant representation.

Paragraph	Comment	Response and section of this document where more detail provided
4.2.7	Natural England is aware that the non-stochastic CRM has been undertaken using R code for the Band model rather than by using the Band (2012) model spreadsheet. Whilst Annex 3 of Appendix 13.1 contains the majority of the CRM input data, it does not contain all of the required information (e.g. on the wind farm width and latitude used for both Vanguard East and Vanguard West). As a result, we have been unable to run the CRM using the Band (2012) spreadsheet and hence check the CRM results presented by the Applicant for the deterministic model outputs. The R code has not been supplied by the Applicant either. Therefore, in order for Natural England to fully appraise the CRM and hence reach conclusions on the level of impact due to Norfolk Vanguard alone, we again advise the Applicant that the full set of input parameters are required in order to be able to run the Band (2012) spreadsheets are presented.	The full set of parameters is provided in Tables A1.1 to A1.7 in Annex 1. Outputs from the deterministic Band (2012) CRM spreadsheet are included in Annex 2.
4.2.8	Natural England notes that the method that has previously been used in offshore wind farm assessments to estimate design-based bird density from a grid of images has been to calculate mean bird density from the images (i.e. number of birds counted / number of images). However our understanding is that Norfolk Vanguard has taken an alternative approach using median rather than mean densities. Natural England has identified areas of potentially significant concern regarding this approach, and would welcome further clarification from the Applicant regarding the approach taken. Please see our detailed advice in Annex 1.	Further discussion on the determination of appropriate measures of central tendency (i.e. mean or median) has been provided in section 1.1. Deterministic CRM outputs calculated using the mean density have been provided to allow NE to compare the outputs with those obtained using the median in Annex 3.
4.2.9 & 4.2.10	In the gannet and kittiwake CRM, the Applicant has used nocturnal activity rates calculated from recent reviews of evidence from tracking studies undertaken by Furness et al. Natural England has previously provided comments on drafts of these reviews and	The gannet nocturnal review has now been published (Furness et al. 2018), although this

Paragraph	Comment	Response and section of this document where more detail provided
	identified aspects that we did not agree with (particularly with regard to the kittiwake review), but we have not seen updated versions of this work. The work on gannet is referred to as Furness et al. (subm.) and that on kittiwake as Furness et al. (in prep.), which suggests that this work has not yet been accepted and is therefore not published and publically available. We are also uncertain of the journal that the gannet work has been submitted to, as no information is provided by the Applicant. Therefore our position remains as previously outlined to the Applicant: We currently do not have any agreed 'empirically derived' nocturnal activity factors that can be used with the Band model. We recognise from recent evidence presented e.g. by MacArthur Green (2015a) that nocturnal activity levels for some species may be lower than the levels that equate to the nocturnal activity factors currently used in CRM, however we also note that there is uncertainty about the empirical activity levels and uncertainty about how these might translate into nocturnal factors applicable to the Band model. We advise that CRM outputs covering a range of nocturnal activity factors are considered to account for the uncertainty/variability (in the same way as has been recommended for bird densities, avoidance rates and flight heights) and the suggested range of nocturnal flight activities to be considered within the Band model CRM are: 1-2 (equating to 0-25% nocturnal activity) for gannet and 2-3 (equating to 25-50% of nocturnal activity) for kittiwake (and the large gulls, which has been used by the Applicant).	recommended slightly different nocturnal activity rates than those used in the ES. Therefore, the CRM for gannet has been updated in line with the recommendations of Furness et al. (2018; Annex 4). The kittiwake review has not yet been published, however the nocturnal rates are not expected to change from those used in the ES. Nevertheless, kittiwake collisions are provided calculated using NE recommended rates (25% and 50%). Large gull collisions have also been presented using the NE recommended rates (25% and 50%), see Annex 4.
4.2.11	We note that herring gull is not fully assessed for CRM from Vanguard alone as it has been excluded due to the collision predictions currently being predicted to be less than 10 per year. The exclusion of herring gull from full assessment of collision impacts and hence consideration of cumulative impacts under EIA is of particular concern to Natural England. Given our concerns regarding the CRM, there is potential for herring gull collision predictions to increase above 10 collisions per year.	Further assessment for herring gull collision risk has been provided in section 1.6. This includes consideration of the various general points on the CRM outlined above.
Detailed comments – Seabird Collision Risk Modelling (CRM) for EIA and HRA		
4.1.1	**Collision risk models** The Applicant has undertaken the CRM using their own version of a stochastic CRM in order to present the uncertainty in the various CRM parameters (PCH, avoidance rates, densities, nocturnal activity) and also to cover off the development scenarios split across the Vanguard East and West sites. Whilst the Applicant's stochastic CRM simulations may be valid, Natural England notes that the potential use of such simulation was discussed with Natural England as part of the Evidence Plan Process. In response to this suggestion, Natural England advised the Applicant that we did not think that it would be possible at that stage to accept the proposal to use the Applicant's stochastic CRM and that the only way at this stage will be to present multiple tables	The additional deterministic tables have been provided in Annex 4.

Paragraph	Comment	Response and section of this document where more detail provided
	where the Applicant varied each parameter in turn using the Band (2012) model, and not all of them at once. As a result the Applicant agreed that they would provide outputs from their stochastic model along with the output tables requested by Natural England. The issues Natural England raised regarding the use of the Applicant's stochastic CRM still stand with regard to the stochastic simulations the Applicant has used and presented outputs for, namely:	
	1. We are not sure what R code the Applicant has for their stochastic CRM. The Marine Science Scotland (MSS) work to produce an agreed version of a stochastic CRM and shiny app was underway at the time of discussions with the Applicant, and we noted to the Applicant that whilst this would be correcting any bugs in the coding of the existing Masden (2015) model and making other fixes, it would also completely recode the Band (2012) model and the R code would be moved across to GIT which is a version control system for R - so there will be a detailed audit-trail of modifications and other developers will be able take over future development relatively easily. This it will provide a level of scrutiny that we don't have with the R code for the Band model available at the moment. Therefore, anything the Applicant used for Vanguard at this stage might not be the same as is eventually produced from the MSS work. The MSS work has recently completed and is available online. As we remain uncertain of the R code the Applicant has used, we do not know whether this is the same as the MSS model and means that potentially we would not end up with the same set of results from Vanguard as with the MSS work. So we could have another set of interim data. We note that now the MSS stochastic CRM is available there is a six month period of ongoing technical support. The general view of Natural England is that the stochastic CRM can be used for assessments, but that assessments should also provide the outputs from the standard Band model spreadsheets as well.	The MSS funded stochastic version of the Band (2012) model is now available and the results it produces have been compared with those produced using the version coded for Norfolk Vanguard. The two stochastic models and the Band model produce identical results (allowing for rounding variations). However, it is not straightforward to compare stochastic outputs for reasons which are detailed in section 1.5. It is important to note that these all relate to how random numbers are generated or inputted and none are structural. Selected outputs from the MSS model have been provided in section 1.5 to permit comparison with the Norfolk Vanguard and Band versions.
	2. Additionally we were not certain about the sampling distributions the Applicant has used and we note that these are not necessarily what is in the MSS stochastic CRM: - We previously noted to the Applicant that we have never seen the raw boot strapped aerial data – we are only ever presented with the mean monthly estimates along with the upper and lower confidence intervals.	The sampling distributions used in the Masden CRM (on which the MSS model is based) and those used in the Norfolk Vanguard model have been compared and

Paragraph	Comment	Response and section of this document where more detail provided
	- For the PCH – in our response to the Applicant we queried whether this will be drawn from the full set of BTO data or based on the confidence limits. - We noted to the Applicant that at present we have not thought about the distribution of nocturnal flight activities and so what would be suitable to use. - We also noted that we would also need to look in more detail at how all of these things would be integrated at the same time.	the merits of each discussed as relevant in a report commissioned for Natural England (NECR237; Trinder 2017). This report has been appended to this note (Annex 5) and the key points summarised in section 1.5.
	3. The Applicant has not presented the multiple tables of non-stochastic (i.e. Band 2012 model) outputs where each parameter in turn is varied that were requested by Natural England. We therefore advise that tables similar to those produced by Hornsea 2 in Appendix J of their Deadline 1 submission are produced for Norfolk Vanguard: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010053/EN010053-001016-Appendix%20J_Collision%20Risk%20Modelling;%20Addressing%20Uncertainty%20Clarification%20Note.pdf	These tables have been provided in Annex 4.
	4. .During the Evidence Plan Process, Natural England was made aware that the non-stochastic CRM for Vanguard has been undertaken using R code for the Band model rather than by using the Band (2012) model spreadsheet. We therefore requested that the Applicant provide evidence to clearly demonstrate that the R code that is used is producing the same results as the Band spreadsheet version for all Band model options presented. Therefore, we requested that in the ES submission, the Applicant provides all of the input parameters used in their R model along with the R code in an Appendix, so that the results can then be checked. Whilst we note that Annex 3 of Appendix 13.1 contains the majority of the CRM input data, it does not contain information on the wind farm width and latitude used for both Vanguard East and Vanguard West. Therefore, we have been unable to run the CRM using the Band (2012) spreadsheet and hence check the CRM results presented by the Applicant for the deterministic model outputs. The R code has not been supplied by the Applicant either. Therefore, in order for us to be able to check the CRM and hence reach conclusions on the level of impact due to Vanguard alone, we again request that the full set of input parameters required in order to be able to run the Band (2012) spreadsheets are presented, i.e.: • Density of birds in flight within each of the Vanguard sites (noting comments above regarding use of the median and mean densities); • Proportion of birds at Vanguard rotor heights (using the Johnston et al. 2014a & b generic data given the issues noted by the Applicant with the site-specific data); • Bird parameters for each species (bird length, wing span, flight speed, nocturnal activity factor, flight type (flapping/gliding);	The comparison between the different implementations of the CRM (Band 2012, MSS and Norfolk Vanguard) have been provided in section 1.5, section 1.3 and Annex 2. Tables of input data are provided in Annex 1.

Paragraph	Comment	Response and section of this document where more detail provided
	• Proportion of flights upwind; • Wind farm data (latitude, number of turbines, width of wind farm, tidal offset); • Turbine data (model, number of blades, rotation speed, rotor radius, hub height, monthly proportion of time operational, maximum blade width, pitch).	
	Derivation of bird densities used in the CRM Natural England notes that the method that has previously been used in offshore wind farm assessments to estimate design-based bird density from a grid of images (as have been collected for Vanguard) has been to calculate mean bird density from the images (i.e. number of birds counted / number of images). Bootstrapping has typically then been applied to provide variance estimates and confidence limits (e.g. East Anglia 1). Our understanding of the approach in Section 4.2 of Appendix 13.1 (paragraph 14 – 16) is that the Applicant has: • Calculated monthly estimates in this way and averaged these to feed mean monthly densities into the displacement assessment (which we agree with); • Then also pooled all resampled estimates from data pertaining to any given month; • Used all of these estimates for stochastic CRMs; • Used the median of these estimates for CRMs not incorporating stochasticity. Based on this, Natural England has a number of queries/areas of uncertainty where it would welcome further clarification from the Applicant regarding the approach taken in order to reach conclusions around the applicability of the CRM outputs presented. These are: • We are uncertain as to why in the stochastic CRMs the Applicant has not used the monthly density estimate +/- 95% confidence limits to give a range of predicted collisions and would welcome clarity regarding this. • We consider the use of a bootstrapped median to estimate density in the non-stochastic CRM to be questionable, when a mean density already exists. We note that the point of bootstrapping is to estimate variance – the Applicant claim's that it has to be this way to enable comparison with stochastic CRM outputs, but we aren't looking to compare the two. Additionally, Appendix 13.1 (Offshore Ornithology Technical Appendix) defends this approach by saying that "all collision predictions accurately reflected the observed densities", but Natural England is not certain that this is true. The observed densities are those derived from the images (average of birds per image), whilst the bootstrapped data is a theoretical distribution of densities, from which the median gives an estimate of central tendency – therefore not a probability of being the 'true' density.	Further discussion on the appropriate values to use to describe seabird densities is provided in section 1.1.

Paragraph	Comment	Response and section of this document where more detail provided
	We note that the use of the median values means that lower monthly densities of birds are used and hence the predicted CRM results will be lower than if the mean densities are used.	
4.1.3	**Nocturnal flight activity rates for gannet and kittiwake** For CRM of Vanguard alone, the stochastic CRM assessment and that where just uncertainty in nocturnal activity was included, the Applicant has used nocturnal activity rates of: • 4.3% (S.E. 2.7%) for the breeding season and 2.3% (S.E. 0.4%) for the non-breeding season for gannet; and • 20% (S.E. 5%) for the breeding season and 17% (S.E. 1.5%) for the non-breeding season for kittiwake. The nocturnal activity factor input parameter used in the Band Model calculation of collision risk is a ranking score from 1 to 5, derived from an assessment of nocturnal activity in different species in Garthe & Huppop (2004), and not a 'nocturnal activity rate' per se. The Band model converts these factors to a percentage 0% (factor 1), 25% (2); 50% (3), 75% (4) and 100% (factor 5) that is applied to the densities of birds in flight collected from surveys during daylight hours to correct for a different pattern of flight behaviour (typically reduced) occurring during the night. Under this broad classification Garthe & Huppop (2004) assigned a factor of 2 to gannet, kittiwake a factor of 3 and herring gull and LBBG a factor of 3 (King et al., 2009, adds great black-backed gull as factor 3). The nocturnal activity rate figures used by the Applicant for gannet and kittiwake are based on the findings of recent reviews of evidence from tracking studies that have been undertaken by Furness et al. Natural England has provided comments on drafts of these reviews, where there were aspects that we did not agree with (particularly with regard to the kittiwake review). However, we note that we have not seen updated version of this work. We also note that the Applicant refers to the work on gannet as being Furness et al. (subm.) and the work on kittiwake as Furness et al. (in prep.), which suggests that this work has not yet been accepted and is therefore not published and publically available. We are also uncertain of the journal that the gannet work has been submitted to, as no information is provided by the Applicant. Therefore Natural England's position remains that which we previously outlined to the Applicant: we currently do not have any agreed 'empirically derived' nocturnal activity factors that can be used with the Band model. We recognise from recent evidence presented e.g. by MacArthur Green (2015a) that nocturnal activity levels for some species may be lower than the levels that equate to the nocturnal activity factors currently used in CRM, however we also note that there is uncertainty about the empirical activity levels and uncertainty about how these might translate into nocturnal factors applicable to the Band model.	The gannet review has now been published (Furness et al. 2018). It should be noted that the final publication recommended slightly higher nocturnal rates than used in the ES. Collisions estimated using the final recommended values have therefore been provided in Annex 4. The kittiwake review is not yet completed, thus while the rates used for this species in the ES are considered robust, the NE recommended ones have also been provided in this update (Annex 4).

Paragraph	Comment	Response and section of this document where more detail provided
	Therefore, Natural England advises that collision risk outputs covering a range of nocturnal activity factors are considered to account for the uncertainty/variability (in the same way as has been recommended for bird densities, avoidance rates and flight heights). The suggested range of nocturnal flight activities to be considered within the Band model CRM are: • Gannet: 1-2 (equating to 0-25% nocturnal activity) • Kittiwake: 2-3 (equating to 25-50% nocturnal activity) • Large gulls: 2-3 (equating to 25-50% nocturnal activity) (as has been used by the Applicant in the stochastic CRM and that where uncertainty in nocturnal activity has been considered).	See above.
4.1.4	**Assessment of herring gull CRM alone and cumulatively at EIA** We note that herring gull is not fully assessed for CRM from Vanguard alone as it has been excluded due to the collision predictions currently being predicted to be less than 10 per year. The exclusion of herring gull from full assessment of collision impacts and hence consideration of cumulative impacts under EIA is of particular concern to Natural England. We note the issues raised above regarding the appropriateness of the use of median values of bird density in the CRM and note that if the mean values of bird density are used in the CRM rather than the median values, then herring gull collision predictions may increase above 10 collisions per year.	Further assessment for herring gull is included in section 1.6.

1.1 Estimation of seabird flight densities

3. NE states that they '*consider use of a bootstrapped median to estimate density in the non-stochastic CRM to be questionable when a mean density already exists*' and that '*the Applicant claims that it has to be this way (use of the median rather than the mean) to enable comparison with stochastic CRM outputs, but we aren't looking to compare the two'*. These two aspects are addressed below.

4. The collision mortalities for the project presented in the ES and technical appendices were calculated using a stochastic implementation of the Band (2012) CRM. One of the inputs to the CRM is the density of birds in flight. To obtain measures of uncertainty in the density estimates for use in the stochastic model, the baseline aerial survey data were analysed using a non-parametric bootstrap method (as described in the Offshore Ornithology Technical Appendix). In brief, this method involved random resampling of the data assigned to each image which was collected during each aerial survey (monthly: 24 for NV West, 32 for NV East). This was done for each survey separately, and in such a way that each randomised resample comprised the same number of images as the original survey. In this manner a series

of datasets is generated which are akin to undertaking repeat surveys. This process was repeated 1,000 times for each survey and the range of densities for each species provides a measure of sampling uncertainty (expressed as variance or confidence intervals) as well as central values (i.e. mean and median). Following this, monthly summaries were calculated since the CRM is based around a calculation for each month.

5. To obtain the random density inputs required as inputs to the stochastic CRM two options were considered:

- Use the summary outputs (e.g. calculated mean and standard deviation) to generate simulated density values using an appropriate probability distribution e.g. mean and standard deviation as inputs to a random normal distribution function (or similar function); or
- Make use of the bootstrapped samples already generated (as described above) for the analysis as direct inputs to the CRM.

6. The latter option was used for two reasons: it simplified the analysis (the random samples were already available and there was no need to repeat this) and, more importantly, because these samples were considered more appropriate. This is due to the fact that the bootstrapped samples are drawn directly from the data and not a pre-defined probability distribution, the latter of which may not be a close match to the data. For example, across the two sampling months available (i.e. April in survey year 1 and April in survey year 2, etc.) there were numerous instances when the seabird density in year 1 was very low (or indeed zero) while that in the second year was higher. This is illustrated in Figure 1.

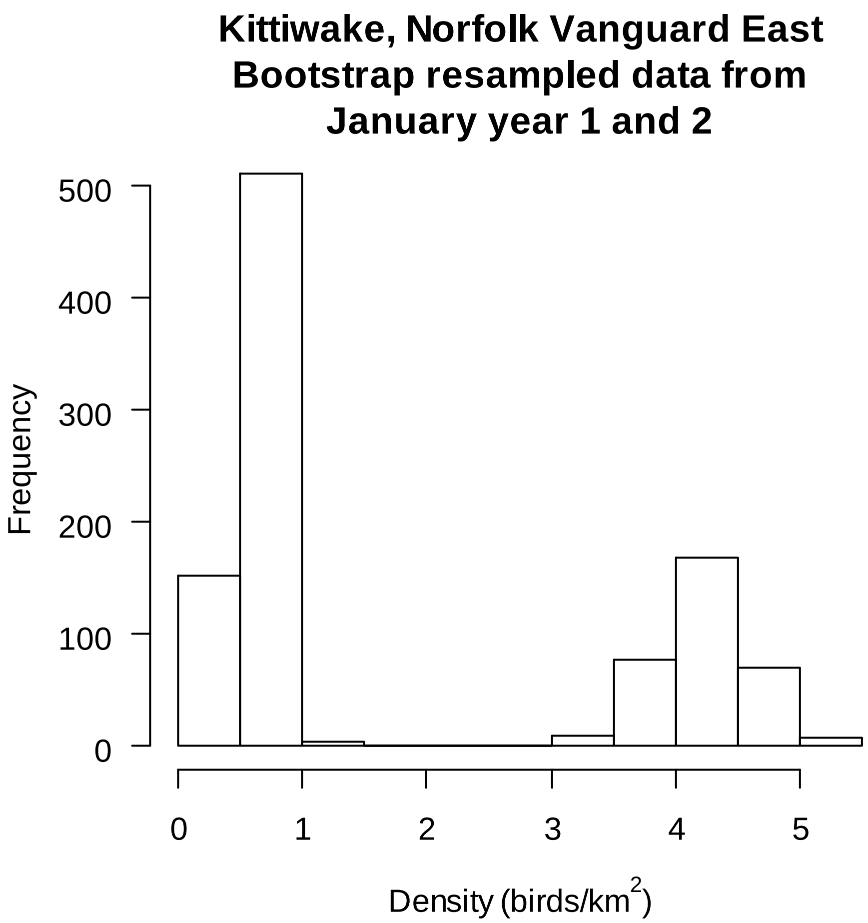

Figure 1. Example histogram of bootstrapped densities of kittiwakes in flight resampled from January survey data collected in 2013, 2014 and 2016.

7. Extracting the mean and standard deviation from the data in Figure 1 for use in a truncated normal distribution (bounded at zero) yields outputs such as those in Figure 2. It is clear that the truncated normal distribution provides a poor representation of the bootstrapped data.

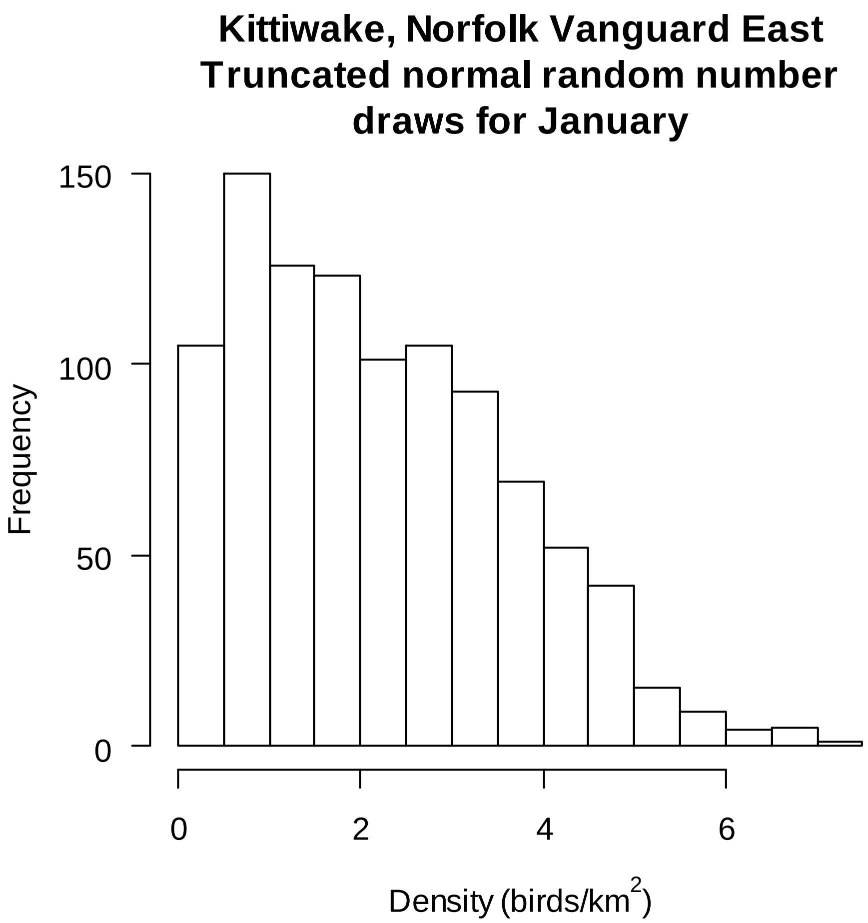

Figure 2. Example histogram of random draws from a truncated normal distribution (bounded at zero) using the mean (1.80) and standard deviation (1.73) calculated from the bootstrapped densities in Figure 1.

8. This was the primary reason for using the bootstrap resampled data directly in the stochastic CRM as it avoided instances such as this with unrepresentative input data.

9. There is a close relationship between the density inputs and the mortality outputs from the CRM, thus the same considerations in terms of how best to present them apply. In the presence of skewed data such as this, it is common practice to use the median as the central value rather than the mean, since the latter is much more heavily influenced by the infrequent but large values (i.e. outliers).

10. On this basis, the median was considered more appropriate for presenting the central mortality from the stochastic model, with the addition of the 95% confidence intervals (and also graphically in box plots, which clearly illustrate the skewed distributions).

11. Since the underlying distributions are present in the data irrespective of whether this is explicitly included in the CRM (i.e. using a stochastic model) or described using a single value for use in a deterministic CRM, it is clear that the median is also more appropriate for reporting the results of the non-stochastic CRM (i.e. deterministic collision predictions).

12. It is also important to note that the difference between the median and mean decreases as the data distribution becomes less skewed, with the two converging for symmetrical data. For seabird densities this convergence of mean and median occurred with more commonly observed species (for which the bootstrap resamples resembled normal distributions). Thus, for more abundant species there is very little difference between the mean and median outputs (and the choice of which to use is unimportant), while for less common species with more skewed distributions the median and mean diverge, with the median more representative (for the reasons outlined above). Thus, using the median ensures that reliable results are obtained irrespective of the underlying data.

13. Thus, the statement from NE that use of the median values means that lower densities are used (than if the mean densities are used) and therefore collision estimates will also be lower is not factually accurate. As explained above, the median is lower (and more representative) than the mean for right-skewed distributions, the same as the mean for symmetrical distributions and higher for left-skewed distributions. For the current data, the median density of gannets in flight on NV East was higher than the mean in September and December, similar in April and August and lower in the remaining months.

14. It seems likely that the reason why the question of whether the mean or median density is more appropriate for offshore wind farm impact assessment has not been considered and discussed in the past is that rather little consideration has been given to the role of uncertainty. The increased emphasis on simulation modelling has highlighted the relevance of the points raised above. It is also pertinent to note that once stochastic CRM has become the standard method used, with results presented as distributions rather than single values, it is likely that this question will become largely irrelevant.

1.2 CRM input parameters

15. The CRM input parameters used in the assessment were provided in annex 3 of the Norfolk Vanguard Offshore Ornithology technical appendix, however as noted by NE in their relevant representation there were three parameters omitted (wind farm latitude, wind farm width and percentage of flights expected to be upwind). These

have now been included in the wind farm details table. The input tables are in Annex 1 of this note.

1.3 Comparison of NV deterministic outputs calculated using the R CRM with those from the Band (2012) Excel

16. The deterministic collision predictions presented for Norfolk Vanguard (Appendix 13.1 Annexes 4 and 5) have been reproduced in Annex 2 along with pdf copies of the Band (2012) Excel input and output sheets. Both sets of outputs were obtained using generic flight height data to obtain the values for the PCH (i.e. option 2). However, to simplify the presentation of the spreadsheet outputs the option 2 PCH (as listed in Table A1.5) was entered on the input sheet as the PCH (i.e. where the option 1 value would typically be entered). This has no effect on the mortality calculated since option 1 and option 2 are identical in structure, differing only in the data source for PCH.

17. The collision predictions obtained using the scripted CRM as presented in the Norfolk Vanguard ES are the same as those obtained using the Band spreadsheet (with minor rounding differences). Thus, the function of the model used to estimate the collision mortalities presented in the ES are robust, subject to agreement over the most appropriate input parameters.

1.4 Deterministic CRM outputs for lower and upper parameter values

18. NE requested tables of deterministic CRM output with alternative parameter values as follows:

- Lower and upper 95% confidence intervals and mean estimates of birds in flight (NB: the ES provided stochastic outputs for the confidence intervals and the median);
- Lower and upper 95% confidence intervals for proportion at potential collision height (PCH; NB the ES provided stochastic outputs for these);
- Lower and upper 95% confidence intervals for the collision avoidance rates (NB the ES provided stochastic outputs for these);
- Nocturnal activity factors reduced from 2 to 1 (gannet) and 3 to 2 (gulls) (NB the ES used evidence based stochastic estimates for gannet and kittiwake).

19. Tables of output for gannet, kittiwake, lesser black-backed gull, herring gull and great black-backed gull are provided in Annex 4.

1.5 Comparison of NV CRM outputs with those obtained using the MSS CRM

20. Marine Scotland Science (MSS) commissioned a project to implement the Band (2012) CRM in a simulation format suitable for producing probabilistic mortality outputs. The stochastic CRM is available on the MSS website to use online and also to download and use in conjunction with the R programming software. The latter has been used here to enable a comparison of the outputs obtained from the MSS model and that coded (also in R) for the Norfolk Vanguard assessment (hereafter the NV model). This was undertaken to provide NE with reassurance that the two models operate in the same manner.

21. There are two aspects to this comparison; the methods used to generate random variables for input to the calculations and the calculations themselves. For the two models to be fully compared it is necessary to consider both aspects.

22. The MSS and NV models do not use the same probability distributions for all the stochastic parameters. Of particular note is the fact that the MSS model (which retains aspects of the Masden (2015) version of the CRM) uses the truncated normal distribution to generate several of the simulated parameter values and this can result in biased outputs for data with an underlying skewed distribution (see Trinder 2017 for further discussion and illustration of this point). For these reasons the NV model uses more reliable distributions for data which have can have central values close to boundaries (e.g. zero for densities and zero or one for proportions such as avoidance rates).

23. In addition, the MSS model does not allow nocturnal flight activity rates to be entered for each month separately, but rather only as a single value applied in all months. In contrast the NV model allows the seasonal variation identified in Furness et al. (2018) to be incorporated.

24. As a consequence, the two models cannot be directly compared in terms of their stochastic outputs, however the structure and collision calculations can be compared for deterministic outputs (i.e. with each input parameter's standard deviation set to to zero).

25. To simplify this, the MSS model was run as if using option 1, although because the actual PCH values entered were those from Johnston et al. (2014a,b) the outputs are therefore in fact equivalent to the option 2 results reported using the NV model.

26. Thus, the deterministic CRM outputs for the 9 MW turbine presented in the Norfolk Vanguard technical appendix were compared with those obtained using the MSS model with all the standard deviations set to zero.

27. The NV model outputs for kittiwake calculated using option 2 for Norfolk Vanguard East (Table 6 in Annex 4 of Technical Appendix 13.1) are reproduced below alongside those generated by the MSS model (Table 2). Input parameters were those provided in Annex 1.

Table 2. Monthly kittiwake collisions calculated using the NV model and the MSS model (note no randomised parameters).

Model	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
NV	39.78	41.37	19.67	5.79	16.68	3.71	1.78	0	0	1.91	65.1	27.99
MSS	39.81	41.39	19.63	5.79	16.61	3.68	1.81	0	0	1.93	65.17	28.06

28. Although only kittiwake outputs have been presented here, the same agreement of results was obtained for each species. It is clear from the outputs in Table 2 that the two models produce almost identical results, with only minor differences due to rounding.

1.6 Herring gull collision risk assessment

29. Norfolk Vanguard is 92 km from the nearest breeding colony for herring gull. This species has a mean maximum foraging range of 61 km, and a maximum of 92 km, therefore the likelihood that herring gulls breeding at Alde-Ore Estuary SPA would reach the Norfolk Vanguard site is extremely small. Consequently, the breeding season impact on herring gull has been assessed against a reference population estimated using the same approach as that used in the ES for other species for which breeding adults were considered unlikely to be present. This is based on the observation that immature birds tend to remain in wintering areas. Thus, the number of immature birds in the relevant populations during the breeding season may be estimated as the proportion of the relevant biologically defined minimum population scale (BDMPS) season (the one immediately preceding the breeding season) which are sub-adults. Thus, the breeding season reference population can be calculated as 66.4% (the proportion of sub-adults in the population, Table 3) of the nonbreeding BDMPS populations of herring gull. This yields a breeding season population of nonbreeding herring gull of 309,763 (nonbreeding BDMPS for the UK North Sea and Channel, 466,511 x 66.4%). The nonbreeding season reference population was 466,511 (Furness 2015).

30. The impacts of mortality caused by collisions on the populations are assessed in terms of the change in the baseline mortality rate which could result. It has been assumed that all age classes are equally at risk of collisions (i.e. in proportion to their presence in the population), therefore it is necessary to calculate an average baseline mortality rate for all age classes for each species assessed. These were

calculated using the different survival rates for each age class and their relative proportions in the population.

31. The first step is to calculate an average survival rate. The demographic rates for each species were taken from reviews of the relevant literature (e.g. Horswill and Robinson, 2015) and recent examples of population modelling (e.g. EATL, 2016). The rates were entered into a matrix population model to calculate the expected proportions in each age class. For each age class the survival rate was multiplied by its proportion and the total for all ages summed to give the average survival rate for all ages. Taking this value away from 1 gives the average mortality rate. The demographic rates and the age class proportions and average mortality rates calculated from them are presented in Table 3.

Table 3 Average mortality across all age classes. Average mortality calculated using age specific demographic rates and age class proportions.

Species	Parameter	Survival (age class)					Productivity	Average mortality
		0-1	1-2	2-3	3-4	Adult		
Herring gull	Demographic rate	0.798	0.834	0.834	0.834	0.834	0.92	0.174
	Population age ratio	0.235	0.175	0.142	0.110	0.337	-	

32. Table 4 provides the baseline survival rates, the relevant breeding season and nonbreeding season BDMPS and the percentage increase in mortality for each seabird species due to collisions.

Table 4. Percentage increases in the background mortality rate of seasonal and annual populations due to predicted collisions (option 2) calculated with stochasticity in density, avoidance rate, flight height and nocturnal activity for the worst case 9MW turbine and species specific worst case project scenario. Note that the annual mortalities have been assessed against both the biogeographic populations and the largest BDMPS (as advised by Natural England) in order to bracket likely effects.

Species		Herring gull		
		Median	Lower c.i.	Upper c.i
Baseline average mortality				0.174
Breeding season	Reference population			309,763
	Seasonal mortality	0	0	0
	Increase in background mortality (%)	**0**	0	0
Wintering	Reference population			466,511
	Seasonal mortality	5.17	0	172.07
	Increase in background mortality (%)	0.006	0	0.212
Annual – largest BDMPS	Reference population			466,511
	Seasonal mortality	5.17	0	172.07
	Increase in background mortality (%)	0.006	0	0.212
Annual - biogeographic	Reference population			1,098,000
	Seasonal mortality	5.17	0	172.07
	Increase in background mortality (%)	**0.003**	0	0.09

33. The median collision prediction for herring gull in all seasons and also summed across the year resulted in increases in background mortality well below 1%. Therefore, the magnitude of effects due to collision mortality for herring gull is considered to be negligible for this low sensitivity species resulting in an impact significance of **negligible adverse**.

1.7 Comparison of annual mortality estimates calculated as the sum of monthly medians, median of months and sum of monthly means

34. In the ES the annual median collision estimate was obtained as the sum of the median value calculated for each individual month. During discussions with the developer of the MSS stochastic CRM it became evident that under certain circumstances, such as if the monthly estimates were heavily skewed, this method would not preserve the complete range of uncertainty associated with each monthly estimate. Consequently, the annual total obtained as the sum of the 12 monthly median estimates will not necessarily equal the median of the annual totals for each model iteration (i.e. the median of the sum of the 12 monthly estimates generated during each iteration of the model).

35. For clarity the two approaches to obtaining the annual median total are:

- Sum of the monthly medians = median estimate for January, plus the median estimate for February, plus the median estimate for March, etc. (i.e. the sum of the median for each month),
- Median of the summed months = median calculated for the annual total for each model iteration (i.e. the sum of January to December for model iteration 1, for model iteration 2, etc.).

36. Note that the monthly estimates are unchanged, but the method to combine these to obtain an annual total is different.

37. The annual totals obtained using the different summation approaches, and the confidence intervals associated with each are provided in Table 5. The confidence intervals for the mean annual estimate have not been included because these are the same as those reported for the medians (in columns 1 and 2 of Table 5), and can also be calculated by either method.

Table 5. Comparison of alternative methods for calculating annual collisions for stochastic collision predictions for Norfolk Vanguard East and West.

Species	Site	Median of summed months for each model iteration (lwr-upr 95% c.i.)	Summed monthly medians (lwr-upr 95% c.i.)	Mean
Gannet	NV East	110.63 (14.79 - 524.03)	142.52 (75.26 - 327.3)	159.34
	NV West	44.73 (7.71 - 205.36)	62.78 (35.56 - 105.94)	65.04
Kittiwake	NV East	158.44 (22.43 - 859.65)	315.92 (90.12 - 458.3)	276.55
	NV West	58.54 (6.01 - 225.92)	81.45 (56.53 - 113.21)	82.3
Lesser black-backed gull	NV East	9.1 (0 - 99.49)	20.27 (3.31 - 49.61)	21.7
	NV West	27.35 (0 - 150.09)	40.03 (16.02 - 81.33)	42.34
Herring gull	NV East	5.17 (0 - 172.06)	17.06 (3.11 - 131.35)	37.1
	NV West	1.42 (0 - 11.84)	2.02 (0 - 8.64)	2.59
Great black-backed gull	NV East	19.97 (1.43 - 451.72)	65.12 (7.05 - 346.17)	107.14
	NV West	22.15 (0 - 138.68)	37.2 (15.57 - 69.8)	38.68

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Annex 1. CRM input tables

Table A1.1. Norfolk Vanguard East monthly median densities (and 95% confidence intervals) of birds in flight used in the collision risk modelling.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0.119)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.216)	0 (0-0)
Fulmar	0.078 (0-0.412)	0.039 (0-0.251)	0.079 (0-0.349)	0.033 (0-0.373)	0.283 (0-0.866)	0 (0-0.522)	0 (0-0.098)	0.228 (0.046-0.539)	0.105 (0-0.434)	0.031 (0-0.184)	0.163 (0-0.401)	0.123 (0-0.448)
Gannet	0 (0-0.137)	0.031 (0-0.188)	0 (0-0.094)	0.031 (0-0.124)	0 (0-0.2)	0.18 (0-0.678)	0 (0-0.074)	0.137 (0-0.317)	0.276 (0-0.552)	0.123 (0.024-0.46)	1.168 (0.678-5.052)	1.142 (0-1.693)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.095)	0 (0-0.237)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0.093)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.026 (0-0.193)	0 (0-0.092)	0 (0-0)	0 (0-0)
Kittiwake	0.686 (0.343-4.82)	0.753 (0.193-1.647)	0.305 (0-2.833)	0.088 (0-1.49)	0.233 (0.033-0.971)	0.052 (0-0.261)	0.025 (0-0.141)	0 (0-0.137)	0 (0-0.11)	0.031 (0-0.337)	1.141 (0-1.942)	0.491 (0.138-1.614)
Black-headed Gull	0 (0-0.155)	0 (0-0)	0 (0-0.131)	0 (0-0)	0 (0-0.1)	0 (0-0)	0 (0-0.098)	0 (0-0)	0 (0-0)	0 (0-0.092)	0 (0-0.163)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0.069)	0 (0-0)	0 (0-0)	0 (0-0.647)	0 (0-0)	0 (0-0)	0.063 (0-0.603)	0 (0-0.078)	0 (0-0)	0 (0-0.326)	0 (0-0)
Common Gull	0.032 (0-0.206)	0 (0-0)	0 (0-0.187)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.215)	0 (0-0.092)	0 (0-0.092)
Lesser Black-backed Gull	0.034 (0-0.272)	0 (0-0.125)	0 (0-0.119)	0 (0-0.098)	0 (0-0)	0 (0-0)	0 (0-0.123)	0.127 (0-0.412)	0 (0-0)	0 (0-0.072)	0 (0-0.123)	0 (0-0.157)
Herring Gull	0.103 (0-1.788)	0 (0-0)	0 (0-0.119)	0 (0-0.093)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.216)	0 (0-0.207)
Great Black-backed Gull	0.158 (0.032-3.382)	0 (0-0.125)	0 (0-0.093)	0 (0-0.131)	0 (0-0)	0 (0-0)	0 (0-0)	0.016 (0-0.507)	0 (0-0)	0 (0-0)	0 (0-0.431)	0.123 (0-0.394)

Table A1.2. Norfolk Vanguard West monthly median densities (and 95% confidence intervals) of birds in flight used in the collision risk modelling.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Red-throated Diver	0.062 (0-0.185)	0 (0-0.093)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.093)
Fulmar	0.062 (0-0.248)	0.062 (0-0.185)	0.031 (0-0.155)	0.032 (0-0.154)	0.031 (0-0.093)	0 (0-0.187)	0 (0-0.248)	0.046 (0-0.465)	0.027 (0-0.093)	0.155 (0-0.963)	0.054 (0-0.163)	0 (0-0.093)
Gannet	0 (0-0.093)	0.031 (0-0.093)	0 (0-0.187)	0 (0-0)	0 (0-0.093)	0.031 (0-0.093)	0.062 (0-0.279)	0.08 (0-0.372)	0.053 (0-0.186)	0.28 (0-0.965)	0.649 (0.371-0.951)	0 (0-0)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.027 (0-0.093)	0 (0-0)	0 (0-0)	0 (0-0)
Kittiwake	0.093 (0-0.247)	0.062 (0-0.185)	0.156 (0.031-0.434)	0 (0-0.255)	0.062 (0-0.186)	0.249 (0.062-0.591)	0 (0-0.372)	0.093 (0-0.217)	0 (0-0.24)	0.093 (0-0.311)	0.362 (0.062-0.896)	0 (0-0.093)
Black-headed Gull	0 (0-0)	0 (0-0.185)	0 (0-0.093)	0 (0-0.124)	0 (0-0)	0 (0-0)	0 (0-0.072)	0 (0-0)	0 (0-0)	0.031 (0-0.125)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.027 (0-0.093)	0 (0-0)	0.054 (0-0.154)	0 (0-0)
Common Gull	0 (0-0)	0 (0-0.154)	0 (0-0.156)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0.08)	0.031 (0-0.093)	0.124 (0-0.402)	0 (0-0)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0.093)	0 (0-0.093)	0 (0-0)	0.093 (0-0.28)	0.109 (0-0.362)	0.186 (0.031-0.453)	0.013 (0-0.342)	0.093 (0-0.311)	0 (0-0)	0 (0-0)
Herring Gull	0 (0-0)	0 (0-0.092)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.027 (0-0.093)	0 (0-0)
Great Black-backed Gull	0.031 (0-0.154)	0.093 (0-0.247)	0 (0-0.093)	0 (0-0)	0 (0-0.093)	0 (0-0)	0 (0-0.124)	0 (0-0.186)	0.134 (0.009-0.321)	0 (0-0.124)	0.054 (0-0.217)	0 (0-0)

Table A1.3. Norfolk Vanguard East. Total number of birds with an estimated flight height, number at collision height (>=22 m) and proportion at collision height. Figures provided for all birds within the 4 km buffer and just those within the wind farm boundary.

	Within 4km buffer			Within wind farm		
Species	**No. height estimates**	**No. >=22m**	**Proportion >=22m**	**No. height estimates**	**No. >=22m**	**Proportion >=22m**
Red-throated Diver	6	3	0.500	5	3	0.600
Fulmar	274	4	0.015	113	1	0.009
Gannet	538	77	0.143	263	45	0.171
Arctic Skua	6	2	0.333	4	1	0.250
Great Skua	14	5	0.357	7	4	0.571
Kittiwake	942	219	0.232	437	102	0.233
Black-headed Gull	13	3	0.231	8	2	0.250
Little Gull	33	2	0.061	24	1	0.042
Common Gull	25	7	0.280	11	4	0.364
Lesser Black-backed Gull	90	26	0.289	26	5	0.192
Herring Gull	93	17	0.183	50	12	0.240
Great Black-backed Gull	204	39	0.191	112	9	0.080

Table A1.4. Norfolk Vanguard West. Total number of birds with an estimated flight height, number at collision height (>=22 m) and proportion at collision height. Figures provided for all birds within the 4 km buffer and just those within the wind farm boundary.

	Within 4km buffer			**Within wind farm**		
Species	**No. height estimates**	**No. >=22m**	**Proportion >=22m**	**No. height estimates**	**No. >=22m**	**Proportion >=22m**
Red-throated Diver	8	3	0.375	4	0	0.000
Fulmar	88	13	0.148	37	4	0.108
Gannet	116	17	0.147	51	6	0.118
Arctic Skua	1	0	0.000	0	0	0.000
Great Skua	4	2	0.500	1	0	0.000
Kittiwake	206	74	0.359	75	27	0.360
Black-headed Gull	21	17	0.810	3	2	0.667
Little Gull	7	1	0.143	5	1	0.200
Common Gull	32	11	0.344	15	4	0.267
Lesser Black-backed Gull	44	16	0.364	11	5	0.455
Herring Gull	10	4	0.400	3	2	0.667
Great Black-backed Gull	57	17	0.298	25	8	0.320

Table A1.5. Proportions at collision height (>=22 m) from Johnston et al. (2014).

	Proportion at collision height (>=22m)			
Species	**Maximum likelihood**	**Median**	**Lower confidence interval**	**Upper confidence interval**
Red-throated Diver	0.047	0.046	0.010	0.320
Fulmar	0.006	0.005	0.000	0.073
Gannet	0.102	0.104	0.047	0.173
Arctic Skua	0.018	0.019	0.010	0.086
Great Skua	0.044	0.047	0.025	0.151
Kittiwake	0.124	0.124	0.093	0.147
Black-headed Gull	0.114	0.108	0.042	0.232
Little Gull	0.125	0.114	0.041	0.245
Common Gull	0.188	0.202	0.159	0.276
Lesser Black-backed Gull	0.249	0.249	0.171	0.408
Herring Gull	0.285	0.287	0.216	0.400
Great Black-backed Gull	0.291	0.310	0.247	0.420

Table A1.6. Species biometrics used in the collision risk modelling. Note that nocturnal activity factors are the generic ones derived from Garthe and Hüppop (2004). In collision modelling simulations which included uncertainty in nocturnal activity the values used for gannet, kittiwake, lesser black-backed gull, herring gull and great black-backed gull were as detailed in Technical Appendix 13.1.

Species	Body length (m)	Wingspan (m)	Flight speed (m/s)	Nocturnal activity factor	Flight type (flapping=0, gliding=1)	Avoidance rate (%)	Flights upwind (%)
Red-throated Diver	0.73	1.30	17.0	0.50	0	98	50
Fulmar	0.48	1.07	13.0	0.75	0	98	50
Gannet	0.94	1.72	14.9	0.25	0	98.9	50
Arctic Skua	0.44	1.18	13.3	0.00	0	98	50
Great Skua	0.56	1.36	14.9	0.00	0	98	50
Kittiwake	0.39	1.08	13.1	0.50	0	98.9	50
Black-headed Gull	0.37	1.10	11.9	0.50	0	99.2	50
Little Gull	0.26	0.78	12.2	0.25	0	99.2	50
Common Gull	0.42	1.30	13.4	0.50	0	99.2	50
Lesser Black-backed Gull	0.58	1.42	13.1	0.50	0	99.5	50
Herring Gull	0.60	1.44	12.8	0.50	0	99.5	50
Great Black-backed Gull	0.71	1.58	13.7	0.50	0	99.5	50

Table A1.7. Wind farm and turbine specifications used in the collision risk modelling.

<table>
<tr><th rowspan="2">Turbine output (MW)</th><th rowspan="2">No. of rotor blades</th><th rowspan="2">RPM</th><th rowspan="2">Rotor radius (m)</th><th rowspan="2">Hub height above HAT (m)</th><th rowspan="2">Predicted operation time (%)</th><th rowspan="2">Max. blade width (m)</th><th rowspan="2">Mean blade pitch (deg.)</th><th rowspan="2">No. of turbines</th><th colspan="2">Latitude</th><th colspan="2">Wind farm width(km)</th></tr>
<tr><th>NV East</th><th>NV West</th><th>NV East</th><th>NV West</th></tr>
<tr><td>9</td><td rowspan="2">3</td><td>11.26</td><td>85.0</td><td>107.0</td><td rowspan="2">90</td><td>7.0</td><td rowspan="2">15</td><td>200</td><td rowspan="2">52.2</td><td rowspan="2">52.9</td><td rowspan="2">22.3</td><td rowspan="2">17.7</td></tr>
<tr><td>20</td><td>5.05</td><td>151.5</td><td>173.5</td><td>10.0</td><td>90</td></tr>
</table>

Annex 2. Comparison of Norfolk Vanguard deterministic CRM outputs and Band (2012) spreadsheet outputs

Table A2.1. Norfolk Vanguard East (1800MW). Deterministic collision mortality for the 9 MW turbine calculated using Band CRM Option 2.

Species	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Red-throated Diver	0	0	0	0	0	0	0	0	0	0	0	0	0
Fulmar	0.47	0.21	0.5	0.2	1.87	0	0	1.48	0.64	0.19	0.96	0.74	7.26
Gannet	0	1.55	0	2.02	0	13.24	0	9.52	16.98	7.01	58.14	54.96	163.42
Arctic Skua	0	0	0	0	0	0	0	0	0	0	0	0	0
Great Skua	0	0	0	0	0	0	0	0	0.92	0	0	0	0.92
Kittiwake	39.78	41.37	19.67	5.79	16.68	3.71	1.78	0	0	1.91	65.1	27.99	223.78
Black-headed Gull	0	0	0	0	0	0	0	0	0	0	0	0	0
Little Gull	0	0	0	0	0	0	0	2.28	0	0	0	0	2.28
Common Gull	2.22	0	0	0	0	0	0	0	0	0	0	0	2.22
Lesser Black-backed Gull	2	0	0	0	0	0	0	8.9	0	0	0	0	10.9
Herring Gull	6.92	0	0	0	0	0	0	0	0	0	0	0	6.92
Great Black-backed Gull	12.4	0	0	0	0	0	0	1.5	0	0	0	9.5	23.4

Table A2.2. Norfolk Vanguard West (1800 MW). Deterministic collision mortality for the 9 MW turbine calculated using Band CRM Option 2.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	3.23	0	0	0	0	0	0	0	0	0	0	0	3.23
Fulmar	0.37	0.34	0.2	0.2	0.2	0	0	0.3	0.16	0.97	0.32	0	3.06
Gannet	0	1.52	0	0	0	2.29	4.62	5.57	3.29	16.01	32.28	0	65.58
Great Skua	0	0	0	0	0	0	0	0	0.93	0	0	0	0.93
Kittiwake	5.38	3.4	10.03	0	4.44	17.69	0	6.48	0	5.82	20.65	0	73.89
Black-headed Gull	0	0	0	0	0	0	0	0	0	1.17	0	0	1.17
Little Gull	0	0	0	0	0	0	0	0	0.85	0	1.4	0	2.25
Common Gull	0	0	0	0	0	0	0	0	0	2.36	8.58	0	10.94
Lesser Black-backed Gull	0	0	0	0	0	6.68	7.95	13.04	0.86	5.85	0	0	34.38
Herring Gull	0	0	0	0	0	0	0	0	0	0	1.8	0	1.8
Great Black-backed Gull	2.44	6.92	0	0	0	0	0	0	11.6	0	4.21	0	25.17

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

Colour key	
used in overall collision risk sheet	used in available hours sheet
used in migrant collision risk sheet	used in large array correction sheet
used in single transit collision risk sheet or extended model	not used in calculation but stated for reference

Bird data	Units	Value	Data sources
Species name		Gannet	
Bird length	m	0.94	
Wingspan	m	1.72	
Flight speed	m/sec	14.9	
Nocturnal activity factor (1-5)		2	
Flight type, flapping or gliding		flapping	

Data sources

Bird survey data	Units	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		0	0.031	0	0.031	0	0.18	0	0.137	0.276	0.123	1.168	1.142
Proportion at rotor height	%	10.2%												
Proportion of flights upwind	%	50.0%												

Data sources

Birds on migration data	Units	Value
Migration passages	birds	
Width of migration corridor	km	
Proportion at rotor height	%	
Proportion of flights upwind	%	

Windfarm data	Units	Value	Data sources
Name of windfarm site		NV East	
53	degrees	52.20	
Number of turbines		200	
Width of windfarm	km	22.3	
Tidal offset	m	0.8	

Turbine data	Units	Value	Data sources
Turbine model		9MW turbine	
No of blades		3	
Rotation speed	rpm	11.26	
Rotor radius	m	85	
Hub height	m	107	
Monthly proportion of time operational	%	(see below)	
Max blade width	m	7.0	
Pitch	degrees	15	

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly proportion of time operational (%)	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%

Avoidance rates used in presenting results		Data sources (if applicable)
	90.00%	
	95.00%	
	98.00%	
	98.90%	

COLLISION RISK ASSESSMENT
Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

Colour key	
(green)	from Sheet 1 - input data
(purple)	from Sheet 6 - available hours
(orange)	from Sheet 3 - single transit collision risk
(yellow)	from survey data
(light blue)	calculated field

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average
Bird details:															
Species		Gannet													
Flight speed	m/sec	14.9													
Nocturnal activity factor (1-5)		2													
Nocturnal activity (% of daytime)		25%													
Windfarm data:															
Latitude	degrees	52.2													
Number of turbines		200													
Rotor radius	m	85													
Minimum height of rotor	m	107													
Total rotor frontal area	sq m	4539601													
Proportion of time operational	%		90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90.0%
Stage A - flight activity															
Daytime areal bird density	birds/sq km		0	0.031	0	0.031	0	0.18	0	0.137	0.276	0.123	1.168	1.142	
Proportion at rotor height	%	10.2%													
Total daylight hours per month	hrs		257	276	367	416	486	500	504	455	382	332	266	242	
Total night hours per month	hrs		487	396	377	304	258	220	240	289	338	412	454	502	
Flux factor			0	16667	0	21851	0	143140	0	103498	184344	76587	634401	601419	
Option 1 -Basic model - Stages B, C and D															**per annum**
Potential bird transits through rotors			0	1700	0	2229	0	14600	0	10557	18803	7812	64709	61345	**181754**
Collision risk for single rotor transit	(from sheet 3)	9.1%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**139**	**0**	**183**	**0**	**1196**	**0**	**864**	**1540**	**640**	**5299**	**5023**	**14883**
Option 2-Basic model using proportion from flight distribution			**0**	**121**	**0**	**159**	**0**	**1041**	**0**	**753**	**1340**	**557**	**4613**	**4373**	**12957**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	8.9%													
Potential bird transits through rotors	Flux integral	0.0487	0	812	0	1065	0	6975	0	5043	8983	3732	30683	8249	51066
Collisions assuming no avoidance	Collision integral	0.00241	**0**	**36**	**0**	**47**	**0**	**310**	**0**	**224**	**400**	**166**	**1447**	**1304**	3936
Average collision risk for single rotor transit		4.9%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	139	0	183	0	1196	0	864	1540	640	5299	5023	**14883**
	birds per month														
Collisions assuming avoidance rate	or year	90.00%	0	14	0	18	0	120	0	86	154	64	530	502	**1488**
		95.00%	0	7	0	9	0	60	0	43	77	32	265	251	**744**
		98.00%	0	3	0	4	0	24	0	17	31	13	106	100	**298**
		98.90%	0	2	0	2	0	13	0	10	17	7	58	55	**163.71**
Collisions after applying large array correction		90.00%	0	14	0	18	0	119	0	86	153	64	527	500	**1482**
		95.00%	0	7	0	9	0	60	0	43	77	32	264	251	**742**
		98.00%	0	3	0	4	0	24	0	17	31	13	106	100	**297**
		98.90%	0	2	0	2	0	13	0	10	17	7	58	55	**164**

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

Colour key	
(light green)	used in overall collision risk sheet
(yellow-green)	used in migrant collision risk sheet
(orange)	used in single transit collision risk sheet or extended model
(lavender)	used in available hours sheet
(pale yellow)	used in large array correction sheet
(pink)	not used in calculation but stated for reference

	Units	Value	Data sources
Bird data			
Species name		Gannet	
Bird length	m	0.94	
Wingspan	m	1.72	
Flight speed	m/sec	14.9	
Nocturnal activity factor (1-5)		2	
Flight type, flapping or gliding		flapping	

Bird survey data	Units	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		0	0.031	0	0	0	0.031	0.062	0.08	0.053	0.28	0.649	0
Proportion at rotor height	%	10.2%												
Proportion of flights upwind	%	50.0%												

Birds on migration data	Units	Value	Data sources
Migration passages	birds		
Width of migration corridor	km		
Proportion at rotor height	%		
Proportion of flights upwind	%		

		Units	Value	Data sources
Windfarm data				
Name of windfarm site			NV West	
	53	degrees	52.90	
Number of turbines			200	
Width of windfarm		km	17.7	
Tidal offset		m	0.8	

Turbine data	Units	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turbine model		9MW turbine												
No of blades		3												
Rotation speed	rpm	11.26												
Rotor radius	m	85												
Hub height	m	107												
Monthly proportion of time operational	%		90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
Max blade width	m	7.0												
Pitch	degrees	15												

Avoidance rates used in presenting results		Data sources (if applicable)
	90.00%	
	95.00%	
	98.00%	
	98.90%	

COLLISION RISK ASSESSMENT

Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

(green)	from Sheet 1 - input data
(lilac)	from Sheet 6 - available hours
(orange)	from Sheet 3 - single transit collision risk
(yellow)	from survey data
(light blue)	calculated field

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average
Bird details:															
Species		Gannet													
Flight speed	m/sec	14.9													
Nocturnal activity factor (1-5)		2													
Nocturnal activity (% of daytime)		25%													
Windfarm data:															
Latitude	degrees	52.9													
Number of turbines		200													
Rotor radius	m	85													
Minimum height of rotor	m	107													
Total rotor frontal area	sq m	4539601													
Proportion of time operational	%		90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90.0%
Stage A - flight activity															
Daytime areal bird density	birds/sq km		0	0.031	0	0	0	0.031	0.062	0.08	0.053	0.28	0.649	0	
Proportion at rotor height	%	10.2%													
Total daylight hours per month	hrs		254	275	366	418	489	504	507	457	382	330	263	238	
Total night hours per month	hrs		490	397	378	302	255	216	237	287	338	414	457	506	
Flux factor			0	16613	0	0	0	24788	50319	60624	35428	174011	350661	0	
Option 1 -Basic model - Stages B, C and D															**per annum**
Potential bird transits through rotors			0	1695	0	0	0	2528	5133	6184	3614	17749	35767	0	**72668**
Collision risk for single rotor transit	(from sheet 3)	9.1%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**0**	**139**	**0**	**0**	**0**	**207**	**420**	**506**	**296**	**1453**	**2929**	**0**	5950
Option 2-Basic model using proportion from flight distribution			**0**	**121**	**0**	**0**	**0**	**180**	**366**	**441**	**258**	**1265**	**2550**	**0**	**5181**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	8.9%													
Potential bird transits through rotors	Flux integral	0.0487	0	810	0	0	0	1208	2452	2954	1726	8480	30683	8249	**51066**
Collisions assuming no avoidance	Collision integral	0.00241	**0**	**36**	**0**	**0**	**0**	**54**	**109**	**131**	**77**	**377**	**1447**	**0**	**2232**
Average collision risk for single rotor transit		4.9%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	0	139	0	0	0	207	420	506	296	1453	2929	0	5950
Collisions assuming avoidance rate	birds per month or year	90.00%	0	14	0	0	0	21	42	51	30	145	293	0	**595**
		95.00%	0	7	0	0	0	10	21	25	15	73	146	0	**298**
		98.00%	0	3	0	0	0	4	8	10	6	29	59	0	**119**
		98.90%	0	2	0	0	0	2	5	6	3	16	32	0	**65.46**
Collisions after applying large array correction		90.00%	0	14	0	0	0	21	42	50	29	145	291	0	**592**
		95.00%	0	7	0	0	0	10	21	25	15	72	146	0	**297**
		98.00%	0	3	0	0	0	4	8	10	6	29	59	0	**119**
		98.90%	0	2	0	0	0	2	5	6	3	16	32	0	**65**

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

(light green)	used in overall collision risk sheet
(yellow-green)	used in migrant collision risk sheet
(orange)	used in single transit collision risk sheet or extended model
(lavender)	used in available hours sheet
(light yellow)	used in large array correction sheet
(pink)	not used in calculation but stated for reference

	Units	Value	Data sources
Bird data			
Species name		**Kittiwake**	
Bird length	m	0.39	
Wingspan	m	1.08	
Flight speed	m/sec	13.1	
Nocturnal activity factor (1-5)		3	
Flight type, flapping or gliding		flapping	

	Units	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Bird survey data														
Daytime bird density	birds/sq km		0.686	0.753	0.305	0.088	0.233	0.052	0.025	0	0	0.031	1.141	0.491
Proportion at rotor height	%	12.4%												
Proportion of flights upwind	%	50.0%												

Data sources

	Units	Value
Birds on migration data		
Migration passages	birds	
Width of migration corridor	km	
Proportion at rotor height	%	
Proportion of flights upwind	%	

		Units	Value	Data sources
Windfarm data				
Name of windfarm site			**NV East**	
	53	degrees	52.20	
Number of turbines			200	
Width of windfarm		km	22.3	
Tidal offset		m	0.8	

	Units	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Turbine data														
Turbine model		**9MW turbine**												
No of blades		3												
Rotation speed	rpm	11.26												
Rotor radius	m	85												
Hub height	m	107												
Monthly proportion of time operational	%		90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%
Max blade width	m	7.0												
Pitch	degrees	15												

Avoidance rates used in presenting results		Data sources (if applicable)
	90.00%	
	95.00%	
	98.00%	
	98.90%	

COLLISION RISK ASSESSMENT
Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

(green)	from Sheet 1 - input data
(lilac)	from Sheet 6 - available hours
(orange)	from Sheet 3 - single transit collision risk
(yellow)	from survey data
(light blue)	calculated field

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average
Bird details:															
Species		Kittiwake													
Flight speed	m/sec	13.1													
Nocturnal activity factor (1-5)		3													
Nocturnal activity (% of daytime)		50%													
Windfarm data:															
Latitude	degrees	52.2													
Number of turbines		200													
Rotor radius	m	85													
Minimum height of rotor	m	107													
Total rotor frontal area	sq m	4539601													
Proportion of time operational	%		90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90.0%
Stage A - flight activity															
Daytime areal bird density	birds/sq km		0.686	0.753	0.305	0.088	0.233	0.052	0.025	0	0	0.031	1.141	0.491	
Proportion at rotor height	%	12.4%													
Total daylight hours per month	hrs		257	276	367	416	486	500	504	455	382	332	266	242	
Total night hours per month	hrs		487	396	377	304	258	220	240	289	338	412	454	502	
Flux factor			432484	449712	213303	62955	180457	39954	19642	0	0	20996	708103	304908	
Option 1 -Basic model - Stages B, C and D															per annum
Potential bird transits through rotors			53628	55764	26450	7806	22377	4954	2436	0	0	2603	87805	37809	301630
Collision risk for single rotor transit	(from sheet 3)	7.5%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**3620**	**3764**	**1785**	**527**	**1511**	**334**	**164**	**0**	**0**	**176**	**5927**	**2552**	**20362**
Option 2-Basic model using proportion from flight distribution			**2593**	**2696**	**1279**	**377**	**1082**	**240**	**118**	**0**	**0**	**126**	**4245**	**1828**	**14582**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	8.9%													
Potential bird transits through rotors	Flux integral	0.0487	21075	21914	10394	3068	8794	1947	957	0	0	1023	30683	8249	51066
Collisions assuming no avoidance	Collision integral	0.00241	**938**	**975**	**463**	**137**	**391**	**87**	**43**	**0**	**0**	**46**	**1447**	**661**	**5187**
Average collision risk for single rotor transit		4.9%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	3620	3764	1785	527	1511	334	164	0	0	176	5927	2552	**20362**
Collisions assuming avoidance rate	birds per month or year	90.00%	362	376	179	53	151	33	16	0	0	18	593	255	**2036**
		95.00%	181	188	89	26	76	17	8	0	0	9	296	128	**1018**
		98.00%	72	75	36	11	30	7	3	0	0	4	119	51	**407**
		98.90%	40	41	20	6	17	4	2	0	0	2	65	28	**223.98**
Collisions after applying large array correction		90.00%	361	375	178	52	150	33	16	0	0	18	591	254	**2029**
		95.00%	181	188	89	26	75	17	8	0	0	9	296	127	**1016**
		98.00%	72	75	36	11	30	7	3	0	0	4	118	51	**407**
		98.90%	40	41	20	6	17	4	2	0	0	2	65	28	**224**

COLLISION RISK ASSESSMENT
Sheet 1 - Input data

Colour key	
(light green)	used in overall collision risk sheet
(yellow-green)	used in migrant collision risk sheet
(orange)	used in single transit collision risk sheet or extended model
(lilac)	used in available hours sheet
(pale yellow)	used in large array correction sheet
(pink)	not used in calculation but stated for reference

Bird data	Units	Value	Data sources
Species name		Kittiwake	
Bird length	m	0.39	
Wingspan	m	1.08	
Flight speed	m/sec	13.1	
Nocturnal activity factor (1-5)		3	
Flight type, flapping or gliding		flapping	

Bird survey data	Units	Value	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Daytime bird density	birds/sq km		0.093	0.062	0.156	0	0.062	0.249	0	0.093	0	0.093	0.362	0
Proportion at rotor height	%	12.4%												
Proportion of flights upwind	%	50.0%												

Data sources

Birds on migration data	Units	Value	Data sources
Migration passages	birds		
Width of migration corridor	km		
Proportion at rotor height	%		
Proportion of flights upwind	%		

Windfarm data		Units	Value	Data sources
Name of windfarm site			NV West	
	53	degrees	52.90	
Number of turbines			200	
Width of windfarm		km	17.7	
Tidal offset		m	0.8	

Turbine data	Units	Value	Data sources
Turbine model		9MW turbine	
No of blades		3	
Rotation speed	rpm	11.26	
Rotor radius	m	85	
Hub height	m	107	
Max blade width	m	7.0	
Pitch	degrees	15	

	Units	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Monthly proportion of time operational	%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%	90.00%

Avoidance rates used in presenting results		Data sources (if applicable)
	90.00%	
	95.00%	
	98.00%	
	98.90%	

COLLISION RISK ASSESSMENT
Sheet 2 - Overall collision risk

All data input on Sheet 1:
no data entry needed on this sheet!

Colour key	
(green)	from Sheet 1 - input data
(purple)	from Sheet 6 - available hours
(orange)	from Sheet 3 - single transit collision risk
(yellow)	from survey data
(light blue)	calculated field

			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	year average / per annum
Bird details:															
Species		Kittiwake													
Flight speed	m/sec	13.1													
Nocturnal activity factor (1-5)		3													
Nocturnal activity (% of daytime)		50%													
Windfarm data:															
Latitude	degrees	52.9													
Number of turbines		200													
Rotor radius	m	85													
Minimum height of rotor	m	107													
Total rotor frontal area	sq m	4539601													
Proportion of time operational	%		90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90%	90.0%
Stage A - flight activity															
Daytime areal bird density	birds/sq km		0.093	0.062	0.156	0	0.062	0.249	0	0.093	0	0.093	0.362	0	
Proportion at rotor height	%	12.4%													
Total daylight hours per month	hrs		254	275	366	418	489	504	507	457	382	330	263	238	
Total night hours per month	hrs		490	397	378	302	255	216	237	287	338	414	457	506	
Flux factor			58439	36965	109080	0	48141	191958	0	70353	0	62922	224054	0	
Option 1 -Basic model - Stages B, C and D															**per annum**
Potential bird transits through rotors			7246	4584	13526	0	5969	23803	0	8724	0	7802	27783	0	99436
Collision risk for single rotor transit	(from sheet 3)	7.5%													
Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**489**	**309**	**913**	**0**	**403**	**1607**	**0**	**589**	**0**	**527**	**1875**	**0**	**6713**
Option 2-Basic model using proportion from flight distribution			**350**	**222**	**654**	**0**	**289**	**1151**	**0**	**422**	**0**	**377**	**1343**	**0**	**4807**
Option 3-Extended model using flight height distribution															
Proportion at rotor height	(from sheet 4)	8.9%													
Potential bird transits through rotors	Flux integral	0.0487	2848	1801	5315	0	2346	9354	0	3428	0	3066	30683	8249	51066
Collisions assuming no avoidance	Collision integral	0.00241	**127**	**80**	**237**	**0**	**104**	**416**	**0**	**153**	**0**	**136**	**1447**	**0**	**2700**
Average collision risk for single rotor transit		4.9%													
Stage E - applying avoidance rates															
Using which of above options?	**Option 1**	0.00%	489	309	913	0	403	1607	0	589	0	527	1875	0	6713
	birds per month or year														
Collisions assuming avoidance rate		90.00%	49	31	91	0	40	161	0	59	0	53	188	0	671
		95.00%	24	15	46	0	20	80	0	29	0	26	94	0	336
		98.00%	10	6	18	0	8	32	0	12	0	11	38	0	134
		98.90%	5	3	10	0	4	18	0	6	0	6	21	0	73.84
Collisions after applying large array correction		90.00%	49	31	91	0	40	160	0	59	0	52	187	0	668
		95.00%	24	15	46	0	20	80	0	29	0	26	94	0	335
		98.00%	10	6	18	0	8	32	0	12	0	11	37	0	134
		98.90%	5	3	10	0	4	18	0	6	0	6	21	0	74

Annex 3. Norfolk Vanguard collision mortality – monthly mean collision estimates

Table A3.1. Norfolk Vanguard East (1800MW). Collision mortality for the 9MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density, proportions at collision height, avoidance rate and nocturnal activity.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0.98 (0-12.11)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.95 (0-22.74)	0 (0-0)	2.93 (0-34.85)
Fulmar	0.75 (0-5.12)	0.39 (0-1.96)	0.72 (0-4.34)	0.49 (0-1.93)	2.01 (0-14.54)	1.08 (0-5.38)	0.15 (0-0.38)	1.4 (0-12)	0.8 (0-7.18)	0.31 (0-1.67)	0.79 (0-8.4)	0.92 (0-6.67)	9.81 (0-69.57)
Gannet	1.08 (0-5.07)	1.77 (0-7.53)	1.13 (0-6.18)	1.77 (0-8.45)	3.34 (0-15.67)	16.81 (0-56.97)	0.85 (0-5.42)	8.48 (0-25.08)	11.76 (0-35.81)	7.28 (0.62-24.32)	76.51 (14.17-252.69)	28.63 (0-80.84)	159.41 (14.79-524.03)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.24 (0-2.51)	0.51 (0-5.59)	0 (0-0)	0 (0-0)	0 (0-0)	0.75 (0-8.1)
Great Skua	0 (0-0)	0 (0-0)	0.35 (0-4)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.54 (0-11.41)	0.61 (0-4.66)	0 (0-0)	0 (0-0)	2.5 (0-20.07)
Kittiwake	71.19 (11.4-228.5)	32.44 (6.21-75.76)	47.32 (0-172.03)	25.43 (0-97.24)	23.58 (0-69.81)	4.64 (0-16.68)	2.34 (0-8.77)	1.35 (0-8.34)	1.37 (0-6.3)	3.76 (0-16.69)	37.36 (0-90.67)	25.9 (4.82-68.86)	276.68 (22.43-859.65)
Black-headed Gull	0.95 (0-7.68)	0 (0-0)	1.08 (0-6.46)	0 (0-0)	0.72 (0-5.29)	0 (0-0)	1 (0-6.12)	0 (0-0)	0 (0-0)	0.4 (0-3.55)	0.68 (0-6.33)	0 (0-0)	4.83 (0-35.43)
Little Gull	0 (0-0)	0.28 (0-2.6)	0 (0-0)	0 (0-0)	7.29 (0-37.25)	0 (0-0)	0 (0-0)	7.49 (0-37.4)	0.29 (0-2.69)	0 (0-0)	1.39 (0-10.11)	0 (0-0)	16.74 (0-90.05)
Common Gull	3.03 (0-13.75)	0 (0-0)	2.48 (0-15.24)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.13 (0-18.9)	1.38 (0-7.22)	0.73 (0-5.68)	10.75 (0-60.79)
Lesser Black-backed Gull	3.85 (0-16.19)	1.03 (0-7.29)	0.77 (0-6.63)	1.35 (0-6.93)	0 (0-0)	0 (0-0)	1.69 (0-8.91)	9.82 (0-33.69)	0 (0-0)	0.45 (0-3.73)	1.46 (0-7.27)	1.31 (0-8.86)	21.73 (0-99.5)
Herring Gull	30.42 (0-131.35)	0 (0-0)	0.91 (0-7.21)	1.44 (0-7.46)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.43 (0-13.93)	1.93 (0-12.12)	37.13 (0-172.07)
Great Black-backed Gull	72.88 (1.43-307.69)	1.31 (0-8.93)	0.83 (0-7.06)	1.82 (0-12.8)	0 (0-0)	0 (0-0)	0 (0-0)	14.15 (0-51.5)	0 (0-0)	0 (0-0)	6.45 (0-33.73)	9.77 (0-30.02)	107.21 (1.43-451.73)

Table A3.2. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density only (mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0.79 (0-6.9)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.17 (0-11.09)	0 (0-0)	2.96 (0-17.99)
Fulmar	0.75 (0-2.48)	0.36 (0-1.39)	0.63 (0-2.2)	0.58 (0-2.33)	2.3 (0-5.71)	1.05 (0-3.71)	0.16 (0-0.65)	1.6 (0.3-3.52)	0.9 (0-2.68)	0.29 (0-1.14)	0.98 (0-2.36)	0.94 (0-2.69)	10.54 (0.3-30.86)
Gannet	1.58 (0-6.82)	2.28 (0-7.74)	1.38 (0-5.67)	1.98 (0-8.07)	3.65 (0-14.55)	18.18 (0-49.9)	0.9 (0-5.49)	9.54 (0-22.11)	14.09 (0-33.97)	9.33 (1.37-26.32)	106.63 (33.74-251.37)	42.17 (0-81.49)	211.71 (35.11-513.5)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.24 (0-1.44)	0.5 (0-2.99)	0 (0-0)	0 (0-0)	0 (0-0)	0.74 (0-4.43)
Great Skua	0 (0-0)	0 (0-0)	0.35 (0-3.13)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.58 (0-6.76)	0.56 (0-2.78)	0 (0-0)	0 (0-0)	2.49 (0-12.67)
Kittiwake	105.12 (19.89-279.25)	44.52 (10.58-90.51)	60.02 (0-184.57)	29.91 (0-98.38)	26.55 (2.38-69.48)	5.05 (0-18.53)	2.62 (0-10.25)	1.5 (0-9.52)	1.71 (0-7.06)	5.12 (0-21.04)	54.19 (0-110.8)	38.78 (7.87-92.07)	375.09 (40.72-991.46)
Black-headed Gull	0.92 (0-5.43)	0 (0-0)	1.07 (0-5.08)	0 (0-0)	0.7 (0-4.31)	0 (0-0)	1.04 (0-4.29)	0 (0-0)	0 (0-0)	0.39 (0-2.3)	0.66 (0-5.6)	0 (0-0)	4.78 (0-27.01)
Little Gull	0 (0-0)	0.29 (0-1.77)	0 (0-0)	0 (0-0)	7.26 (0-24.34)	0 (0-0)	0 (0-0)	7.43 (0-22.82)	0.27 (0-1.66)	0 (0-0)	1.41 (0-8.37)	0 (0-0)	16.66 (0-58.96)
Common Gull	3.19 (0-14.52)	0 (0-0)	2.61 (0-14.65)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.12 (0-16.29)	1.38 (0-6.42)	0.72 (0-6.39)	11.02 (0-58.27)
Lesser Black-backed Gull	4.35 (0-15.87)	1.15 (0-6.94)	0.88 (0-7.71)	1.48 (0-6.53)	0 (0-0)	0 (0-0)	1.82 (0-8.96)	10.52 (0-28.94)	0 (0-0)	0.52 (0-4.51)	1.69 (0-7.08)	1.49 (0-9.04)	23.9 (0-95.58)
Herring Gull	34.88 (0-120.09)	0 (0-0)	1.06 (0-8.88)	1.47 (0-7.13)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.81 (0-14.27)	2.26 (0-13.69)	42.48 (0-164.06)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	83.23 (2.48-269.07)	1.49 (0-9.36)	0.89 (0-8.17)	1.9 (0-11.73)	0 (0-0)	0 (0-0)	0 (0-0)	14.89 (0-48.03)	0 (0-0)	0 (0-0)	7.27 (0-33.43)	11.27 (0-30.49)	120.94 (2.48-410.28)

Table A3.3. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in avoidance rate only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	0.47 (0.38-0.56)	0.21 (0.17-0.26)	0.5 (0.41-0.6)	0.2 (0.17-0.25)	1.87 (1.51-2.23)	0 (0-0)	0 (0-0)	1.49 (1.21-1.8)	0.64 (0.52-0.78)	0.19 (0.15-0.23)	0.96 (0.78-1.15)	0.74 (0.6-0.89)	7.27 (5.9-8.75)
Gannet	0 (0-0)	1.55 (1.04-2.15)	0 (0-0)	2.01 (1.35-2.81)	0 (0-0)	13.24 (8.86-18.33)	0 (0-0)	9.46 (6.38-13.25)	16.96 (11.5-23.45)	7.05 (4.7-9.78)	58.33 (39.69-80.6)	54.89 (37.29-75.84)	163.49 (110.81-226.21)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.91 (0.75-1.11)	0 (0-0)	0 (0-0)	0 (0-0)	0.91 (0.75-1.11)
Kittiwake	39.77 (26.66-55.31)	41.27 (28.01-57.14)	19.68 (13.19-27.47)	5.81 (3.92-8.08)	16.71 (11.25-23.19)	3.72 (2.54-5.13)	1.77 (1.21-2.46)	0 (0-0)	0 (0-0)	1.91 (1.29-2.65)	64.98 (44.16-89.77)	28.07 (19.13-38.54)	223.69 (151.36-309.74)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.28 (1.31-3.5)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.28 (1.31-3.5)
Common Gull	2.23 (1.29-3.45)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.23 (1.29-3.45)
Lesser Black-backed Gull	2.01 (1.31-2.88)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	8.92 (5.78-12.73)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.93 (7.09-15.61)
Herring Gull	6.9 (4.55-9.82)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.9 (4.55-9.82)
Great Black-backed Gull	12.41 (8.07-17.7)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.5 (0.98-2.17)	0 (0-0)	0 (0-0)	0 (0-0)	9.47 (6.13-13.52)	23.38 (15.18-33.39)

Table A3.4. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in proportions at collision height (Option 2) only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	0.53 (0-6.61)	0.24 (0-2.67)	0.47 (0-5.37)	0.21 (0-2.48)	2.17 (0-26.45)	0 (0-0)	0 (0-0)	1.34 (0-12.95)	0.56 (0-4.97)	0.19 (0-1.88)	1.17 (0-14.21)	0.69 (0-7.31)	7.57 (0-84.9)
Gannet	0 (0-0)	1.55 (0.67-2.76)	0 (0-0)	2.05 (0.9-3.56)	0 (0-0)	13.33 (5.93-23.54)	0 (0-0)	9.53 (4.13-16.81)	16.84 (7.63-29.28)	6.99 (3.05-12.21)	58.41 (25.37-103.7)	55.09 (24.25-97.78)	163.79 (71.93-289.64)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.01-3.84)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.01-3.84)
Kittiwake	39.82 (30.49-50.07)	41.36 (31.53-52.19)	19.6 (15.09-24.83)	5.79 (4.41-7.32)	16.71 (12.86-21.04)	3.7 (2.81-4.65)	1.78 (1.36-2.25)	0 (0-0)	0 (0-0)	1.91 (1.47-2.41)	65.13 (49.45-82.13)	28.03 (21.45-35.4)	223.83 (170.92-282.29)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.3 (0.42-5.44)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.3 (0.42-5.44)
Common Gull	2.2 (1.47-3.07)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.2 (1.47-3.07)
Lesser Black-backed Gull	1.99 (0.84-3.4)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	9.02 (3.91-15.38)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.01 (4.75-18.78)
Herring Gull	6.93 (4.3-9.77)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.93 (4.3-9.77)
Great Black-backed Gull	12.35 (8.1-16.96)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.5 (0.99-2.05)	0 (0-0)	0 (0-0)	0 (0-0)	9.52 (6.41-13.02)	23.37 (15.5-32.03)

Table A3.5. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in nocturnal activity only (mean values for seabird density and mean values for proportions at collision height and avoidance rate).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	0.47 (0.47-0.47)	0.21 (0.21-0.21)	0.5 (0.5-0.5)	0.2 (0.2-0.2)	1.87 (1.87-1.87)	0 (0-0)	0 (0-0)	1.48 (1.48-1.48)	0.64 (0.64-0.64)	0.19 (0.19-0.19)	0.96 (0.96-0.96)	0.74 (0.74-0.74)	7.26 (7.26-7.26)
Gannet	0 (0-0)	1.17 (1.16-1.19)	0 (0-0)	1.76 (1.72-1.85)	0 (0-0)	12.18 (11.99-12.53)	0 (0-0)	8.45 (8.26-8.78)	14.44 (14-15.27)	5.49 (5.45-5.55)	42.16 (41.67-42.77)	37.71 (37.16-38.38)	123.36 (121.41-126.32)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.92 (0.92-0.92)	0 (0-0)	0 (0-0)	0 (0-0)	0.92 (0.92-0.92)
Kittiwake	26.89 (25.79-28.09)	29.93 (28.95-31)	15.69 (14.49-17.12)	4.87 (4.59-5.19)	14.61 (14-15.35)	3.31 (3.2-3.45)	1.58 (1.52-1.65)	0 (0-0)	0 (0-0)	1.43 (1.38-1.47)	45.13 (43.43-46.97)	18.49 (17.7-19.37)	161.93 (155.05-169.66)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.28 (2.28-2.28)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.28 (2.28-2.28)
Common Gull	2.22 (2.22-2.22)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.22 (2.22-2.22)
Lesser Black-backed Gull	1.76 (1.51-2)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	8.37 (7.84-8.9)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.13 (9.35-10.9)
Herring Gull	6.04 (5.22-6.92)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.04 (5.22-6.92)
Great Black-backed Gull	10.86 (9.36-12.4)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.41 (1.32-1.5)	0 (0-0)	0 (0-0)	0 (0-0)	8.27 (7.06-9.5)	20.54 (17.74-23.4)

Table A3.6. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations with no uncertainty in any parameters.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	0.47 (0.47-0.47)	0.21 (0.21-0.21)	0.5 (0.5-0.5)	0.2 (0.2-0.2)	1.87 (1.87-1.87)	0 (0-0)	0 (0-0)	1.48 (1.48-1.48)	0.64 (0.64-0.64)	0.19 (0.19-0.19)	0.96 (0.96-0.96)	0.74 (0.74-0.74)	7.26 (7.26-7.26)
Gannet	0 (0-0)	1.55 (1.55-1.55)	0 (0-0)	2.02 (2.02-2.02)	0 (0-0)	13.24 (13.24-13.24)	0 (0-0)	9.52 (9.52-9.52)	16.98 (16.98-16.98)	7.01 (7.01-7.01)	58.14 (58.14-58.14)	54.96 (54.96-54.96)	163.42 (163.42-163.42)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.92 (0.92-0.92)	0 (0-0)	0 (0-0)	0 (0-0)	0.92 (0.92-0.92)
Kittiwake	39.78 (39.78-39.78)	41.37 (41.37-41.37)	19.67 (19.67-19.67)	5.79 (5.79-5.79)	16.68 (16.68-16.68)	3.71 (3.71-3.71)	1.78 (1.78-1.78)	0 (0-0)	0 (0-0)	1.91 (1.91-1.91)	65.1 (65.1-65.1)	27.99 (27.99-27.99)	223.78 (223.78-223.78)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.28 (2.28-2.28)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.28 (2.28-2.28)
Common Gull	2.22 (2.22-2.22)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.22 (2.22-2.22)
Lesser Black-backed Gull	2 (2-2)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	8.9 (8.9-8.9)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.9 (10.9-10.9)
Herring Gull	6.92 (6.92-6.92)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.92 (6.92-6.92)
Great Black-backed Gull	12.4 (12.4-12.4)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.5 (1.5-1.5)	0 (0-0)	0 (0-0)	0 (0-0)	9.5 (9.5-9.5)	23.4 (23.4-23.4)

Table A3.7. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density, proportions at collision height, avoidance rate and nocturnal activity.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	8.83 (0-68.03)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	23.27 (0-124.97)	0 (0-0)	32.1 (0-193)
Fulmar	2.03 (0-6.79)	0.94 (0-3.75)	1.69 (0-6.16)	1.53 (0-6.43)	6.13 (0-15.88)	2.78 (0-9.55)	0.44 (0-2.07)	4.26 (0.67-9.52)	2.37 (0-7.11)	0.78 (0-2.87)	2.57 (0-6.43)	2.5 (0-7.49)	28.02 (0.67-84.05)
Gannet	1.51 (0-6.53)	2.44 (0-9.33)	1.57 (0-7.82)	2.45 (0-10.99)	4.61 (0-19.42)	23.06 (0-65.83)	1.17 (0-6.68)	11.82 (0-29.55)	16.36 (0-41.91)	10.13 (1.22-29.23)	106.76 (29.89-284.43)	39.92 (0-87.65)	221.8 (31.11-599.37)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.17 (0-25.43)	8.95 (0-50.27)	0 (0-0)	0 (0-0)	0 (0-0)	13.12 (0-75.7)
Great Skua	0 (0-0)	0 (0-0)	2.75 (0-21.97)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	12.11 (0-51.19)	4.49 (0-21.8)	0 (0-0)	0 (0-0)	19.35 (0-94.96)
Kittiwake	133.06 (21.86-406.9)	60.52 (12.4-135.38)	88.48 (0-307.56)	47.25 (0-177)	44.22 (0-126.72)	8.72 (0-31.18)	4.38 (0-15.89)	2.53 (0-15.19)	2.57 (0-11.73)	7.02 (0-30.22)	70.09 (0-162.27)	48.48 (9.4-125.22)	517.32 (43.66-1545.26)
Black-headed Gull	1.95 (0-12.45)	0 (0-0)	2.28 (0-10.94)	0 (0-0)	1.54 (0-9.75)	0 (0-0)	2.2 (0-10.71)	0 (0-0)	0 (0-0)	0.84 (0-6.62)	1.42 (0-11.13)	0 (0-0)	10.23 (0-61.6)
Little Gull	0 (0-0)	0.15 (0-1.17)	0 (0-0)	0 (0-0)	3.84 (0-14.28)	0 (0-0)	0 (0-0)	3.94 (0-13.72)	0.16 (0-1.27)	0 (0-0)	0.74 (0-4.31)	0 (0-0)	8.83 (0-34.75)
Common Gull	4.23 (0-19.12)	0 (0-0)	3.43 (0-20.61)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.36 (0-24.45)	1.91 (0-9.64)	1 (0-7.64)	14.93 (0-81.46)
Lesser Black-backed Gull	4.44 (0-16.84)	1.2 (0-7.97)	0.89 (0-7.19)	1.55 (0-7.59)	0 (0-0)	0 (0-0)	1.98 (0-9.55)	11.42 (0-34.4)	0 (0-0)	0.52 (0-4.22)	1.71 (0-7.81)	1.51 (0-9.54)	25.22 (0-105.11)
Herring Gull	19.38 (0-77.65)	0 (0-0)	0.58 (0-4.44)	0.92 (0-4.57)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.56 (0-8.74)	1.23 (0-7.43)	23.67 (0-102.83)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	44.89 (0.98-177.57)	0.8 (0-5.26)	0.52 (0-4.2)	1.13 (0-7.75)	0 (0-0)	0 (0-0)	0 (0-0)	8.7 (0-30.11)	0 (0-0)	0 (0-0)	3.98 (0-19.93)	6.03 (0-17.85)	66.05 (0.98-262.67)

Table A3.8. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density only (mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	8.52 (0-74.74)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	23.54 (0-120.16)	0 (0-0)	32.06 (0-194.9)
Fulmar	2 (0-6.62)	0.96 (0-3.72)	1.68 (0-5.86)	1.55 (0-6.21)	6.13 (0-15.24)	2.8 (0-9.89)	0.43 (0-1.74)	4.26 (0.79-9.38)	2.39 (0-7.13)	0.78 (0-3.05)	2.61 (0-6.28)	2.51 (0-7.17)	28.1 (0.79-82.29)
Gannet	2.19 (0-9.42)	3.16 (0-10.69)	1.91 (0-7.84)	2.74 (0-11.16)	5.05 (0-20.12)	25.12 (0-68.96)	1.24 (0-7.59)	13.18 (0-30.56)	19.48 (0-46.95)	12.89 (1.89-36.37)	147.37 (46.63-347.43)	58.29 (0-112.63)	292.62 (48.52-709.72)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.2 (0-25.52)	8.87 (0-53.08)	0 (0-0)	0 (0-0)	0 (0-0)	13.07 (0-78.6)
Great Skua	0 (0-0)	0 (0-0)	2.69 (0-24.04)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	12.11 (0-51.88)	4.31 (0-21.35)	0 (0-0)	0 (0-0)	19.11 (0-97.27)
Kittiwake	196.84 (37.24-522.88)	83.35 (19.81-169.48)	112.38 (0-345.59)	56 (0-184.21)	49.7 (4.46-130.1)	9.45 (0-34.7)	4.91 (0-19.2)	2.8 (0-17.82)	3.2 (0-13.23)	9.58 (0-39.39)	101.46 (0-207.46)	72.6 (14.74-172.39)	702.27 (76.25-1856.45)
Black-headed Gull	1.95 (0-11.55)	0 (0-0)	2.27 (0-10.81)	0 (0-0)	1.48 (0-9.17)	0 (0-0)	2.2 (0-9.13)	0 (0-0)	0 (0-0)	0.82 (0-4.91)	1.41 (0-11.93)	0 (0-0)	10.13 (0-57.5)
Little Gull	0 (0-0)	0.15 (0-0.94)	0 (0-0)	0 (0-0)	3.87 (0-12.97)	0 (0-0)	0 (0-0)	3.96 (0-12.17)	0.15 (0-0.88)	0 (0-0)	0.75 (0-4.46)	0 (0-0)	8.88 (0-31.42)
Common Gull	4.42 (0-20.14)	0 (0-0)	3.62 (0-20.32)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.32 (0-22.6)	1.91 (0-8.91)	1 (0-8.86)	15.27 (0-80.83)
Lesser Black-backed Gull	5.05 (0-18.44)	1.34 (0-8.06)	1.02 (0-8.96)	1.71 (0-7.58)	0 (0-0)	0 (0-0)	2.12 (0-10.41)	12.21 (0-33.61)	0 (0-0)	0.61 (0-5.24)	1.96 (0-8.23)	1.73 (0-10.5)	27.75 (0-111.03)
Herring Gull	22.19 (0-76.4)	0 (0-0)	0.67 (0-5.65)	0.93 (0-4.53)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.79 (0-9.08)	1.44 (0-8.71)	27.02 (0-104.37)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	51.32 (1.53-165.9)	0.92 (0-5.77)	0.55 (0-5.04)	1.17 (0-7.24)	0 (0-0)	0 (0-0)	0 (0-0)	9.18 (0-29.61)	0 (0-0)	0 (0-0)	4.48 (0-20.61)	6.95 (0-18.8)	74.57 (1.53-252.97)

Table A3.9. Norfolk Vanguard East (1800 MW). Collision mortality for the 9MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in avoidance rate only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	1.25 (1.01-1.5)	0.57 (0.46-0.69)	1.33 (1.08-1.6)	0.55 (0.44-0.66)	4.97 (4.03-5.95)	0 (0-0)	0 (0-0)	3.96 (3.23-4.8)	1.72 (1.4-2.08)	0.51 (0.41-0.62)	2.55 (2.08-3.07)	1.96 (1.59-2.37)	19.37 (15.73-23.34)
Gannet	0 (0-0)	2.14 (1.43-2.97)	0 (0-0)	2.78 (1.87-3.89)	0 (0-0)	18.31 (12.24-25.33)	0 (0-0)	13.08 (8.82-18.31)	23.44 (15.89-32.41)	9.74 (6.49-13.51)	80.62 (54.86-111.4)	75.87 (51.54-104.83)	225.98 (153.14-312.65)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	7.01 (5.72-8.5)	0 (0-0)	0 (0-0)	0 (0-0)	7.01 (5.72-8.5)
Kittiwake	74.46 (49.92-103.57)	77.28 (52.44-106.99)	36.84 (24.69-51.44)	10.87 (7.34-15.13)	31.29 (21.07-43.43)	6.97 (4.76-9.6)	3.32 (2.27-4.6)	0 (0-0)	0 (0-0)	3.57 (2.42-4.97)	121.66 (82.69-168.09)	52.56 (35.81-72.17)	418.82 (283.41-579.99)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.21 (0.7-1.87)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.21 (0.7-1.87)
Common Gull	3.09 (1.8-4.79)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.09 (1.8-4.79)
Lesser Black-backed Gull	2.34 (1.52-3.35)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.37 (6.72-14.79)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	12.71 (8.24-18.14)
Herring Gull	4.39 (2.89-6.25)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.39 (2.89-6.25)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	7.65 (4.97-10.92)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.6-1.34)	0 (0-0)	0 (0-0)	0 (0-0)	5.84 (3.78-8.34)	14.42 (9.35-20.6)

Table A3.10. Norfolk Vanguard East (1800 MW). Collision mortality for the 9MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in proportions at collision height (Option 2) only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	1.25 (1.25-1.25)	0.57 (0.57-0.57)	1.33 (1.33-1.33)	0.55 (0.55-0.55)	4.98 (4.98-4.98)	0 (0-0)	0 (0-0)	3.96 (3.96-3.96)	1.72 (1.72-1.72)	0.51 (0.51-0.51)	2.55 (2.55-2.55)	1.96 (1.96-1.96)	19.38 (19.38-19.38)
Gannet	0 (0-0)	2.14 (2.14-2.14)	0 (0-0)	2.79 (2.79-2.79)	0 (0-0)	18.3 (18.3-18.3)	0 (0-0)	13.15 (13.15-13.15)	23.47 (23.47-23.47)	9.69 (9.69-9.69)	80.36 (80.36-80.36)	75.96 (75.96-75.96)	225.86 (225.86-225.86)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	7.02 (7.02-7.02)	0 (0-0)	0 (0-0)	0 (0-0)	7.02 (7.02-7.02)
Kittiwake	74.48 (74.48-74.48)	77.47 (77.47-77.47)	36.84 (36.84-36.84)	10.84 (10.84-10.84)	31.23 (31.23-31.23)	6.94 (6.94-6.94)	3.33 (3.33-3.33)	0 (0-0)	0 (0-0)	3.58 (3.58-3.58)	121.89 (121.89-121.89)	52.41 (52.41-52.41)	419.01 (419.01-419.01)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.22 (1.22-1.22)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.22 (1.22-1.22)
Common Gull	3.08 (3.08-3.08)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.08 (3.08-3.08)
Lesser Black-backed Gull	2.33 (2.33-2.33)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.34 (10.34-10.34)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	12.67 (12.67-12.67)
Herring Gull	4.4 (4.4-4.4)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.4 (4.4-4.4)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	7.64 (7.64-7.64)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.93-0.93)	0 (0-0)	0 (0-0)	0 (0-0)	5.86 (5.86-5.86)	14.43 (14.43-14.43)

Table A3.11. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in nocturnal activity only (mean values for seabird density and mean values for proportions at collision height and avoidance rate).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	1.25 (1.25-1.25)	0.57 (0.57-0.57)	1.33 (1.33-1.33)	0.55 (0.55-0.55)	4.98 (4.98-4.98)	0 (0-0)	0 (0-0)	3.96 (3.96-3.96)	1.72 (1.72-1.72)	0.51 (0.51-0.51)	2.55 (2.55-2.55)	1.96 (1.96-1.96)	19.38 (19.38-19.38)
Gannet	0 (0-0)	1.62 (1.61-1.64)	0 (0-0)	2.44 (2.37-2.55)	0 (0-0)	16.83 (16.58-17.32)	0 (0-0)	11.67 (11.42-12.14)	19.96 (19.35-21.1)	7.59 (7.53-7.67)	58.27 (57.59-59.11)	52.12 (51.35-53.05)	170.5 (167.8-174.58)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	7.02 (7.02-7.02)	0 (0-0)	0 (0-0)	0 (0-0)	7.02 (7.02-7.02)
Kittiwake	50.35 (48.29-52.59)	56.04 (54.2-58.05)	29.38 (27.14-32.05)	9.11 (8.6-9.72)	27.35 (26.2-28.75)	6.2 (5.99-6.46)	2.95 (2.84-3.08)	0 (0-0)	0 (0-0)	2.67 (2.59-2.75)	84.51 (81.31-87.94)	34.62 (33.13-36.27)	303.18 (290.29-317.66)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.22 (1.22-1.22)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.22 (1.22-1.22)
Common Gull	3.08 (3.08-3.08)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.08 (3.08-3.08)
Lesser Black-backed Gull	2.05 (1.76-2.33)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	9.72 (9.11-10.34)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.77 (10.87-12.67)
Herring Gull	3.84 (3.32-4.4)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.84 (3.32-4.4)
Great Black-backed	6.7 (5.77-7.64)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.87 (0.81-0.93)	0 (0-0)	0 (0-0)	0 (0-0)	5.1 (4.35-5.86)	12.67 (10.93-14.43)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Gull													

Table A3.12. Norfolk Vanguard East (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations with no uncertainty in any parameters.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Fulmar	1.25 (1.25-1.25)	0.57 (0.57-0.57)	1.33 (1.33-1.33)	0.55 (0.55-0.55)	4.98 (4.98-4.98)	0 (0-0)	0 (0-0)	3.96 (3.96-3.96)	1.72 (1.72-1.72)	0.51 (0.51-0.51)	2.55 (2.55-2.55)	1.96 (1.96-1.96)	19.38 (19.38-19.38)
Gannet	0 (0-0)	2.14 (2.14-2.14)	0 (0-0)	2.79 (2.79-2.79)	0 (0-0)	18.3 (18.3-18.3)	0 (0-0)	13.15 (13.15-13.15)	23.47 (23.47-23.47)	9.69 (9.69-9.69)	80.36 (80.36-80.36)	75.96 (75.96-75.96)	225.86 (225.86-225.86)
Arctic Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	7.02 (7.02-7.02)	0 (0-0)	0 (0-0)	0 (0-0)	7.02 (7.02-7.02)
Kittiwake	74.48 (74.48-74.48)	77.47 (77.47-77.47)	36.84 (36.84-36.84)	10.84 (10.84-10.84)	31.23 (31.23-31.23)	6.94 (6.94-6.94)	3.33 (3.33-3.33)	0 (0-0)	0 (0-0)	3.58 (3.58-3.58)	121.89 (121.89-121.89)	52.41 (52.41-52.41)	419.01 (419.01-419.01)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.22 (1.22-1.22)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.22 (1.22-1.22)
Common Gull	3.08 (3.08-3.08)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.08 (3.08-3.08)
Lesser Black-backed Gull	2.33 (2.33-2.33)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.34 (10.34-10.34)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	12.67 (12.67-12.67)
Herring Gull	4.4 (4.4-4.4)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.4 (4.4-4.4)
Great Black-backed Gull	7.64 (7.64-7.64)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.93-0.93)	0 (0-0)	0 (0-0)	0 (0-0)	5.86 (5.86-5.86)	14.43 (14.43-14.43)

Table A3.13. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density, proportions at collision height, avoidance rate and nocturnal activity.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	3.67 (0-40.69)	0.82 (0-10.17)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.83 (0-10.07)	5.32 (0-60.93)
Fulmar	0.48 (0-3.79)	0.34 (0-2.42)	0.29 (0-2.33)	0.25 (0-2.82)	0.18 (0-1.19)	0.32 (0-1.47)	0.58 (0-2.24)	1.02 (0-5.61)	0.22 (0-1.49)	3.02 (0-12.29)	0.3 (0-2.31)	0.1 (0-0.07)	7.1 (0-38.03)
Gannet	0.53 (0-3.46)	1.2 (0-4.77)	2.46 (0-11.26)	0 (0-0)	1.07 (0-6.61)	2.12 (0-8.47)	6.24 (0-23.17)	7.52 (0-27.6)	3.09 (0-11.28)	17.66 (0-59.45)	23.18 (7.71-49.29)	0 (0-0)	65.07 (7.71-205.36)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.05 (0-6.71)	0 (0-0)	0 (0-0)	0 (0-0)	1.05 (0-6.71)
Kittiwake	4.3 (0-10.18)	3.11 (0-8.35)	9.53 (0.86-25.36)	3.63 (0-14.81)	4.89 (0-13.16)	17.63 (3.19-40.48)	6.97 (0-25.28)	5.92 (0-14.12)	3.37 (0-12.81)	5.71 (0-15.67)	16.65 (1.97-42.05)	0.62 (0-3.65)	82.33 (6.02-225.92)
Black-headed Gull	0 (0-0)	1.53 (0-8.82)	0.58 (0-4.08)	1.17 (0-7.19)	0 (0-0)	0 (0-0)	0.51 (0-3.68)	0 (0-0)	0 (0-0)	1.75 (0-7.37)	0 (0-0)	0 (0-0)	5.54 (0-31.14)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.89 (0-4.15)	0 (0-0)	1.49 (0-5.74)	0 (0-0)	2.38 (0-9.89)
Common Gull	0 (0-0)	2 (0-10.24)	2.48 (0-12.94)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.01 (0-6.25)	2.38 (0-9.01)	10.39 (0-33.72)	0 (0-0)	18.26 (0-72.16)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0.9 (0-6.15)	0.91 (0-5.91)	0 (0-0)	7.76 (0-24.78)	9.36 (0-32.24)	13.44 (0-40.5)	3.71 (0-16.9)	6.27 (0-23.6)	0 (0-0)	0 (0-0)	42.35 (0-150.08)
Herring Gull	0 (0-0)	0.92 (0-5.59)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.67 (0-6.25)	0 (0-0)	2.59 (0-11.84)
Great Black-backed Gull	3.35 (0-11.25)	7.23 (0-19.51)	1.26 (0-7.9)	0 (0-0)	1.38 (0-8.17)	0 (0-0)	2.91 (0-13.93)	4.13 (0-17.99)	11.01 (0-31.47)	2.27 (0-11.13)	5.16 (0-17.33)	0 (0-0)	38.7 (0-138.68)

Table A3.14. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density only (mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	3.98 (0-9.65)	0.79 (0-4.59)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.82 (0-4.79)	5.59 (0-19.03)
Fulmar	0.48 (0-1.49)	0.34 (0-1.03)	0.29 (0-0.78)	0.29 (0-0.97)	0.21 (0-0.61)	0.31 (0-1.21)	0.42 (0-1.65)	0.91 (0-2.83)	0.18 (0-0.57)	2.23 (0-5.98)	0.33 (0-0.96)	0.09 (0-0.56)	6.08 (0-18.64)
Gannet	0.74 (0-4.61)	1.53 (0-4.57)	2.95 (0-11.35)	0 (0-0)	1.18 (0-6.79)	2.26 (0-6.87)	6.79 (0-20.81)	8.5 (0-25.91)	3.68 (0-11.43)	22.37 (0-55.21)	31.9 (18.45-47.31)	0 (0-0)	81.9 (18.45-194.86)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.05 (0-3.74)	0 (0-0)	0 (0-0)	0 (0-0)	1.05 (0-3.74)
Kittiwake	6.35 (0-14.29)	4.35 (0-10.19)	12.04 (2.01-27.95)	4.27 (0-16.82)	5.65 (0-13.33)	19.81 (4.42-42.01)	7.81 (0-26.99)	6.8 (0-15.11)	4.11 (0-15.38)	7.69 (0-19.41)	23.66 (3.53-49.61)	0.89 (0-5.31)	103.43 (9.96-256.4)
Black-headed Gull	0 (0-0)	1.49 (0-6.14)	0.61 (0-3.61)	1.19 (0-4.92)	0 (0-0)	0 (0-0)	0.51 (0-3.17)	0 (0-0)	0 (0-0)	1.77 (0-4.68)	0 (0-0)	0 (0-0)	5.57 (0-22.52)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.89 (0-2.95)	0 (0-0)	1.51 (0-3.97)	0 (0-0)	2.4 (0-6.92)
Common Gull	0 (0-0)	2.06 (0-10.33)	2.48 (0-12.21)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.04 (0-6.24)	2.37 (0-7.09)	10.5 (0-27.9)	0 (0-0)	18.45 (0-63.77)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0.97 (0-6.06)	0.92 (0-6.16)	0 (0-0)	8.02 (0-20.03)	9.99 (0-26.54)	14.47 (2.17-31.8)	3.99 (0-15.96)	6.91 (0-19.5)	0 (0-0)	0 (0-0)	45.27 (2.17-126.05)
Herring Gull	0 (0-0)	0.99 (0-5.89)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.93 (0-6.13)	0 (0-0)	2.92 (0-12.02)
Great Black-backed Gull	3.74 (0-12.12)	8.14 (0-18.44)	1.32 (0-8.13)	0 (0-0)	1.46 (0-9.05)	0 (0-0)	3.04 (0-12.21)	4.38 (0-17.59)	12.11 (0-27.84)	2.53 (0-10.52)	5.86 (0-19.15)	0 (0-0)	42.58 (0-135.05)

Table A3.15. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in avoidance rate only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	3.23 (2.63-3.88)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.23 (2.63-3.88)
Fulmar	0.37 (0.3-0.45)	0.34 (0.28-0.41)	0.2 (0.16-0.24)	0.2 (0.16-0.24)	0.2 (0.17-0.25)	0 (0-0)	0 (0-0)	0.3 (0.25-0.37)	0.17 (0.14-0.2)	0.96 (0.79-1.16)	0.32 (0.26-0.38)	0 (0-0)	3.06 (2.51-3.7)
Gannet	0 (0-0)	1.52 (1.03-2.12)	0 (0-0)	0 (0-0)	0 (0-0)	2.29 (1.57-3.16)	4.62 (3.14-6.42)	5.55 (3.76-7.68)	3.28 (2.19-4.52)	15.99 (10.82-22.08)	32.28 (21.67-45.01)	0 (0-0)	65.53 (44.18-90.99)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.76-1.12)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.76-1.12)
Kittiwake	5.4 (3.66-7.49)	3.39 (2.31-4.72)	10.05 (6.83-13.88)	0 (0-0)	4.44 (3.02-6.16)	17.64 (11.97-24.51)	0 (0-0)	6.49 (4.38-9.03)	0 (0-0)	5.8 (3.92-8.03)	20.6 (13.96-28.76)	0 (0-0)	73.81 (50.05-102.58)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.17 (0.66-1.8)	0 (0-0)	0 (0-0)	1.17 (0.66-1.8)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.85 (0.49-1.31)	0 (0-0)	1.39 (0.81-2.15)	0 (0-0)	2.24 (1.3-3.46)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.36 (1.35-3.63)	8.58 (4.9-13.41)	0 (0-0)	10.94 (6.25-17.04)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.7 (4.32-9.55)	7.97 (5.16-11.39)	13.04 (8.41-18.66)	0.86 (0.55-1.22)	5.86 (3.78-8.4)	0 (0-0)	0 (0-0)	34.43 (22.22-49.22)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.8 (1.16-2.58)	0 (0-0)	1.8 (1.16-2.58)
Great Black-backed Gull	2.43 (1.58-3.46)	6.95 (4.45-9.86)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.62 (7.56-16.55)	0 (0-0)	4.2 (2.74-6.03)	0 (0-0)	25.2 (16.33-35.9)

Table A3.16. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in proportions at collision height (Option 2) only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	3.55 (0-41.35)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.55 (0-41.35)
Fulmar	0.34 (0-3.84)	0.34 (0-3.86)	0.17 (0-1.62)	0.22 (0-2.62)	0.2 (0-2.41)	0 (0-0)	0 (0-0)	0.33 (0-3.77)	0.18 (0-1.91)	1.09 (0-11.19)	0.34 (0-3.37)	0 (0-0)	3.21 (0-34.59)
Gannet	0 (0-0)	1.52 (0.68-2.69)	0 (0-0)	0 (0-0)	0 (0-0)	2.29 (1.04-4.08)	4.59 (1.94-8.12)	5.57 (2.47-9.79)	3.3 (1.49-5.7)	15.99 (7.04-28.36)	32.29 (13.89-56.97)	0 (0-0)	65.55 (28.55-115.71)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.01-3.99)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.01-3.99)
Kittiwake	5.38 (4.11-6.78)	3.4 (2.58-4.29)	10.05 (7.73-12.68)	0 (0-0)	4.45 (3.36-5.62)	17.71 (13.64-22.47)	0 (0-0)	6.49 (4.96-8.17)	0 (0-0)	5.84 (4.42-7.39)	20.67 (15.82-26.11)	0 (0-0)	73.99 (56.62-93.51)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.16 (0.19-2.8)	0 (0-0)	0 (0-0)	1.16 (0.19-2.8)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.85 (0.15-2.06)	0 (0-0)	1.41 (0.26-3.36)	0 (0-0)	2.26 (0.41-5.42)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.35 (1.53-3.23)	8.56 (5.64-11.97)	0 (0-0)	10.91 (7.17-15.2)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.65 (2.81-11.34)	7.98 (3.49-13.58)	12.87 (5.7-21.92)	0.86 (0.36-1.46)	5.8 (2.51-10.05)	0 (0-0)	0 (0-0)	34.16 (14.87-58.35)
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.8 (1.14-2.55)	0 (0-0)	1.8 (1.14-2.55)
Great Black-backed Gull	2.43 (1.62-3.36)	6.91 (4.55-9.48)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.61 (7.68-15.9)	0 (0-0)	4.23 (2.78-5.78)	0 (0-0)	25.18 (16.63-34.52)

Table A3.17. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in nocturnal activity only (mean values for seabird density and mean values for proportions at collision height and avoidance rate).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	3.23 (3.23-3.23)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.23 (3.23-3.23)
Fulmar	0.37 (0.37-0.37)	0.34 (0.34-0.34)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0 (0-0)	0 (0-0)	0.3 (0.3-0.3)	0.16 (0.16-0.16)	0.97 (0.97-0.97)	0.32 (0.32-0.32)	0 (0-0)	3.06 (3.06-3.06)
Gannet	0 (0-0)	1.15 (1.14-1.17)	0 (0-0)	0 (0-0)	0 (0-0)	2.11 (2.07-2.16)	4.22 (4.15-4.35)	4.95 (4.84-5.15)	2.79 (2.71-2.96)	12.55 (12.44-12.68)	23.42 (23.14-23.75)	0 (0-0)	51.19 (50.49-52.22)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.93-0.93)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.93-0.93)
Kittiwake	3.64 (3.49-3.8)	2.46 (2.38-2.54)	7.99 (7.38-8.71)	0 (0-0)	3.89 (3.73-4.08)	15.81 (15.27-16.49)	0 (0-0)	5.55 (5.27-5.9)	0 (0-0)	4.35 (4.22-4.48)	14.32 (13.78-14.92)	0 (0-0)	58.01 (55.52-60.92)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.17 (1.17-1.17)	0 (0-0)	0 (0-0)	1.17 (1.17-1.17)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.85 (0.85-0.85)	0 (0-0)	1.4 (1.4-1.4)	0 (0-0)	2.25 (2.25-2.25)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.36 (2.36-2.36)	8.58 (8.58-8.58)	0 (0-0)	10.94 (10.94-10.94)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.39 (6.09-6.68)	7.57 (7.2-7.95)	12.24 (11.49-13.04)	0.79 (0.73-0.86)	5.29 (4.72-5.85)	0 (0-0)	0 (0-0)	32.28 (30.23-34.38)
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.59 (1.38-1.8)	0 (0-0)	1.59 (1.38-1.8)
Great Black-backed Gull	2.13 (1.84-2.44)	6.19 (5.47-6.92)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.72 (9.82-11.6)	0 (0-0)	3.71 (3.23-4.21)	0 (0-0)	22.75 (20.36-25.17)

Table A3.18. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 2. Values are the mean and 95% confidence intervals calculated across 5,000 simulations with no uncertainty in any parameters.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	3.23 (3.23-3.23)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	3.23 (3.23-3.23)
Fulmar	0.37 (0.37-0.37)	0.34 (0.34-0.34)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0.2 (0.2-0.2)	0 (0-0)	0 (0-0)	0.3 (0.3-0.3)	0.16 (0.16-0.16)	0.97 (0.97-0.97)	0.32 (0.32-0.32)	0 (0-0)	3.06 (3.06-3.06)
Gannet	0 (0-0)	1.52 (1.52-1.52)	0 (0-0)	0 (0-0)	0 (0-0)	2.29 (2.29-2.29)	4.62 (4.62-4.62)	5.57 (5.57-5.57)	3.29 (3.29-3.29)	16.01 (16.01-16.01)	32.28 (32.28-32.28)	0 (0-0)	65.58 (65.58-65.58)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.93-0.93)	0 (0-0)	0 (0-0)	0 (0-0)	0.93 (0.93-0.93)
Kittiwake	5.38 (5.38-5.38)	3.4 (3.4-3.4)	10.03 (10.03-10.03)	0 (0-0)	4.44 (4.44-4.44)	17.69 (17.69-17.69)	0 (0-0)	6.48 (6.48-6.48)	0 (0-0)	5.82 (5.82-5.82)	20.65 (20.65-20.65)	0 (0-0)	73.89 (73.89-73.89)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.17 (1.17-1.17)	0 (0-0)	0 (0-0)	1.17 (1.17-1.17)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.85 (0.85-0.85)	0 (0-0)	1.4 (1.4-1.4)	0 (0-0)	2.25 (2.25-2.25)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.36 (2.36-2.36)	8.58 (8.58-8.58)	0 (0-0)	10.94 (10.94-10.94)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.68 (6.68-6.68)	7.95 (7.95-7.95)	13.04 (13.04-13.04)	0.86 (0.86-0.86)	5.85 (5.85-5.85)	0 (0-0)	0 (0-0)	34.38 (34.38-34.38)
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.8 (1.8-1.8)	0 (0-0)	1.8 (1.8-1.8)
Great Black-backed Gull	2.44 (2.44-2.44)	6.92 (6.92-6.92)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.6 (11.6-11.6)	0 (0-0)	4.21 (4.21-4.21)	0 (0-0)	25.17 (25.17-25.17)

Table A3.19. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density, proportions at collision height, avoidance rate and nocturnal activity.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	31.92 (0-82.02)	6.49 (0-37.18)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.6 (0-39.27)	45.01 (0-158.47)
Fulmar	13.04 (0-41.08)	9.24 (0-28.87)	7.71 (0-24.53)	7.92 (0-25.11)	5.38 (0-18.14)	7.97 (0-33.55)	11.02 (0-42.88)	24.43 (0-80.65)	4.77 (0-16.27)	60.3 (0-166.48)	8.8 (0-26.34)	2.45 (0-14.56)	163.03 (0-518.46)
Gannet	0.75 (0-4.66)	1.68 (0-5.8)	3.46 (0-14.5)	0 (0-0)	1.54 (0-8.63)	3.01 (0-10.65)	8.83 (0-29.34)	10.66 (0-33.24)	4.36 (0-14.32)	24.9 (0-67.61)	32.98 (16.97-54.46)	0 (0-0)	92.17 (16.97-243.21)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.11 (0-38.67)	0 (0-0)	0 (0-0)	0 (0-0)	11.11 (0-38.67)
Kittiwake	12.47 (0-28.89)	9.03 (0-23.54)	27.51 (2.84-71.15)	10.5 (0-41.54)	14.11 (0-36.84)	51.07 (9.44-114.41)	20.13 (0-70.46)	17.1 (0-39.91)	9.73 (0-35.81)	16.5 (0-44.23)	47.98 (5.98-115.38)	1.78 (0-10.41)	237.91 (18.26-632.57)
Black-headed Gull	0 (0-0)	11.43 (0-51.58)	4.5 (0-27.67)	8.74 (0-42.33)	0 (0-0)	0 (0-0)	3.85 (0-24.04)	0 (0-0)	0 (0-0)	13 (0-43.58)	0 (0-0)	0 (0-0)	41.52 (0-189.2)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.14 (0-4.09)	0 (0-0)	1.9 (0-5.34)	0 (0-0)	3.04 (0-9.43)
Common Gull	0 (0-0)	3.41 (0-16.96)	4.21 (0-21.53)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.72 (0-10.38)	4.04 (0-14.74)	17.64 (0-52.54)	0 (0-0)	31.02 (0-116.15)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	1.32 (0-8.17)	1.32 (0-7.8)	0 (0-0)	11.16 (0-31.37)	13.78 (0-40.8)	19.61 (0-49.29)	5.46 (0-22.75)	9.05 (0-29.57)	0 (0-0)	0 (0-0)	61.7 (0-189.75)
Herring Gull	0 (0-0)	1.27 (0-7.27)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.33 (0-8.6)	0 (0-0)	3.6 (0-15.87)
Great Black-backed Gull	3.22 (0-10.22)	6.93 (0-17.36)	1.23 (0-7.26)	0 (0-0)	1.35 (0-7.92)	0 (0-0)	2.82 (0-13.26)	3.98 (0-16.7)	10.59 (0-28.8)	2.19 (0-10.37)	4.96 (0-16.5)	0 (0-0)	37.27 (0-128.39)

Table A3.20. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in seabird density only (mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	32.36 (0-78.43)	6.46 (0-37.29)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	6.7 (0-38.9)	45.52 (0-154.62)
Fulmar	13.06 (0-40.32)	9.27 (0-27.73)	7.87 (0-21.18)	7.88 (0-26.06)	5.58 (0-16.59)	8.24 (0-32.56)	11.22 (0-44.42)	24.53 (0-76.32)	4.81 (0-15.46)	60.25 (0-161.44)	8.87 (0-25.85)	2.43 (0-15.06)	164.01 (0-502.99)
Gannet	1.04 (0-6.53)	2.17 (0-6.47)	4.17 (0-16.06)	0 (0-0)	1.66 (0-9.6)	3.2 (0-9.72)	9.61 (0-29.45)	12.03 (0-36.67)	5.2 (0-16.18)	31.65 (0-78.13)	45.15 (26.11-66.95)	0 (0-0)	115.88 (26.11-275.76)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.25 (0-40.17)	0 (0-0)	0 (0-0)	0 (0-0)	11.25 (0-40.17)
Kittiwake	18.38 (0-41.33)	12.59 (0-29.48)	34.83 (5.8-80.85)	12.36 (0-48.66)	16.35 (0-38.56)	57.31 (12.79-121.53)	22.6 (0-78.07)	19.68 (0-43.73)	11.9 (0-44.5)	22.24 (0-56.17)	68.46 (10.2-143.52)	2.56 (0-15.37)	299.26 (28.79-741.77)
Black-headed Gull	0 (0-0)	11.16 (0-45.84)	4.56 (0-26.94)	8.89 (0-36.7)	0 (0-0)	0 (0-0)	3.78 (0-23.68)	0 (0-0)	0 (0-0)	13.19 (0-34.94)	0 (0-0)	0 (0-0)	41.58 (0-168.1)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.11 (0-3.71)	0 (0-0)	1.9 (0-4.98)	0 (0-0)	3.01 (0-8.69)
Common Gull	0 (0-0)	3.51 (0-17.59)	4.23 (0-20.79)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.77 (0-10.62)	4.04 (0-12.07)	17.88 (0-47.49)	0 (0-0)	31.43 (0-108.56)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	1.42 (0-8.86)	1.35 (0-9.01)	0 (0-0)	11.72 (0-29.29)	14.61 (0-38.8)	21.15 (3.18-46.49)	5.84 (0-23.33)	10.1 (0-28.51)	0 (0-0)	0 (0-0)	66.19 (3.18-184.29)
Herring Gull	0 (0-0)	1.38 (0-8.2)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.68 (0-8.54)	0 (0-0)	4.06 (0-16.74)
Great Black-backed Gull	3.6 (0-11.66)	7.83 (0-17.74)	1.27 (0-7.82)	0 (0-0)	1.4 (0-8.7)	0 (0-0)	2.92 (0-11.75)	4.21 (0-16.92)	11.65 (0-26.78)	2.43 (0-10.12)	5.64 (0-18.42)	0 (0-0)	40.95 (0-129.91)

Table A3.21. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in avoidance rate only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	26.27 (21.35-31.56)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	26.27 (21.35-31.56)
Fulmar	10.08 (8.2-12.14)	9.24 (7.55-11.16)	5.29 (4.31-6.36)	5.36 (4.36-6.45)	5.48 (4.45-6.62)	0 (0-0)	0 (0-0)	8.2 (6.67-9.9)	4.46 (3.66-5.36)	26.01 (21.19-31.18)	8.63 (7.01-10.33)	0 (0-0)	82.75 (67.4-99.5)
Gannet	0 (0-0)	2.15 (1.46-2.99)	0 (0-0)	0 (0-0)	0 (0-0)	3.24 (2.22-4.47)	6.54 (4.45-9.08)	7.85 (5.32-10.86)	4.64 (3.1-6.4)	22.63 (15.32-31.25)	45.69 (30.67-63.7)	0 (0-0)	92.74 (62.54-128.75)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.01 (8.18-12.01)	0 (0-0)	0 (0-0)	0 (0-0)	10.01 (8.18-12.01)
Kittiwake	15.62 (10.58-21.66)	9.8 (6.68-13.65)	29.07 (19.77-40.16)	0 (0-0)	12.86 (8.75-17.82)	51.05 (34.63-70.91)	0 (0-0)	18.79 (12.66-26.11)	0 (0-0)	16.79 (11.34-23.23)	59.59 (40.38-83.2)	0 (0-0)	213.57 (144.79-296.74)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	8.72 (4.94-13.44)	0 (0-0)	0 (0-0)	8.72 (4.94-13.44)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.07 (0.61-1.65)	0 (0-0)	1.75 (1.02-2.7)	0 (0-0)	2.82 (1.63-4.35)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.02 (2.29-6.18)	14.62 (8.34-22.84)	0 (0-0)	18.64 (10.63-29.02)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	9.8 (6.31-13.96)	11.65 (7.55-16.65)	19.06 (12.29-27.29)	1.25 (0.8-1.78)	8.56 (5.52-12.28)	0 (0-0)	0 (0-0)	50.32 (32.47-71.96)
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.51 (1.62-3.59)	0 (0-0)	2.51 (1.62-3.59)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	2.33 (1.52-3.33)	6.68 (4.28-9.48)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.17 (7.27-15.92)	0 (0-0)	4.04 (2.64-5.8)	0 (0-0)	24.22 (15.71-34.53)

Table A3.22. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in proportions at collision height (Option 2) only (mean values for seabird density and mean values for proportions at collision height, avoidance rate and nocturnal activity).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	26.27 (26.27-26.27)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	26.27 (26.27-26.27)
Fulmar	10.08 (10.08-10.08)	9.24 (9.24-9.24)	5.29 (5.29-5.29)	5.37 (5.37-5.37)	5.49 (5.49-5.49)	0 (0-0)	0 (0-0)	8.18 (8.18-8.18)	4.45 (4.45-4.45)	26.04 (26.04-26.04)	8.62 (8.62-8.62)	0 (0-0)	82.76 (82.76-82.76)
Gannet	0 (0-0)	2.15 (2.15-2.15)	0 (0-0)	0 (0-0)	0 (0-0)	3.24 (3.24-3.24)	6.54 (6.54-6.54)	7.89 (7.89-7.89)	4.65 (4.65-4.65)	22.66 (22.66-22.66)	45.69 (45.69-45.69)	0 (0-0)	92.82 (92.82-92.82)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.04 (10.04-10.04)	0 (0-0)	0 (0-0)	0 (0-0)	10.04 (10.04-10.04)
Kittiwake	15.58 (15.58-15.58)	9.83 (9.83-9.83)	29.02 (29.02-29.02)	0 (0-0)	12.85 (12.85-12.85)	51.17 (51.17-51.17)	0 (0-0)	18.74 (18.74-18.74)	0 (0-0)	16.85 (16.85-16.85)	59.76 (59.76-59.76)	0 (0-0)	213.8 (213.8-213.8)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	8.73 (8.73-8.73)	0 (0-0)	0 (0-0)	8.73 (8.73-8.73)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.07 (1.07-1.07)	0 (0-0)	1.75 (1.75-1.75)	0 (0-0)	2.82 (2.82-2.82)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.01 (4.01-4.01)	14.61 (14.61-14.61)	0 (0-0)	18.62 (18.62-18.62)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	9.76 (9.76-9.76)	11.62 (11.62-11.62)	19.07 (19.07-19.07)	1.26 (1.26-1.26)	8.55 (8.55-8.55)	0 (0-0)	0 (0-0)	50.26 (50.26-50.26)
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.5 (2.5-2.5)	0 (0-0)	2.5 (2.5-2.5)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	2.34 (2.34-2.34)	6.65 (6.65-6.65)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.16 (11.16-11.16)	0 (0-0)	4.05 (4.05-4.05)	0 (0-0)	24.2 (24.2-24.2)

Table A3.23. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations incorporating uncertainty in nocturnal activity only (mean values for seabird density and mean values for proportions at collision height and avoidance rate).

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	26.27 (26.27-26.27)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	26.27 (26.27-26.27)
Fulmar	10.08 (10.08-10.08)	9.24 (9.24-9.24)	5.29 (5.29-5.29)	5.37 (5.37-5.37)	5.49 (5.49-5.49)	0 (0-0)	0 (0-0)	8.18 (8.18-8.18)	4.45 (4.45-4.45)	26.04 (26.04-26.04)	8.62 (8.62-8.62)	0 (0-0)	82.76 (82.76-82.76)
Gannet	0 (0-0)	1.63 (1.62-1.65)	0 (0-0)	0 (0-0)	0 (0-0)	2.98 (2.93-3.06)	5.98 (5.88-6.16)	7 (6.85-7.28)	3.95 (3.83-4.18)	17.76 (17.6-17.94)	33.14 (32.74-33.61)	0 (0-0)	72.44 (71.45-73.88)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.04 (10.04-10.04)	0 (0-0)	0 (0-0)	0 (0-0)	10.04 (10.04-10.04)
Kittiwake	10.53 (10.09-10.99)	7.11 (6.88-7.36)	23.11 (21.37-25.21)	0 (0-0)	11.26 (10.78-11.81)	45.74 (44.17-47.7)	0 (0-0)	16.06 (15.26-17.06)	0 (0-0)	12.57 (12.2-12.96)	41.43 (39.86-43.17)	0 (0-0)	167.81 (160.61-176.26)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	8.73 (8.73-8.73)	0 (0-0)	0 (0-0)	8.73 (8.73-8.73)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.07 (1.07-1.07)	0 (0-0)	1.75 (1.75-1.75)	0 (0-0)	2.82 (2.82-2.82)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.01 (4.01-4.01)	14.61 (14.61-14.61)	0 (0-0)	18.62 (18.62-18.62)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	9.34 (8.9-9.76)	11.07 (10.52-11.62)	17.89 (16.79-19.07)	1.16 (1.06-1.26)	7.73 (6.91-8.55)	0 (0-0)	0 (0-0)	47.19 (44.18-50.26)
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.21 (1.92-2.5)	0 (0-0)	2.21 (1.92-2.5)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	2.05 (1.77-2.34)	5.96 (5.26-6.65)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.32 (9.45-11.16)	0 (0-0)	3.57 (3.11-4.05)	0 (0-0)	21.9 (19.59-24.2)

Table A3.24. Norfolk Vanguard West (1800 MW). Collision mortality for the 9 MW turbine calculated using Band CRM Option 1. Values are the mean and 95% confidence intervals calculated across 5,000 simulations with no uncertainty in any parameters.

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Red-throated Diver	26.27 (26.27-26.27)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	26.27 (26.27-26.27)
Fulmar	10.08 (10.08-10.08)	9.24 (9.24-9.24)	5.29 (5.29-5.29)	5.37 (5.37-5.37)	5.49 (5.49-5.49)	0 (0-0)	0 (0-0)	8.18 (8.18-8.18)	4.45 (4.45-4.45)	26.04 (26.04-26.04)	8.62 (8.62-8.62)	0 (0-0)	82.76 (82.76-82.76)
Gannet	0 (0-0)	2.15 (2.15-2.15)	0 (0-0)	0 (0-0)	0 (0-0)	3.24 (3.24-3.24)	6.54 (6.54-6.54)	7.89 (7.89-7.89)	4.65 (4.65-4.65)	22.66 (22.66-22.66)	45.69 (45.69-45.69)	0 (0-0)	92.82 (92.82-92.82)
Great Skua	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	10.04 (10.04-10.04)	0 (0-0)	0 (0-0)	0 (0-0)	10.04 (10.04-10.04)
Kittiwake	15.58 (15.58-15.58)	9.83 (9.83-9.83)	29.02 (29.02-29.02)	0 (0-0)	12.85 (12.85-12.85)	51.17 (51.17-51.17)	0 (0-0)	18.74 (18.74-18.74)	0 (0-0)	16.85 (16.85-16.85)	59.76 (59.76-59.76)	0 (0-0)	213.8 (213.8-213.8)
Black-headed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	8.73 (8.73-8.73)	0 (0-0)	0 (0-0)	8.73 (8.73-8.73)
Little Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.07 (1.07-1.07)	0 (0-0)	1.75 (1.75-1.75)	0 (0-0)	2.82 (2.82-2.82)
Common Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	4.01 (4.01-4.01)	14.61 (14.61-14.61)	0 (0-0)	18.62 (18.62-18.62)
Lesser Black-backed Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	9.76 (9.76-9.76)	11.62 (11.62-11.62)	19.07 (19.07-19.07)	1.26 (1.26-1.26)	8.55 (8.55-8.55)	0 (0-0)	0 (0-0)	50.26 (50.26-50.26)
Herring Gull	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	2.5 (2.5-2.5)	0 (0-0)	2.5 (2.5-2.5)

Species	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Great Black-backed Gull	2.34 (2.34-2.34)	6.65 (6.65-6.65)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	11.16 (11.16-11.16)	0 (0-0)	4.05 (4.05-4.05)	0 (0-0)	24.2 (24.2-24.2)

Annex 4. Deterministic tables of CRM with lower and upper parameter estimates

Table A4.1. Norfolk Vanguard East gannet CRM deterministic outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (10.22%, 4.66%, 17.25% respectively), mean and 95% confidence intervals for avoidance rates (98.9% +/-0.2) and nocturnal activity of 25%, 0% (all year round) and 8% (breeding season) and 3% (nonbreeding season) as recommended in Furness et al. (2018).

Density	**PCH (%)**	**AR (%)**	**NAF (%)**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Median	10.22	98.9	25	0	1.55	0	2.02	0	13.24	0	9.52	16.98	7.01	58.14	54.96	163.42
Mean	10.22	98.9	25	1.61	1.92	1.5	2.05	3.64	18	0.92	9.81	14.07	9.43	106.31	42.14	211.40
Lwr95	10.22	98.9	25	0	0	0	0	0	0	0	0	0	1.37	33.74	0	35.11
Upr95	10.22	98.9	25	6.82	7.74	5.67	8.07	14.55	49.9	5.49	22.11	33.97	26.32	251.37	81.49	513.50
Median	4.66	98.9	25	0	0.71	0	0.92	0	6.04	0	4.34	7.75	3.2	26.52	25.07	74.55
Median	17.25	98.9	25	0	2.62	0	3.41	0	22.36	0	16.08	28.67	11.84	98.18	92.81	275.97
Median	10.22	99.1	25	0	1.27	0	1.65	0	10.83	0	7.79	13.89	5.74	47.57	44.97	133.71
Median	10.22	98.7	25	0	1.83	0	2.39	0	15.65	0	11.25	20.07	8.28	68.71	64.95	193.13
Median	10.22	98.9	BS 8% / NBS 3%	0	1.19	0	1.81	0	12.35	0	8.63	14.89	5.55	42.81	38.46	125.69
Median	10.22	98.9	0	0	1.14	0	1.71	0	11.96	0	8.23	13.91	5.34	40.53	35.92	118.74

Table A4.2 Norfolk Vanguard East kittiwake CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (12.36%, 9.32%, 14.72% respectively), mean and 95% confidence intervals for avoidance rates (98.9% +/-0.2) and nocturnal activity of 50% and 25% (all year round).

Density	PCH (%)	AR (%)	NAF (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Median	12.36	98.9	50	39.78	41.37	19.67	5.79	16.68	3.71	1.78	0	0	1.91	65.1	27.99	223.78
Mean	12.36	98.9	50	105.36	44.65	60.22	29.98	26.73	4.98	2.6	1.59	1.73	5.1	53.88	39.28	376.10
Lwr95	12.36	98.9	50	19.89	10.58	0	0	2.38	0	0	0	0	0	0	7.87	40.72
Upr95	12.36	98.9	50	279.25	90.51	184.57	98.38	69.48	18.53	10.25	9.52	7.06	21.04	110.8	92.07	991.46
Median	9.32	98.9	50	30	31.19	14.83	4.37	12.58	2.8	1.34	0	0	1.44	49.09	21.11	168.75
Median	14.72	98.9	50	47.38	49.27	23.43	6.9	19.86	4.42	2.12	0	0	2.27	77.53	33.33	266.51
Median	12.36	99.1	50	32.55	33.85	16.09	4.74	13.65	3.04	1.46	0	0	1.56	53.26	22.9	183.10
Median	12.36	98.9	50	47.01	48.89	23.25	6.84	19.71	4.38	2.1	0	0	2.26	76.94	33.08	264.46
Median	12.36	98.9	25	30.01	32.69	16.33	5.02	14.96	3.38	1.61	0	0	1.54	49.96	20.79	176.29

Table A4.3 Norfolk Vanguard East lesser black-backed gull CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (24.85%, 17.14%, 40.84% respectively), mean and 95% confidence intervals for avoidance rates (99.5% +/-0.1) and nocturnal activity of 50% and 25% (all year round).

Density	**PCH**	**AR**	**NAF**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Median	24.85	99.5	50	2	0	0	0	0	0	0	8.9	0	0	0	0	10.90
Mean	24.85	99.5	50	4.3	1.16	0.86	1.41	0	0	1.79	10.5	0	0.5	1.74	1.51	23.77
Lwr95	24.85	99.5	50	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Upr95	24.85	99.5	50	15.87	6.94	7.71	6.53	0	0	8.96	28.94	0	4.51	7.08	9.04	95.58
Median	17.14	99.5	50	1.38	0	0	0	0	0	0	6.14	0	0	0	0	7.52
Median	40.84	99.5	50	3.29	0	0	0	0	0	0	14.63	0	0	0	0	17.92
Median	24.85	99.6	50	1.6	0	0	0	0	0	0	7.12	0	0	0	0	8.72
Median	24.85	99.4	50	2.4	0	0	0	0	0	0	10.68	0	0	0	0	13.08
Median	24.85	99.5	25	1.51	0	0	0	0	0	0	7.84	0	0	0	0	9.35

Table A4.4 Norfolk Vanguard East herring gull CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (28.53%, 21.6%, 40.03% respectively), mean and 95% confidence intervals for avoidance rates (99.5% +/-0.1) and nocturnal activity of 50% and 25% (all year round).

Density	**PCH**	**AR**	**NAF**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Median	28.53	99.5	50	6.92	0	0	0	0	0	0	0	0	0	0	0	6.92
Mean	28.53	99.5	50	34.5	0	0.99	1.54	0	0	0	0	0	0	2.72	2.28	42.03
Lwr95	28.53	99.5	50	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Upr95	28.53	99.5	50	120.09	0	8.88	7.13	0	0	0	0	0	0	14.27	13.69	164.06
Median	21.6	99.5	50	5.24	0	0	0	0	0	0	0	0	0	0	0	5.24
Median	40.03	99.5	50	9.71	0	0	0	0	0	0	0	0	0	0	0	9.71
Median	28.53	99.6	50	5.54	0	0	0	0	0	0	0	0	0	0	0	5.54
Median	28.53	99.4	50	8.3	0	0	0	0	0	0	0	0	0	0	0	8.30
Median	28.53	99.5	25	5.22	0	0	0	0	0	0	0	0	0	0	0	5.22

Table A4.5 Norfolk Vanguard East great black-backed gull CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (29.11%, 24.68%, 41.96% respectively), mean and 95% confidence intervals for avoidance rates (99.5% +/-0.1) and nocturnal activity of 50% and 25% (all year round).

Density	PCH (%)	AR (%)	NAF (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Median	29.11	99.5	50	12.4	0	0	0	0	0	0	1.5	0	0	0	9.5	23.40
Mean	29.11	99.5	50	83.39	1.56	0.91	1.95	0	0	0	15.01	0	0	7.16	11.24	121.22
Lwr95	29.11	99.5	50	2.52	0	0	0	0	0	0	0	0	0	0	0	2.52
Upr95	29.11	99.5	50	269.07	9.36	8.17	11.73	0	0	0	48.03	0	0	33.43	30.49	410.28
Median	24.68	99.5	50	10.51	0	0	0	0	0	0	1.27	0	0	0	8.05	19.83
Median	41.96	99.5	50	17.87	0	0	0	0	0	0	2.16	0	0	0	13.69	33.72
Median	29.11	99.6	50	9.92	0	0	0	0	0	0	1.2	0	0	0	7.6	18.72
Median	29.11	99.4	50	14.88	0	0	0	0	0	0	1.8	0	0	0	11.4	28.08
Median	29.11	99.5	25	9.36	0	0	0	0	0	0	1.32	0	0	0	7.06	17.74

Table A4.6. Norfolk Vanguard West gannet CRM deterministic outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (10.22%, 4.66%, 17.25% respectively), mean and 95% confidence intervals for avoidance rates (98.9% +/-0.2) and nocturnal activity of 25%, 0% (all year round) and 8% (breeding season) and 3% (nonbreeding season) as recommended in Furness et al. (2018).

Density	PCH (%)	AR (%)	NAF (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Median	10.22	98.9	25	0	1.52	0	0	0	2.29	4.62	5.57	3.29	16.01	32.28	0	65.58
Mean	10.22	98.9	25	0.74	1.52	2.93	0	1.18	2.29	6.78	8.41	3.66	22.34	31.93	0	81.78
Lwr95	10.22	98.9	25	0	0	0	0	0	0	0	0	0	0	18.45	0	18.45
Upr95	10.22	98.9	25	4.61	4.57	11.35	0	6.79	6.87	20.81	25.91	11.43	55.21	47.31	0	194.86
Median	4.66	98.9	25	0	0.69	0	0	0	1.04	2.11	2.54	1.5	7.3	14.73	0	29.91
Median	17.25	98.9	25	0	2.57	0	0	0	3.87	7.8	9.41	5.56	27.04	54.51	0	110.76
Median	10.22	99.1	25	0	1.24	0	0	0	1.87	3.78	4.56	2.69	13.1	26.41	0	53.65
Median	10.22	98.7	25	0	1.8	0	0	0	2.71	5.46	6.58	3.89	18.92	38.15	0	77.51
Median	10.22	98.9	BS 8% / NBS 3%	0	1.12	0	0	0	2.07	4.14	4.82	2.69	12.2	22.5	0	49.54
Median	10.22	98.9	0	0	1.17	0	0	0	2.14	4.29	5.06	2.89	12.65	23.68	0	51.88

Table A4.7 Norfolk Vanguard West kittiwake CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (12.36%, 9.32%, 14.72% respectively), mean and 95% confidence intervals for avoidance rates (98.9% +/-0.2) and nocturnal activity of 50% and 25% (all year round).

Density	PCH (%)	AR (%)	NAF (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Median	12.36	98.9	50	5.38	3.4	10.03	0	4.44	17.69	0	6.48	0	5.82	20.65	0	73.89
Mean	12.36	98.9	50	6.35	4.33	11.98	4.27	5.66	19.71	7.87	6.88	4.23	7.7	23.1	0.9	102.98
Lwr95	12.36	98.9	50	0	0	2.01	0	0	4.42	0	0	0	0	3.53	0	9.96
Upr95	12.36	98.9	50	14.29	10.19	27.95	16.82	13.33	42.01	26.99	15.11	15.38	19.41	49.61	5.31	256.40
Median	9.32	98.9	50	4.06	2.56	7.56	0	3.35	13.34	0	4.89	0	4.39	15.57	0	55.72
Median	14.72	98.9	50	6.41	4.05	11.95	0	5.29	21.07	0	7.72	0	6.93	24.59	0	88.01
Median	12.36	99.1	50	4.4	2.78	8.21	0	3.63	14.47	0	5.3	0	4.76	16.9	0	60.45
Median	12.36	98.9	50	6.36	4.02	11.85	0	5.25	20.91	0	7.66	0	6.88	24.4	0	87.33
Median	12.36	98.9	25	4.06	2.69	8.33	0	3.98	16.13	0	5.71	0	4.7	15.85	0	61.45

Table A4.8 Norfolk Vanguard West lesser black-backed gull CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (24.85%, 17.14%, 40.84% respectively), mean and 95% confidence intervals for avoidance rates (99.5% +/-0.1) and nocturnal activity of 50% and 25% (all year round).

Density	PCH	AR	NAF	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Median	24.85	99.5	50	0	0	0	0	0	6.68	7.95	13.04	0.86	5.85	0	0	34.38
Mean	24.85	99.5	50	0	0	0.99	0.96	0	7.99	10.02	14.35	2.91	6.89	0	0	44.11
Lwr95	24.85	99.5	50	0	0	0	0	0	0	0	2.17	0	0	0	0	2.17
Upr95	24.85	99.5	50	0	0	6.06	6.16	0	20.03	26.54	31.8	15.96	19.5	0	0	126.05
Median	17.14	99.5	50	0	0	0	0	0	4.61	5.48	8.99	0.59	4.03	0	0	23.70
Median	40.84	99.5	50	0	0	0	0	0	10.98	13.07	21.43	1.41	9.61	0	0	56.50
Median	24.85	99.6	50	0	0	0	0	0	5.34	6.36	10.43	0.69	4.68	0	0	27.50
Median	24.85	99.4	50	0	0	0	0	0	8.02	9.54	15.65	1.03	7.02	0	0	41.26
Median	24.85	99.5	25	0	0	0	0	0	6.09	7.2	11.48	0.73	4.72	0	0	30.22

Table A4.9 Norfolk Vanguard West herring gull CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (28.53%, 21.6%, 40.03% respectively), mean and 95% confidence intervals for avoidance rates (99.5% +/-0.1) and nocturnal activity of 50% and 25% (all year round).

Density	**PCH**	**AR**	**NAF**	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Median	28.53	99.5	50	0	0	0	0	0	0	0	0	0	0	1.8	0	1.80
Mean	28.53	99.5	50	0	0.99	0	0	0	0	0	0	0	0	1.91	0	2.90
Lwr95	28.53	99.5	50	0	0	0	0	0	0	0	0	0	0	0	0	0.00
Upr95	28.53	99.5	50	0	5.89	0	0	0	0	0	0	0	0	6.13	0	12.02
Median	21.6	99.5	50	0	0	0	0	0	0	0	0	0	0	1.36	0	1.36
Median	40.03	99.5	50	0	0	0	0	0	0	0	0	0	0	2.53	0	2.53
Median	28.53	99.6	50	0	0	0	0	0	0	0	0	0	0	1.44	0	1.44
Median	28.53	99.4	50	0	0	0	0	0	0	0	0	0	0	2.16	0	2.16
Median	28.53	99.5	25	0	0	0	0	0	0	0	0	0	0	1.38	0	1.38

Table A4.10 Norfolk Vanguard West great black-backed gull CRM outputs calculated using median, mean and 95% confidence intervals of density, mean and 95% confidence intervals for PCH (29.11%, 24.68%, 41.96% respectively), mean and 95% confidence intervals for avoidance rates (99.5% +/-0.1) and nocturnal activity of 50% and 25% (all year round).

Density	PCH (%)	AR (%)	NAF (%)	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Median	29.11	99.5	50	2.44	6.92	0	0	0	0	0	0	11.6	0	4.21	0	25.17
Mean	29.11	99.5	50	3.79	8.04	1.34	0	1.47	0	3.05	4.41	12	2.58	6.6	0	43.28
Lwr95	29.11	99.5	50	0	0	0	0	0	0	0	0	0.74	0	0	0	0.74
Upr95	29.11	99.5	50	12.12	18.44	8.13	0	9.05	0	12.21	17.59	27.84	10.52	19.15	0	135.05
Median	24.68	99.5	50	2.07	5.87	0	0	0	0	0	0	9.83	0	3.57	0	21.34
Median	41.96	99.5	50	3.52	9.97	0	0	0	0	0	0	16.72	0	6.07	0	36.28
Median	29.11	99.6	50	1.95	5.54	0	0	0	0	0	0	9.28	0	3.37	0	20.14
Median	29.11	99.4	50	2.93	8.3	0	0	0	0	0	0	13.92	0	5.05	0	30.20
Median	29.11	99.5	25	1.84	5.47	0	0	0	0	0	0	9.82	0	3.23	0	20.36

Annex 5. Natural England Commissioned Report NECR237.

Natural England Commissioned Report NECR237

Offshore wind farms and birds: incorporating uncertainty in collision risk models: a test of Masden (2015)

First published 28 September 2017

www.gov.uk/natural-england

Foreword

Natural England commission a range of reports from external contractors to provide evidence and advice to assist us in delivering our duties. The views in this report are those of the authors and do not necessarily represent those of Natural England.

Background

Operational offshore wind farms are known to have a number of potential impacts on birds and these include mortality from collision with turbine blades and ancillary structures (moving and stationary). Offshore windfarm developers routinely use collision risk models (CRMs) to assess this potential impact on birds when undertaking environmental impact assessments. In the UK, for offshore windfarms, the most frequently used avian collision risk model is the Band model (Band 2012).

The Band (2012) model requires a number of input parameters, including information on the density of birds in the windfarm area, bird avoidance rates, flight speed, flight height and size information for the bird species involved and various turbine parameters like rotor diameter, pitch and operational time. All of these input parameters have variability and uncertainty associated with them and since the predicted collision risk from the Band model is sensitive to the input parameters, variability in the input parameters can have a significant effect on predicted collision risk.

However, consideration of this variability in the key input parameters is not routinely included when collision risk modelling is undertaken as part of the Environmental Impact Assessment (EIA) process, and uncertainty/variability around the collision predictions is rarely presented in environmental statements from offshore windfarm (OWF) developers.

For these reasons a project was undertaken to develop the Band (2012) model using a simulation approach to incorporate variability and uncertainty in the collision risk modelling process. The output of this project was the development of a stochastic version of the Band (2012) collision risk model (Masden 2015) which allows variability around input parameters to be entered in the model and used to calculate a distribution of collision risk estimates which reflects the variability in the input parameters.

Natural England, as part of its statutory advice responsibilities in relation to Nationally Significant Infrastructure Projects (NSIPs) in the offshore environment, would like developers to take account of variability and uncertainty in their assessment of potential collision impacts, and the stochastic version of the Band model developed by Masden (2015) offers a means of doing that. However, there has been limited testing of the application of this stochastic version of the Band model to datasets typically used by developers for collision risk modelling. Therefore Natural England commissioned this project to review and test the stochastic version of the model to determine the best way to parameterise the model using data available from EIAs, and to compare outputs derived from the stochastic version of the model against those generated by the Band (2012) model.

Natural England will use the results of this project to inform our advice to offshore windfarm developers and the Planning Inspectorate regarding the assessment and significance of potential collision impacts to birds as part of the Environmental Impact Assessment (EIA) and Habitats Regulations Assessment (HRA) processes.

The results of this Natural England project will also be used in a project commissioned by Marine Scotland that is developing an updated version of the stochastic Band model that builds on the work undertaken to date and will address the gaps and issues identified in the current version by industry and statutory agencies..

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Key words – Nationally Significant Infrastructure Project (NSIP), Habitats Regulations, HRA, Environmental Impact Assessment, EIA, marine, seabird, collision risk modelling, CRM, Band model, uncertainty, stochastic modelling, offshore renewables, development planning, sustainable development, marine casework

Further information
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Incorporating Uncertainty in Collision Risk Models: a test of Masden (2015)

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CONTENTS

1 INTRODUCTION

Natural England would like offshore wind farm developers to be able to present robust collision mortality estimates for birds which reflect parameter uncertainty.

Offshore windfarm developers routinely use collision risk models (CRMs) to assess the potential impacts of wind turbines on birds when undertaking environmental impact assessments. In the UK, the most frequently used avian collision risk model is the Band model (Band 2000, Band et al. 2007), which was subsequently updated to be applicable to the offshore environment for a Strategic Ornithological Support Services (SOSS) project (Band 2012).

The Band (2012) model requires a number of input parameters, including information on the density of birds in the windfarm area, bird avoidance rates, flight speed, flight height and size information for the bird species involved and various turbine parameters like rotor diameter, pitch and operational time. All of these input parameters have variability and uncertainty associated with them and since the predicted collision risk from the Band model is sensitive to the input parameters, variability in the input parameter can have a significant effect on predicted collision risk.

To address this issue, the Band (2012) update of the model includes guidance about how to express uncertainty around the model input parameters when reporting a predicted collision risk. However, this approach is relatively simplistic and is only statistically valid when the sources of variability are independent of one another (Masden 2015). Furthermore, as the approach to considering uncertainty is not an intrinsic part of the modelling process, it is not routinely followed when collision risk modelling is undertaken as part of the EIA process, and uncertainty/variability around the collision predictions is rarely presented in environmental statements from offshore windfarm (OWF) developers.

For these reasons, a stochastic version of the (deterministic) Band (2012) Collision Risk Model (CRM) for birds was developed by Masden (2015). This simulation based model (hereafter referred to as 'the Masden model') was implemented in the R programming environment and used by Masden (2015) to investigate the magnitude of variation in mortality estimates obtained using realistic levels of parameter variance and to perform a sensitivity analysis.

Natural England is interested to understand how the Masden model operates and if it can be parameterised and run using the format of data typically available in reporting for offshore wind farm assessments. The aim of the current project was to review, test and set out options for incorporating variability and uncertainty in CRM input parameters into the Masden (2015) collision risk model update in a statistically and ecologically appropriate way and to compare outputs from the Masden (2015) model with those derived using the Band (2012) model.

This has included consideration of the way in which parameters are inputted to the Masden model and an investigation of methods for quantifying the variability and/or uncertainty around the input parameters. For the purposes of this review only Band model Option 1 results have been compared.

2 ESTIMATING COLLISION MODEL INPUT PARAMETERS FROM SURVEY DATA

The following section provides an overview of data analysis methods which are appropriate for generating robust input parameters for stochastic collision modelling. The methods proposed are based on an understanding of the type of data most likely to be collected (e.g. repeat samples providing a sequence of counts). Alternative methods may also be suitable, however a key factor of relevance to the current project is that under most circumstances the survey data are very unlikely to be well suited to statistical methods based on the normal distribution.

Density of flying birds

Observations of seabirds in flight at a wind farm site are collected using a form of snapshot sampling (the data are conceptually very similar for either boat or digital aerial survey methods). Count data should be analysed using an appropriate method, such as a Generalized Linear Model (GLM) or a General Additive Model (GAM; if spatial covariates are to be included) with a Poisson error structure (ideally, the method should also allow for over-dispersion, with options to use quasi-Poisson errors). Categorical explanatory variables can be used (e.g. month, year, season or survey ID) to obtain density estimates with an appropriate temporal scale (omitting an intercept term makes the outputs simpler to interpret as a single coefficient is produced for each period specified in the model). If spatial covariates such as distance to coast and sea depth are available a GAM type of model can be used. These may also be structured to account for auto-correlation (using modelling approaches such as MRSea developed by the Centre for Research in Ecological and Environmental Modelling[1]).

Most recent wind farm assessments (e.g. Forewind 2013, SmartWind 2015) have undertaken modelling using methods similar to those described above, although in the past a more basic method of density estimation was often applied, with the total number of individuals observed during a survey divided by the total area of snapshot samples. The advantage of the modelling approach is that the results include measures of parameter uncertainty (e.g. SE and confidence intervals), which are lacking from the simple approach. These are informative in their own right, but also enable subsequent assessment to explicitly consider uncertainty.

Offshore wind farm baseline surveys to inform environmental impact assessments for birds are typically conducted each month for a period of two years. Thus, there will be two density estimates available for calculating collision risk in each month. The common currencies when discussing collisions are the estimate for each month and the annual total predicted collisions. To obtain these, the number of collisions can either be calculated for each monthly survey separately and then averaged by month across the two years, or the average monthly density of birds across the two years can be estimated as a first step from which a single monthly collision is estimated. While averaging means is straightforward, it is less simple to combine estimates which include uncertainty. The simplest solution is to avoid the need to do this by fitting a GLM (or similar) to the counts with month as an explanatory variable, but not year (see Annex 1 for an example GLM summary from analysis of snapshot count data). The resulting monthly estimates will accommodate inter-annual variation (albeit derived across only two years), and measures of variance around the estimates can be calculated. The alternative is to use a method for averaging variables which have been estimated with

[1] https://creem2.st-andrews.ac.uk/download/mrsea-guidance/

uncertainty in order to obtain a joint mean and joint uncertainty (e.g. the delta method; see Annex 2 for an example for how to calculate the overall variance for two sample variances). Use of the first approach removes the need to consider such options. For completeness in an assessment, stochastic collision estimates could also be presented using the individual monthly density estimates (e.g. 24 values), but with the former monthly averaged values used for the actual impact assessment.

If collision modelling is being conducted deterministically (e.g. using the Band model) then an indication of the range of collision estimates can be obtained by using the upper and lower confidence interval density estimates as well as the mean density. However, this provides no indication of the probability distribution of collisions which can be derived from a stochastic collision model using randomised parameter values.

If deterministic collisions are being calculated then the method used to estimate the mean and SD density has no impact on how collisions are estimated. However, if a stochastic collision model is being used (such as Masden) it is critically important that the method used in the CRM to generate the simulated (random) density estimates shares the same statistical properties as that used to estimate the densities from the survey data. For example, if an over-dispersed Poisson model has been used for data analysis, random number generation should also use this distribution. Although it is possible to back-calculate a standard deviation (SD) from model coefficients derived with a Poisson error structure (e.g. SD = square-root(n) x (upper C.I. – lower C.I.)/3.92) this makes the assumption that the confidence intervals are symmetrical around the mean. This assumption of symmetrical confidence intervals is often violated for Poisson data, particularly at lower values.

Normal or truncated normal random numbers generated from a back-calculated SD of an asymmetrical confidence interval will therefore be biased to the right (i.e. over-estimated). To illustrate this effect, consider an example with 1,000 random numbers generated using a Poisson random number function with lambda=1 (i.e. mean=SD=1), modelled as an intercept only model (i.e. to obtain the mean) using a GLM with Poisson errors, from which a symmetrical SD is back-calculated and used to generate 1,000 truncated normal random numbers:

```
rnd.pois = rpois(n=1000, lambda = 1)
model1 = glm(rnd.pois~1, family=”poisson”)
ci = exp(confint(model1))
sd = sqrt(1000) * (((ci)[2]-(ci)[1])/3.92)
rnd.rt.norm = rtnorm(1000, mean=1, sd=sd, lower=0, upper=Inf)
mean(rnd.rt.norm) = 1.309
mean(rnd.pois) = 0.98
```

The mean of the 1,000 truncated normal random numbers was 1.309, 30% higher than the mean of the original data (1) for the underlying process. This effect will be more pronounced if the underlying distribution is over-dispersed. In this case, using this approach (truncated normal numbers estimated for a Poisson variable) to generate densities for CRM would produce a mean estimate 30% higher than it should be.

This is relevant for the current project because the Masden model generates random density values using a truncated normal distribution which uses a mean and SD (like a normal distribution) but also upper and lower limits (the lower limit in this case set to zero). Although the lower limit prevents 'impossible' (i.e. negative) values, there is still an underlying assumption of symmetry. The consequence is that the 'centre' of the distribution is shifted away from the limits (in this case zero).

Using a different probability distribution for random number generation than that which best fits and is used for data analysis is likely to result in a poor match between the resulting random draws and the original data. Further discussion on this is provided in a later section with respect to parameterising the Masden model.

Proportion at collision height

A similar data analysis approach can be used for calculating the proportion of individuals at collision height (PCH), using a GLM with binomial errors (e.g. a binary response of 'at PCH / not at PCH'). Explanatory variables can include month and year, although the temporal resolution that can be used will depend on the sample sizes available. Thus, if sufficient data on flight heights are available in all months (or surveys) then monthly (or survey) PCH can be estimated, but if sample sizes are small, seasonal or annual estimates may be more appropriate.

As for density estimates, randomised values are most appropriately estimated using the same probability distribution (e.g. binomial) to ensure reasonable correspondence between data and simulations. While the Masden model uses a normal distribution to simulate PCH, the risk of generating skewed values is lower because the mean is typically farther away from the constraints of 0 and 1 which apply to proportional data.

If site specific data are not considered suitable for estimating PCH (e.g. insufficient observations) then an alternative is to use the modelled estimates presented in Johnston et al. (2014). This is incorporated in the Masden model (Option 2) and discussed below.

3 MASDEN MODEL REVIEW

Model structure

To convert the deterministic Band model to a stochastic one it is necessary to run the model multiple times with the input parameters for each run drawn at random from appropriate probability distributions. Each iteration of the model generates a different result and summary outputs can be obtained from the multiple iterations that are run (e.g. the mean and confidence intervals). The Masden model generates stochastic mortality estimates by nesting the calculations within a loop. New random numbers are drawn at the beginning of each run through the loop and the outputs of the model are stored at the end of each iteration. The number of simulations (i.e. runs through the loop) is user defined.

Input parameters

Input parameters (e.g. mean and SD) for the Masden model are entered in pro-forma text files ('.csv'). Table 1 lists the input parameters and the file name where they are entered. The three input files listed in Table 1 (CountData.csv, BirdData.csv, TurbineData.csv) can have multiple rows; CountData and BirdData have a row for each species and TurbineData has a row for each specification of turbine.

As can be seen in Table 1, the proportion at collision height (PCH) is modelled as a single value and multiple values (e.g. for different months) cannot be entered (without modifying the script) into the Masden model.

Table 1. Input parameters required for the Masden model. For most parameters the mean is entered in the cell with parameter name and the SD is identified with a suffix ('SD'). Further details on parameter inputs are provided in Masden (2015). Note some parameters are also entered in the model code (e.g. wind speed).

Filename	Parameter	Value	Note
CountData.csv	Monthly density (labelled as Jan-Dec)	Mean & SD	Density of birds in flight in each month
BirdData.csv	AvoidanceBasic	Mean & SD	Option 1 & 2 avoidance rate
	AvoidanceExtended	Mean & SD	Option 3 & 4 avoidance rate
	Body_Length	Mean & SD	From literature
	Wingspan	Mean & SD	From literature
	Flight_Speed	Mean & SD	From literature
	Nocturnal_Activity	Mean & SD	Value in range 0-1
	Flight	Flapping / Gliding	
	Prop_CRH_Obs	Mean & SD	Single value (i.e. not monthly, etc.)
TurbineData.csv	TurbineModel	Name (e.g. output in MW)	
	Blades	Integer	No. of blades
	RotationSpeed	Mean & SD	RPM
	RotorRadius	Mean & SD	
	HubHeightAdd	Mean & SD	Distance between lower rotor tip and highest astronomical tide (HAT). (NB: added to rotor radius this equals hub height).
	BladeWidth	Mean & SD	Max. width (at c. 25% along length from hub)
	Pitch	Mean & SD	Angle of the blade from plane of rotation, degrees
	(Jan-Dec)Op	Mean	% wind availability in each month
	(Jan-Dec)OpMean	Mean & SD	% maintenance downtime in each month

Probability distributions

The Masden model makes use of two probability distributions to generate the random parameter values for each simulation: the normal distribution and the truncated normal distribution. The truncated normal distribution is used when it is necessary to generate random numbers which are constrained by lower and/or upper limits (e.g. a lower limit of 0 prevents negative values being generated). However, the truncated normal distribution is based on the standard normal distribution and therefore it is not appropriate for parameters in the CRM which are poorly represented by the normal distribution (see previous section on density estimation).

The key aspect is that there is no straightforward method for converting a Poisson distribution to the truncated normal (as required for input to the Masden model). This limits the reliability of the outputs obtained from the Masden model, since biased density estimates will result in biased collision estimates. Further consideration of this aspect is provided in a later section.

In addition to these statistical considerations, there are two instances where the Masden model in its original state (i.e. as downloaded from the Marine Scotland website) has errors in how the random number functions are used. The truncated normal distribution function used to generate seabird densities has an upper limit set at 2 (i.e. seabird densities cannot exceed 2 birds per km^2). While this may not be of concern at some sites, there may be instances when this would cause densities to be under-estimated. The second error is the use of the normal distribution for generating random proportions of birds at collision height, rather than the truncated normal with a lower limit of zero. This error means it is possible to obtain negative values, which will in turn result in negative collision estimates (since collisions are calculated as the product of this and other variables). Guidance on how to correct these errors is provided in a later section.

Turbine parameters

Turbine hub height is modelled as a random addition to the rotor radius, measured from Highest Astronomical Tide (HAT). This is simulated as a normal random number. Surveys are likely to have been conducted over a range of tidal states, so the proportion of birds at collision height would be expected to approximate to Mean Sea Level (MSL; this will depend on the extent to which height observations are pooled, although even across a single survey the span of heights may cover several hours). Thus, to accommodate the difference between HAT and MSL the Masden model includes an offset term in the script (i.e. this is not specified in the input tables but is embedded in the model code) which has a pre-set value of 2.5m. The end-user needs to modify this for their wind farm location.

The rationale for modelling hub height and the other turbine dimensions as random variables is that this captures the uncertainty about turbine model selection which may be present at the assessment stage of wind farm development (note this does not simulate tidal variation as this follows a 'u' shaped distribution, not a normal distribution). However, while the final turbine design may not be determined when the collision analysis is undertaken, there will be one or more candidate models. Collision modelling, as with all other aspects of the assessment, proceeds on the basis of the 'worst case scenario' for any given feature, following the Rochdale Envelope approach. In the case of collision modelling this requires that each candidate turbine is used in the model in order to establish which produces the highest (and hence most precautionary) collision estimates.

It is therefore unnecessary to model these fixed turbine parameters as random variables since for any given turbine they will be known with certainty (or at least have a fixed range of alternative values). Making these random is also inconsistent with the Rochdale Envelope assessment approach. Adapting the Masden model to 'fix' these parameters to be constant is straightforward, by setting the SDs for rotor radius, hub height and blade width to be zero in the TurbineData.csv file.

However, other turbine parameters in the model (RPM and blade pitch) vary in relation to wind speed and it is therefore appropriate to model these as random variables. In its unmodified form the Masden script derives values for RPM and blade pitch from a table which relates these to wind speed (e.g. '*windpower_6.csv*' and '*windpower_8.csv*' are included with the model code for 6MW and 8MW turbines respectively). This table is automatically read into the R workspace during model execution. Values for wind speed (mean and SD) are entered directly into the model script (i.e. these are not included in the tables of input data), from which normal random variables are generated. During each simulation the value for random wind speed is used to obtain the corresponding RPM and blade pitch for use in that simulation. Note that the wind speed is specified as an annual value, not monthly.

Modelling RPM and blade pitch as related functions of wind speed is a sensible approach. However, the values for this relationship have not been derived from any specific turbine model but are instead generic estimates based on expert opinion (during the current project an approach was made to turbine manufacturers to ask if this relationship could be supplied, but these requests were declined on commercial grounds). Thus, it is impossible to be certain if the tables in Masden are suitable for CRM.

In acknowledgement of this, it is stated in Masden (2015) that if mean and standard deviations for RPM and blade pitch are entered in '*TurbineData.csv*' these will be used instead of the *windpower* relationships. However, review of the model code and testing this aspect found that there is no mechanism to enable this switch, and in fact the model always defaults to use the tabulated relationship in the *windpower_6.csv* and *windpower_8.csv* files??, irrespective of RPM and blade pitch values being entered *in TurbineData.csv*.

Flight height distributions

The Masden model generates outputs using Options 1, 2 and 3 of the Band model. For the current comparisons the focus was on Option 1 (site specific flight heights). For Option 1 the Masden model uses the mean and standard deviation of the proportion of birds at collision height (*Prop_CRH_Obs*) in the *BirdData.csv* file to simulate from a normal distribution, which in most cases will provide a reasonable approximation to the underlying proportion data (although see note above about the potential for negative values). For option 2 the overlap between rotor height and bird height (i.e. PCH) is calculated from a pre-defined sample of bird flight heights using data stored in species-specific files (e.g. *Black_legged_kittiwake_ht.csv*). In Masden (2015) it is stated that these were generated by the BTO from the modelling in Johnston et al. (2014). Each species file contains 200 bootstrap samples (200 columns) of the proportion of birds in 1m height intervals between 0 and 300m (300 rows). During each simulation one column is selected at random from the table and the proportion at collision height calculated as the overlap with rotor heights. This approach is considered robust and appropriate and will not result in the generation of negative PCH values.

4 MODEL COMPARISONS

As noted above, the unedited Masden model always uses the *windpower.csv* relationships (wind speed : RPM & blade pitch) even when these parameters are entered in the *TurbineData.csv* file. For the purposes of comparing the Masden model outputs against the Band model (i.e. to run the Masden model as a deterministic model) it was therefore necessary to provide an alternative *windpower.csv* file. This contained constant RPM and blade pitch values (i.e. these had the same value at all wind speeds) to ensure these parameters could not vary.

A second related modification was required to permit comparison of stochastic outputs from the Masden model with Band model outputs derived from upper and lower parameter values (e.g. as presented in SmartWind 2015). This required editing of one of the model scripts ('*sampleturbineparams.txt*'), to allow the alternative sampling method to be used (i.e. use of the mean and SD for rotor speed and blade pitch values in the turbine data sheet to generate normal random variables, rather than the relationship in *windpower.csv*). This was necessary to ensure that RPM and blade pitch varied in a predictable manner around their means, rather than the non-linear relationships specified in *windpower.csv*.

It is worth noting that modelling RPM and blade pitch as independent variables in this manner is expected to inflate the variance of collision model outputs because these variables are actually related to one another (as noted by Masden, and hence the tabulated approach). However, in the absence of manufacturer data this covariance cannot be estimated and it is therefore necessary to model these as independent variables. For interest, outputs using the wind speed version are also presented for comparison, using the *windpower_6.csv* provided with the Masden script.

Deterministic comparison - Masden Model outputs compared to Band Model

The generic bird parameters and turbine parameters in Tables 2 and 5 were made up for the purposes of this comparison. The bird densities (Tables 3 and 6) were estimated from a snapshot boat survey dataset, modelled using a GLM with quasi-Poisson errors (see Appendix 1 for model details). The mean densities for use with the Masden model were the monthly coefficients from the model, while the SDs were calculated from the model confidence intervals (using sqrt(n) x (upper c.i. – lower c.i.)/3.92; where n was the number of snapshots). As discussed above, this makes the assumption that the confidence intervals were symmetrical around the mean, which is unlikely to be the case. However, this method was used here to illustrate the potential influence of this assumption on the outputs obtained.

The input parameter values used are provided in tables 2 and 3. The results obtained from each models are provided in Table 4.

Table 2. Generic bird parameters and wind farm parameters used in the Masden and Band models for deterministic comparison.

Category	Parameter	Masden		Band
		Mean	SD	
Bird (generic)	Body length	0.39	0	0.39
	Wing span	1.08	0	1.08

Category	Parameter	Masden		Band
		Mean	SD	
	Flight speed	13.1	0	13.1
	Nocturnal activity	50	0	3
	Flight type	Flapping	NA	Flapping
	Avoidance rate	98.9	0	98.9
	PCH	0.20	0	0.20
Wind farm	Latitude	55.80	NA	55.80
	Wind farm capacity	600	NA	NA
	Turbine capacity	6	NA	NA
	No. of turbines	Calculated from previous 2 values	NA	100
	Rotor radius	80.00	0	80.00
	No. of blades	3.00	NA	3.00
	RPM	11.00	0	11.00
	Blade pitch	15.00	0	15.00
	Max. blade width	5.50	0	5.50
	Hub height	NA	NA	106.5
	Hub height addition	26.50	0	NA

Table 3. Monthly bird density and wind farm operational parameters for deterministic comparison. Note that the Operation values for the Band model are Operation minus OperationMean for the Masden model (e.g. for January 96.28 - 6.3 = 89.98)

Model	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Masden	Density	0.13	0.31	1.03	0.86	0.77	1.274	0.57	0.11	0.18	0.87	0.48	0.09
	Operation	96.28	96.53	95.83	92.78	90.86	92.22	89.11	89.92	93.71	96.14	97.14	96.41
	OperationMean	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	operationSD	0	0	0	0	0	0	0	0	0	0	0	0
Band	Density	0.13	0.31	1.03	0.86	0.77	1.274	0.57	0.11	0.18	0.87	0.48	0.09
	Operation	89.98	90.23	89.53	86.48	84.56	85.92	82.81	83.62	87.41	89.84	90.84	90.11
	OperationMean	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	operationSD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

Table 4. Deterministic collision modelling results obtained from the Masden model (with all variance =0) and Band model.

Model	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Masden	4.9	10.9	42.9	35.5	33.9	56.6	25.1	4.6	7.2	34.9	17.7	3.3	277.5
Band	4.9	10.9	42.9	35.5	33.9	56.6	25.1	4.6	7.2	34.9	17.7	3.3	277.5

With all parameter variances set to zero and RPM and blade pitch fixed (i.e. not taken from the *windpower.csv* table) the Masden model produces identical results to the Band Model. This is the expected result, since the Masden model was derived from the Band model (however as noted above this could only be confirmed following code modifications to allow all parameters to be fixed).

Stochastic comparison - Masden Model outputs compared to Band Model

Masden Model in original format

The following simulations were conducted without making any adjustments to the Masden script. The input parameters used are provided in Tables 5 and 6. Note that rotor RPM and blade pitch used in the Band model were derived from the calculations using wind speed in the Masden model. In order to obtain the same mean values for use in the Band model it was necessary to run the Masden model first and then extract the mean RPM and blade pitch from the outputs.

A mean wind speed of 16ms^{-1} (and SD of 3.2) was entered in the Masden code as this corresponded to a blade angle (in the original *windpower.csv* table) of 15 degrees and an RPM of 10.2, which were considered to be similar to typical values used in collision modelling. Following completion of the Masden simulations the actual mean RPM and mean blade pitch generated during simulations were 9.87 and 13.3 respectively, and these were used in the Band model.

Table 5. Generic bird parameters and wind farm parameters used in the Masden and Band models for stochastic comparison.

Category	Parameter	Masden		Band
		Mean	SD	
Bird (generic)	Body length	0.39	0.005	0.39
	Wing span	1.08	0.04	1.08
	Flight speed	13.1	1.5	13.1
	Nocturnal activity	50	0.0045	3
	Flight type	Flapping	NA	Flapping
	Avoidance rate	98.9	0.001	98.9
	PCH	0.20	0.033	0.20
Wind farm	Wind speed	16	3.2	NA
	Latitude	55.80	NA	55.80
	Wind farm capacity	600	NA	NA
	Turbine capacity	6	NA	NA
	No. of turbines	Calculated from previous 2 values	NA	100
	Rotor radius	80.00	0	80.00
	No. of blades	3.00	NA	3.00
	RPM	NA	NA	9.87
	Blade pitch	NA	NA	13.3
	Max. blade width	5.50	0	5.50
	Hub height	NA	NA	106.5
	Hub height addition	26.50	2	NA

Table 6. Monthly bird density and wind farm operational parameters for stochastic comparison. Note that the Operation values for the Band model are Operation minus OperationMean for the Masden model (e.g. for January 96.28 - 6.3 = 89.98)

Model	Parameter	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Masden	Density (mean)	0.13	0.31	1.03	0.86	0.77	1.274	0.57	0.11	0.18	0.87	0.48	0.09
	Density (SD)	0.10	0.15	0.28	0.25	0.23	0.31	0.21	0.09	0.12	0.24	0.16	0.08
	Operation	96.28	96.53	95.83	92.78	90.86	92.22	89.11	89.92	93.71	96.14	97.14	96.41
	OperationMean	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3	6.3
	operationSD	2	2	2	2	2	2	2	2	2	2	2	2
Band	Density	0.13	0.31	1.03	0.86	0.77	1.274	0.57	0.11	0.18	0.87	0.48	0.09
	Operation	89.98	90.23	89.53	86.48	84.56	85.92	82.81	83.62	87.41	89.84	90.84	90.11
	OperationMean	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA
	operationSD	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA	NA

The results obtained from the original Masden model and the Band model are provided in Table 7.

Table 7. Stochastic collision modelling results obtained from the unmodified Masden model (with input variances as defined in tables 4 and 5) and Band model.

Model		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Masden	Mean	5.6	10.6	40.9	34.0	32.9	54.2	24.5	5.2	7.5	34.0	16.9	3.9	270.2
	SD	3.4	5.2	14.6	13.0	11.9	17.0	10.6	3.2	4.5	11.9	6.8	2.5	
	CV	61.9	48.9	35.6	38.1	36.2	31.3	43.0	62.6	60.5	34.9	40.2	64.5	
	Median	5.0	10.2	39.3	32.7	32.0	53.0	23.6	4.9	7.0	32.9	16.4	3.6	260.6
	IQR	4.8	7.0	18.9	16.6	15.9	23.3	14.6	4.4	6.0	15.8	8.9	3.4	
Band		4.6	10.2	40.1	33.2	31.7	52.9	23.5	4.3	6.8	32.7	16.5	3.1	259.6
Band as percentage of Masden	Mean	82.7	96.0	98.1	97.7	96.3	97.7	95.8	82.1	90.6	96.2	98.0	77.6	96.1
	Median	91.9	100.0	102.1	101.4	99.0	99.8	99.8	87.7	96.6	99.4	100.8	85.7	99.6

Using the parameters detailed in Tables 5 and 6 the unmodified Masden model produced slightly higher mean collision estimates (c. 4% higher), although the median outputs were very similar (<0.5% higher).

Masden Model modified to correct misspecifications

For the following comparison the Masden code was edited to remove the upper limit on bird density and to allow rotor RPM and blade pitch to be entered as independent variables. The input parameters were the same as those used for the unmodified Masden model (Tables 5 and 6).

Table 8. Stochastic collision modelling results obtained from the modified Masden model (with variances as defined in tables 4 and 5) and Band model.

Model		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Masden	Mean	5.4	10.9	40.2	34.4	32.3	54.8	24.5	5.1	7.6	33.7	17.2	3.9	270.0
	SD	3.3	5.3	14.3	12.9	11.9	18.7	10.6	3.2	4.5	12.1	6.9	2.6	
	CV	61.1	48.5	35.5	37.5	36.8	34.1	43.2	62.5	59.9	35.9	40.1	66.4	
	Median	5.0	10.5	38.2	33.2	31.3	52.4	23.2	4.7	7.0	32.9	16.7	3.5	258.6
	IQR	4.4	7.0	18.5	17.3	16.0	24.6	14.1	4.3	6.2	15.3	9.0	3.6	
Band		4.6	10.2	40.1	33.2	31.7	52.9	23.5	4.3	6.8	32.7	16.5	3.1	259.6
Band as percentage of Masden	Mean	85.2	94.0	99.9	96.6	98.1	96.5	96.0	83.7	89.3	96.9	96.2	77.5	96.1
	Median	93.0	97.4	105.0	99.9	101.2	100.9	101.4	91.1	96.6	99.4	99.0	87.2	100.4

A visual comparison of the results in Table 8 is provided in Figure 1. The Masden model produced mean collision estimates that were consistently higher than the Band model, by up to 23%, although the absolute differences were comparatively small with the annual total only 4% higher. The median estimates were closer to the Band outputs. In both cases the magnitude of difference in each month between Band and Masden is negatively related to the CV of seabird density. Thus, the greater the relative uncertainty on density (i.e. larger CV), the greater the difference between the Masden mean (or median) estimate and the Band output. While greater uncertainty should be reflected in less precise estimates, in this case the difference is one of reduced accuracy (not precision), due to the introduction of positive bias in the resampled densities resulting from use of the truncated normal distribution: the mean of the 1,000 resampled densities for each month were larger than the input means in 10 of the 12 months, by up to 2.3%.

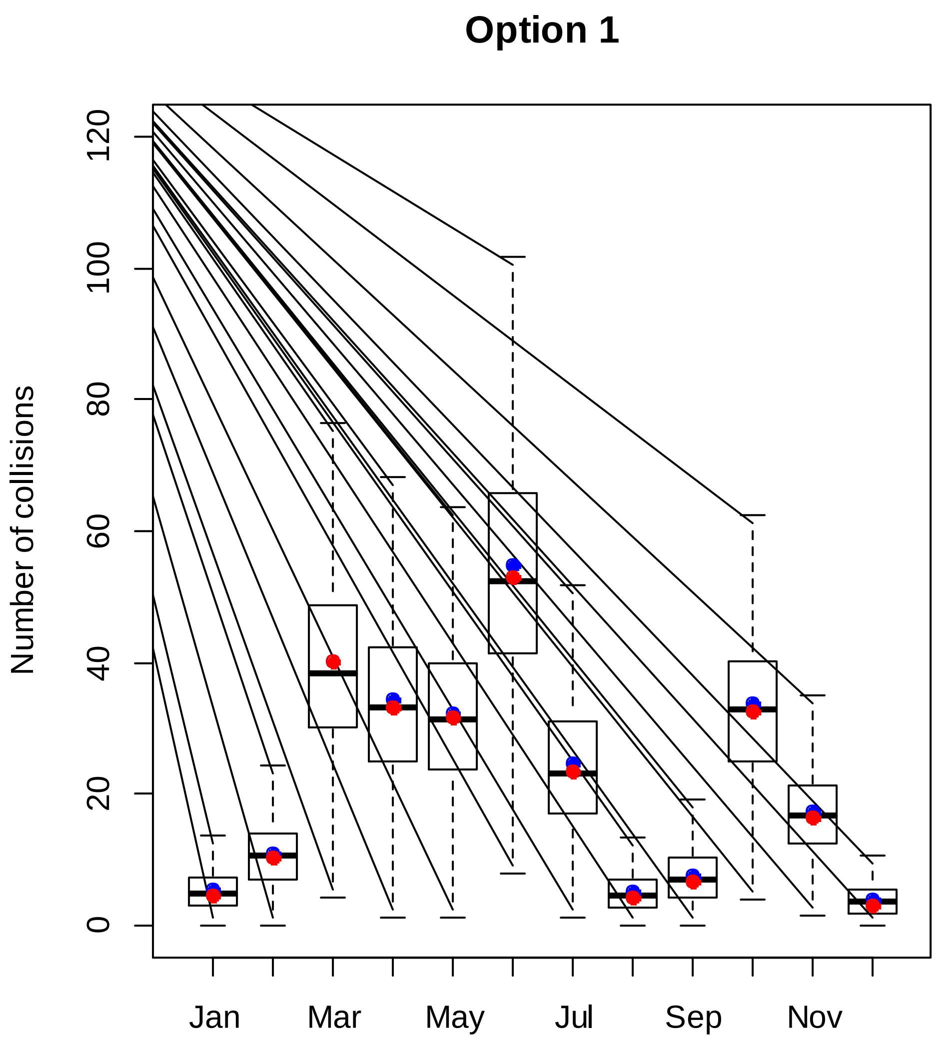


Figure 1. Box and whisker plot of Masden model outputs (in Table 8) using the parameters listed in Tables 5 and 6. The heavy horizontal lines are the medians, the boxes the 25th and 75th percentiles and the whiskers represent the range (the default setting for boxplot as used in the Masden model). The mean Masden values (blue dots) and Band model outputs (red dots) have been overlaid (note the March blue dot is hidden under the red dot).

For the dataset used in this analysis the modified Masden model produced the same results as the unmodified version. However, this would not have been the case if the data contained higher density estimates (i.e. >2/km^2) which would be truncated by the unedited Masden model by the upper limit of 2 defined for that parameter. In addition, the wind speed, RPM and blade pitch values were all standardised across the model runs (to ensure comparisons were based on the same data). However, ensuring the unedited Masden model and the Band model had the same values for RPM and blade pitch can only be achieved through a process of trial and error or by modifying the wind speed table (e.g. setting all RPM and blade pitches to the same value, although this removes the stochastic aspect for these parameters).

An alternative option to present uncertainty in collision predictions without using a stochastic model such as Masden is to calculate Band outputs using the upper and lower values for selected input parameters (e.g. SmartWind 2015). This can't provide a probability distribution of outputs, but does indicate the range over which estimates could lie. The Band model results obtained using upper and lower confidence values for seabird density (i.e. 95% confidence interval values obtained from the GLM of survey data derived using the 'confint' function) on their own and also with the avoidance rate set to upper and lower levels (i.e. +/- 0.002) are provided in Table 9 and Figure 2.

Table 9. Collision modelling results obtained from the modified Masden model (with variances as defined in Tables 5 and 6) and Band model using upper and lower 95% confidence seabird density estimates obtained from a GLM and also with recommended upper and lower avoidance rates (98.7 - 99.1%).

Model		**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Total**
Masden	Mean	5.4	10.9	40.2	34.4	32.3	54.8	24.5	5.1	7.6	33.7	17.2	3.9	270.0
	SD	3.3	5.3	14.3	12.9	11.9	18.7	10.6	3.2	4.5	12.1	6.9	2.6	
	CV (%)	61.1	48.5	35.5	37.5	36.8	34.1	43.2	62.5	59.9	35.9	40.1	66.4	
	Median	5.0	10.5	38.2	33.2	31.3	52.4	23.2	4.7	7.0	32.9	16.7	3.5	258.6
	IQR	4.4	7.0	18.5	17.3	16.0	24.6	14.1	4.3	6.2	15.3	9.0	3.6	
Band	Mean	4.6	10.2	40.1	33.2	31.7	52.9	23.5	4.3	6.8	32.7	16.5	3.1	259.6
Density range	Lwr 95%	0.7	3.6	17.8	20.5	16.8	32.9	11.0	0.8	0.9	18.1	8.4	0.3	131.71
	Uppr 95%	15.3	22.4	75.2	50.7	52.9	79.8	43.3	12.3	23.0	54.0	30.7	11.7	471.37
Density range & Avoidance rate range	Lwr 95% & 99.1% AR	0.6	2.9	14.5	16.8	13.7	26.9	9.0	0.7	0.7	14.8	6.9	0.2	107.76
	Uppr 95% & 98.7% AR	18.0	26.5	88.9	60.0	62.5	94.4	51.2	14.6	27.2	63.8	36.3	13.8	557.08

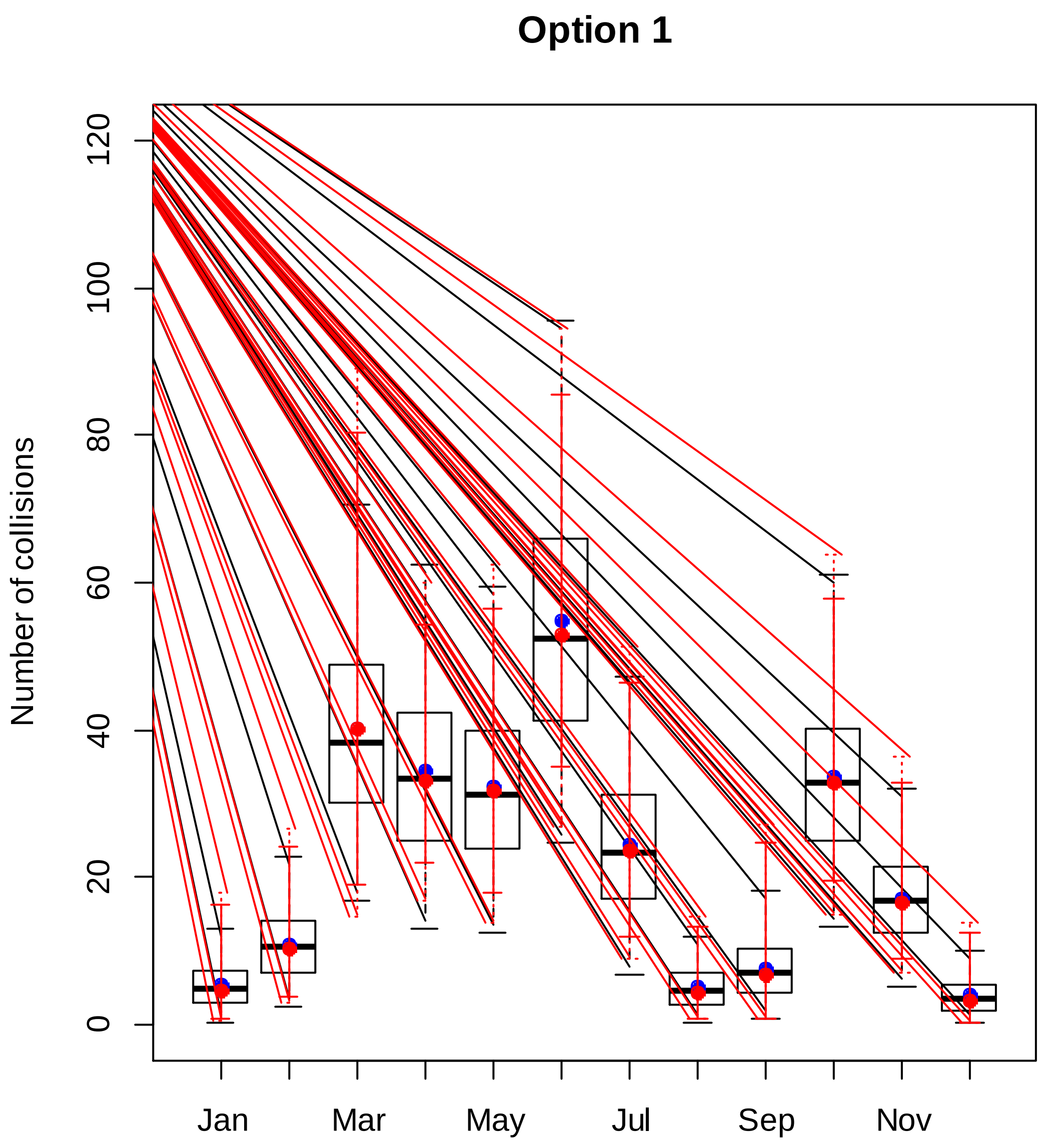


Figure 2. Box and whisker plot of Masden model outputs (in Table 9) using the parameters listed in Tables 5 and 6. The black horizontal lines are the median, the boxes the 25th and 75th percentiles and the black whiskers the 95% confidence interval (i.e. 2.5% - 97.5%). The mean Masden values (blue dots) and Band model outputs (red dots) have been overlaid. The solid red lines indicate the upper and lower Band outputs using 95% confidence intervals (i.e. 2.5% - 97.5%) from the seabird density GLM, the dotted red lines also include +/- 0.002 applied to the avoidance rate (i.e. 98.7 - 99.1%). It should be noted that for this figure the boxplot function has been modified from that defined in the Masden model to generate whiskers (black dotted lines) at the 95% confidence range for comparison with the intervals presented around the Band model outputs (red whiskers).

Comparing the Band model upper and lower estimates with those from the Masden model, it can be seen that the 95% confidence ranges generated by the Masden are generally fairly similar, although there is no consistent pattern (i.e. in some months the Band model outputs are wider and in others the Masden model outputs are wider). It should be noted that for comparison the boxplot function used in the Masden model has been modified slightly for Figure 2 to obtain the equivalent 95% confidence range as that presented for the Band model outputs.

It is interesting to note that the extent of the Band model ranges was more influenced by the uncertainty in the density estimates than the avoidance rate, the latter contributing a maximum of 30% to the range of collision estimates (peaking for the higher absolute collision estimates).

5 RECOMMENDATIONS FOR EDITING THE MASDEN MODEL

The Masden model script without modification (i.e. as downloaded) produces mean collision estimates which may be different (depending on input parameter values) from those obtained by the Band model for the following reasons:

- The simulated proportion at collision height can generate negative values (depending on the mean and SD entered),
- The simulated seabird densities are capped at 2/km^2, and
- Rotor RPM and blade pitch are simulated as a function of a randomly generated wind speed variable, using a tabulated relationship which is not based on actual turbine parameters (it should be noted that the reports which accompany the Masden model state that this relationship is over-ridden if a mean and SD for rotor speed and blade pitch are entered, however this is incorrect as the model code does not include a mechanism to perform this switch).
- The mean of the density values generated from the normal (or truncated normal) distribution may differ from the input mean values, due to inherent differences between the underlying distribution and the normal or truncated normal distributions.

As a consequence, the model should not be used for wind farm assessment without modification. The following steps can be taken to correct the above aspects. These modifications were applied to obtain the outputs in Table 9.

- The R script '*sampleCRH.R*' should be changed from:

```
sampleCRH <- function(meanCRH, sdCRH) {
  rnorm(1, meanCRH, sdCRH)
 }
```

To :

```
sampleCRH <- function(meanCRH, sdCRH) {
  rtnorm(1, meanCRH, sdCRH,lower=0,upper=1)
 }
```

This constrains the resampled collision height estimates to lie between 0 and 1. Note this is only necessary when using site specific flight height data (e.g. Option 1).

- The R script '*samplecount.R*' should be changed from:

```
sampleCount <- function(meancount, sdcount){
  rtnorm(1, meancount, sdcount,0,2)
 }
```

To:

```
sampleCount <- function(meancount, sdcount){
  rtnorm(1, meancount, sdcount,lower=0,upper=Inf)
 }
```

This removes the upper seabird density cap of 2.

- The text file '*sampleturbineparams.txt*' should be modified as follows.

Lines 3 to 10 (inclusive) shown below, should be commented out – add '#' at the beginning of each line. This prevents these lines from being used by R.

```
 ####ROTOR SPEED (related to wind speed)####
source("scripts\\get_rotor_plus_pitch_auto.txt")
randomSample<-sample(length(rotorSpeed),1)
sampledRotorSpeed[i]<-rotorSpeed[randomSample]

 ###PITCH (related to wind speed and linked to above)####
sampledRotorPitch[i]<-rotorPitch[randomSample]
Pitch = sampledRotorPitch[i]*pi / 180 #### Transform Pitch, needed for Collision Risk Sheet
```

Becomes:

```
####ROTOR SPEED (related to wind speed)####
#source("scripts\\get_rotor_plus_pitch_auto.txt")
#randomSample<-sample(length(rotorSpeed),1)
#sampledRotorSpeed[i]<-rotorSpeed[randomSample]

###PITCH (related to wind speed and linked to above)####
#sampledRotorPitch[i]<-rotorPitch[randomSample]
#Pitch = sampledRotorPitch[i]*pi / 180 #### Transform Pitch, needed for Collision Risk Sheet
```

- The following lines should then be pasted in below the commented lines:

```
## Modified script to generate resampled rotor speed and blade pitch from input data in TurbineData.csv
ifelse(!is.na(TurbineData$RotationSpeedSD[t]), rotorSpeed<-sampleRotorRadius(TurbineData$RotationSpeed[t], TurbineData$RotationSpeedSD[t]), rotorSpeed<-TurbineData$RotationSpeed[t])
  sampledRotorSpeed[i]<-rotorSpeed

ifelse(!is.na(TurbineData$PitchSD[t]), rotorPitch<-sampleRotorRadius(TurbineData$Pitch[t], TurbineData$PitchSD[t]), rotorPitch<-TurbineData$Pitch[t])
  sampledRotorPitch[i]<-rotorPitch
  Pitch=sampledRotorPitch[i]*pi / 180 #### Transform Pitch, needed for Collision Risk Sheet
```

This ensures that the Masden model will sample the RPM and blade pitch from the mean and SD values entered in the *TurbineData.csv* file rather than the windpower.csv file.

There is an option in the Masden script which allows the initial state for the random number generator to be set to a fixed value (this is set to 100 in the code: *'set.seed(100')*). The advantage of this is that results are repeatable (i.e. the same sequence of 'random' numbers is generated on each run of the model). However, failing to switch this off (or alternatively, setting the seed to a new value each time (e.g. using the CPU clock: '*set.seed(as.numeric(Sys.time()))*') will lead to unexpected outputs (e.g. identical results on every simulation).

The above aspects of the code are relatively straightforward to correct through editing of the Masden model code, however this requires an understanding of the R programming language.

More fundamentally, in its current state without modification (i.e. as available on the Marine Scotland Datasets webpage[2]) the Masden model uses inappropriate probability distributions for some parameters. As a consequence, there is a high likelihood that use of the Masden model will result in erroneous collision estimates (i.e. estimates which do not accurately reflect input parameters due to errors in the model code and the way data are simulated).

6 OTHER CONSIDERATIONS FOR STOCHASTIC COLLISION MODELLING

The Masden model in its unedited state samples rotor RPM and blade pitch jointly using wind speed. This approach correctly identifies that these turbine parameters are not independent of one another, but are closely related and jointly dependent on wind speed. However, while this is an appropriate method to model these variables, the relationship between wind speed and the turbine rotor operation has not been made available by the turbine manufacturers, therefore the accuracy of the relationship is unknown. Thus, to permit comparison of outputs with the Band model it was necessary to derive the mean values for RPM and blade pitch from the ones generated by running the Masden model (using the RPM, blade pitch, and windspeed relationships table provided with the Masden model). The alternative is to set the mean and SD using turbine data and modify the code (as described

[2] http://marinedata.scotland.gov.uk/dataset/developing-avian-collision-risk-model-incorporate-variability-and-uncertainty-r-code

above) to make these variables independent of one another. This allows closer comparability with the Band model, but will inflate the overall variance of the outputs. Furthermore, this highlights the fact that there are several other components of the collision model which are related and which should therefore covary in a stochastic model.

A key example of this is the avoidance rate. Seabird avoidance rates have been estimated from long term datasets (Cook et al. 2014). The estimates are therefore mean values for the study periods used, and equivalent mean parameter estimates should be used for the other model input parameters (e.g. flight speed, proportion at collision height, etc. should be derived over similar time frames). It therefore follows that simulating each parameter around its mean value should ensure that the mean collision estimate obtained will correspond to the individual input parameter means. However, unless the parameters have been combined within each model iteration in such a way as to avoid inappropriate combinations the variance around the mean collision estimate will be inflated. Incorporating covariance in the model is an important consideration for development of a reliable stochastic model.

This is important, since the main objective of a stochastic collision model is to improve understanding of the variance around the mean estimates. As demonstrated above, the Masden model produces mean and median values which are very similar to those from the Band model. But because the parameters are simulated independently the overall 'parameter space' generated will be inflated to an unknown extent with a result that the collision estimates will also have wider confidence intervals than if the input parameters were simulated with realistic levels of covariance.

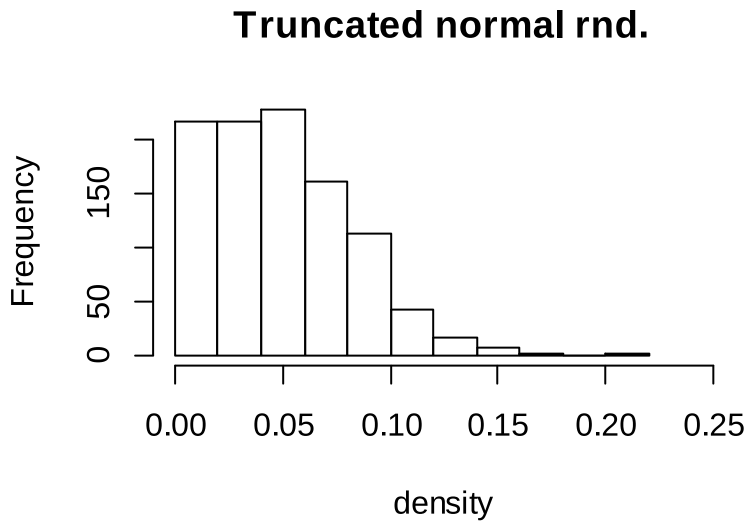
The proportion of birds at collision height can only be entered in the Masden model as a single value (mean and SD) which is applied as an annual average (although the model could be run for a single month or months to apply seasonal variation in this and other parameters). It would be appropriate to model collisions using a monthly value for this parameter if it can be estimated for a given location. This would require considerably more editing of the current scripts and is beyond the scope of the current project.

The simplest robust option for producing randomised density estimates for input to a stochastic collision model is to bootstrap the snapshot counts for a given month. The drawback of this approach is that for low density species there may be a limited number of non-zero counts from which to draw (i.e. there may be a very small range of possible outputs). A more flexible approach is to use a function such as *generateNoise* (MRSea Power) which uses the outputs from a model of the snapshot counts (e.g. GLM or GAM), including any over-dispersion parameter. Unlike bootstrapping, this method is not constrained by the original observations. For example, if the original sample only included snapshot counts of 1, 2 and 5 individuals, the bootstrap resamples will have the same three count sizes. In contrast, resamples obtained using *generateNoise* can take any integer value within the range defined by the model. In both cases the output is a vector of counts the same length as the original number of surveyed samples. The column sum divided by the total area of snapshots is a random density estimate for input to the CRM. Repeating this process generates bird density estimates that can be used to produce collision estimates incorporating uncertainty in species density at the project site in a statistically robust way.

As discussed above, seabird counts used to derive densities are poorly represented by the normal or truncated normal distribution. Thus, a stochastic CRM either needs to permit random number generation using different distributions (e.g. Poisson) or alternative parameter inputs (e.g. external generation of multiple densities using bootstrap methods which can be used in simulations as outlined in the paragraph above).

As described above, one option is to use the results of a Poisson GLM to generate random resamples which correspond to the observed distribution. However, there is no means in the unedited Masden script to specify alternative random number generation or alternative density inputs (the user must supply mean and SD values for use with a truncated normal random number generator).

The best option currently available is to calculate the mean and SD from the resampled GLM data (as above) and use these as Masden model inputs. The drawback to this is that a Poisson (or over-dispersed Poisson) process is likely to be poorly represented by the truncated normal distribution that the Masden model uses to sample densities from. The magnitude of difference between the underlying (over-dispersed Poisson) process and that obtained using the truncated normal as described above, depends on how close the mean density is to zero. At low mean densities (e.g. <0.5 birds / km^2) the truncated normal estimates are biased high (Figure 3), although this bias decreases as the mean increases and is effectively undetectable at higher (e.g. >1 bird / km^2 (Figure 4).



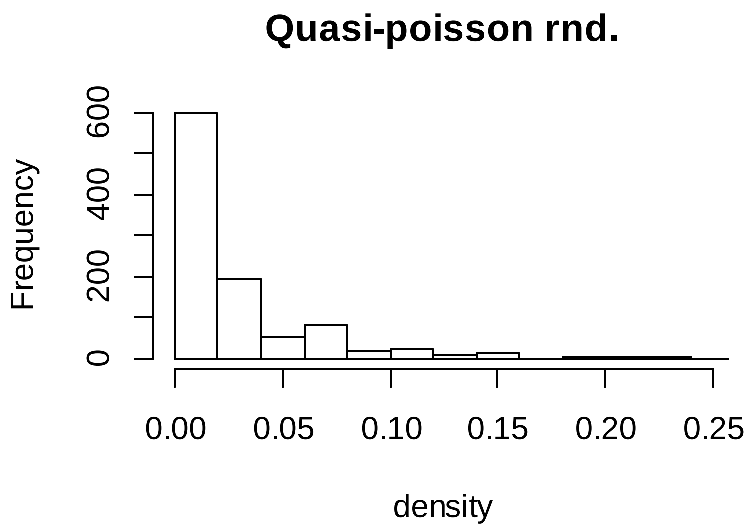
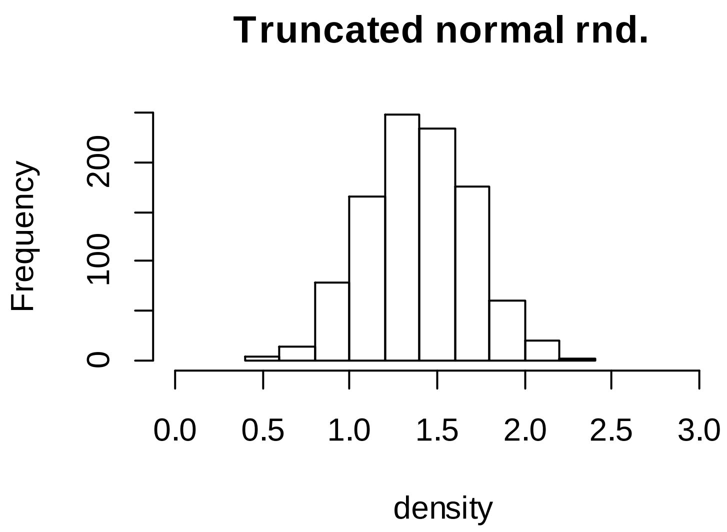


Figure 3. Low density resampled seabird densities, the values in the lower plot have been generated directly from an over-dispersed Poisson GLM using the generateNoise function. The values in the upper plot have been obtained using the mean and standard deviation (of the samples in the lower plot) as inputs to the rtnorm function (truncated normal random numbers). The truncated normal random deviates are shifted to the left compared with the underlying distribution. The original distribution (lower plot) has a mean (sd) of 0.031 (0.044) while the mean (sd) of the truncated normal distribution in the upper plot is 0.049 (0.032).



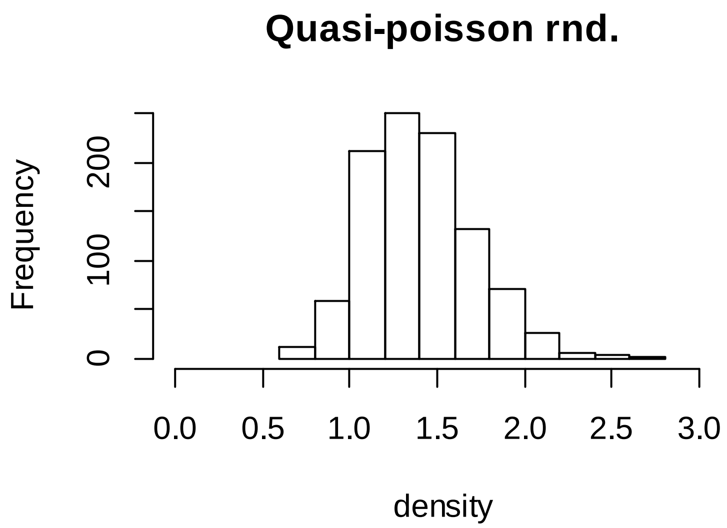


Figure 4. Medium density resampled seabird densities, the values in the lower plot have been generated directly from an over-dispersed Poisson GLM using the generateNoise function. The values in the upper plot have been obtained using the mean and standard deviation (of the samples in the lower plot) as inputs to the tnorm function (truncated normal random numbers). These illustrate that as density increases the bias declines to undetectable levels. The original distribution (lower plot) has a mean (sd) of 1.39 (0.304) while the mean (sd) of the truncated normal distribution in the upper plot is 1.39 (0.0297).

As noted above, the truncated normal distribution is used to obtain normal random numbers which are constrained by lower and/or upper limits. While this can prevent inappropriate values, the results are not necessarily a good match for the underlying process. In addition, the bird densities generated in the unedited Masden model using the truncated normal distribution have an upper limit which has been fixed at 2 birds / km^2. It is assumed that this is an error in the relevant script which if uncorrected risks generating incorrect densities for abundant species.

A GLM approach is also a robust method for estimating the proportion of birds at collision height with variability. The first step is to convert observed flight heights to a binary state (0 = not at PCH, 1 = at PCH). These data can then be modelled using a GLM with binomial errors. As for density estimates, these can be resampled directly to be used as CRM inputs. In order to use PCH data modelled in this manner with the unedited Masden model the mean and SD can be calculated across the resampled values. However, there is a potentially important error in the Masden script when using option 1 and site specific flight height data: the proportion of birds at collision height is simulated using a normal distribution (i.e. these are not truncated at zero) and it is therefore possible to obtain negative values for this parameter if the mean PCH is low, or the SD is large (or both). Using a negative value for PCH will result in a negative collision estimate, and reducing the summary values obtained. Unless there are a lot of negative values (i.e. resulting in a negative lower confidence interval) this is unlikely to be obvious in the summary outputs. This should be corrected (see section 5) prior to use of the Masden model.

On a practical level, the Masden model generates stochastic mortality estimates by nesting the calculations within a loop. New random numbers are drawn at the beginning of each run through the loop and the outputs of the model are stored at the end of each iteration. While this approach is conceptually straightforward, it is inefficient (i.e. the model runs slowly). Simulations can be undertaken much more efficiently through the use of vectorisation. This minimises the use of loops by generating multiple random values for each parameter in a single step and then multiplying these together to obtain tables of outputs which are the same as those obtained at the end of a looped process.

It is important to state that regardless of the method used (looped or vectorised), the results obtained are the same. Therefore, although the Masden code is slow compared with vectorised script, this does not preclude its use (although the time saving may be significant: as an example, to complete 1,000 simulations for a single species the run time for the unedited Masden code was 45 minutes, while a vectorised version achieved the same outputs in less than 4 seconds).

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ANNEX 1.

Bird density modelling. Note that no surveys were conducted in November in the example dataset. For the CRM tests density parameters for November (mean, c.i.) were averaged across October and December. The original data comprises 22 surveys across a two year period, with regular snapshot counts (range: 362 – 461) collected by boat survey.

```
> summary(mod1)
Call:
glm(formula = Numbers ~ as.factor(Month) - 1 +  offset(log(area)), family = quasipoisson)

Deviance Residuals:
Min        1Q        Median    3Q         Max
-0.4781    -0.3944   -0.3220   -0.1577    21.1670
```

Coefficient	Estimate*	Std. Error	t value	Pr(>|t|)	Lower c.i. #	Upper c.i. #
Month1	0.1372	0.7360	-2.690	0.00716	0.02088	0.4424
Month2	0.3129	0.4604	-2.538	0.01118	0.10758	0.6814
Month3	1.0340	0.3630	0.075	0.93983	0.45868	1.9414
Month4	0.8727	0.2302	-0.635	0.52571	0.53050	1.3145
Month5	0.7795	0.2899	-0.926	0.35425	0.40813	1.2846
Month6	1.2580	0.2253	1.060	0.28911	0.78830	1.9160
Month7	0.5705	0.3448	-1.600	0.10959	0.26898	1.0572
Month8	0.1071	0.6657	-3.361	0.00078	0.02026	0.3119
Month9	0.1847	0.7806	-2.195	0.02822	0.02342	0.6111
Month10	0.8798	0.2760	-0.476	0.63391	0.4838	1.4401
Month12	0.0851	0.9014	-2.700	0.00695	0.0074	0.3446

* Note these estimates have been converted using 'exp()' to obtain values on the response scale.
# The confidence intervals were obtained using function 'confint()'

```
(Dispersion parameter for quasipoisson family taken to be 4.874795)
Null deviance: 3789.4  on 8812  degrees of freedom
Residual deviance: 3360.7  on 8801  degrees of freedom
AIC: NA
Number of Fisher Scoring iterations: 7
```

ANNEX 2.

The following sets out a method for calculating an overall (or average) variance for two variables which have their own mean and variances (i.e. the average variance for two monthly densities which each have their own average and variance).

For a two-sample calculation, the input parameters are:

- n1 and n2 (sample sizes, e.g. n1= 300, n2 = 400)
- x1 and x2 (sample means, e.g. x1= 25, c2 = 15)
- x.bar (mean of x1 and x2, e.g. x.bar = 20)
- v1 and v2 (variance estimates, e.g. v1 = 25, v2 = 9)

Calculate the overall error sum of squares:

ESS.total = (v1 * n1-1) + (v2 * n2-1)

Calculate the overall group sum of squares:

GSS.total = ((x1 – x.bar)^2 *n1-1) + ((x2 – x.bar)^2 *n2-1)

Calculate the overall variance:

Overall variance = (ESS.total + GSS.total) / ((n1+n2)-1)

Using the example values the following distributions are obtained: