Norfolk Boreas Offshore Wind Farm

Flamborough and Filey Coast Collision Risk Modelling and Population Viability Analysis

Applicant: Norfolk Boreas Limited
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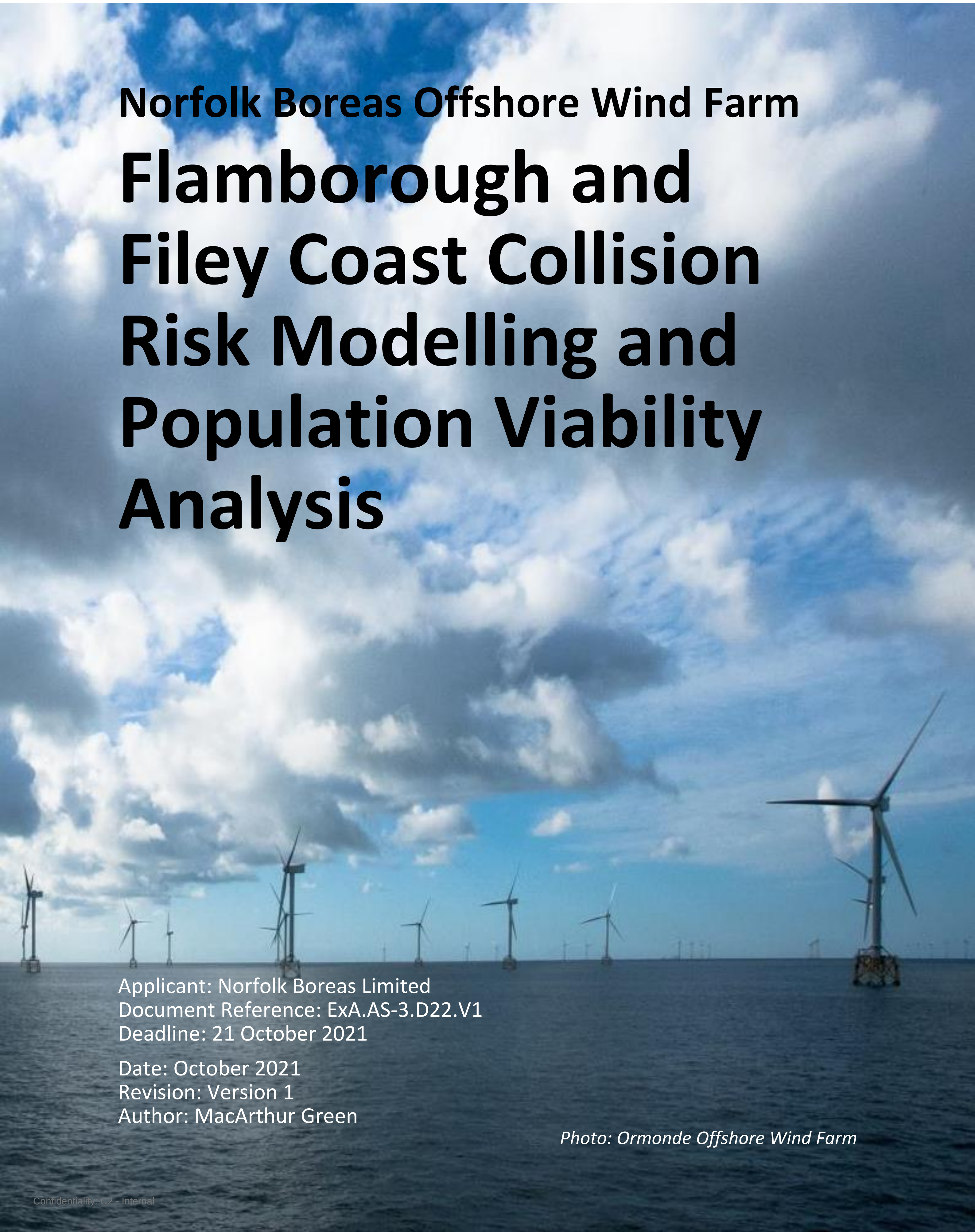

Photo: Ormonde Offshore Wind Farm

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Glossary of Acronyms

AEoI	Adverse Effect on Integrity
BEIS	Department for Business, Energy & Industrial Strategy
CRM	Collision Risk Model
FFC	Flamborough and Filey Coast
HRA	Habitats Regulations Assessment
PVA	Population Viability Analysis
SoS	Secretary of State
SPA	Special Protection Area

1 Introduction

1. This note provides updated collision risk models (CRM) and population viability analysis (PVA) for kittiwake and gannet as per the request from the Secretary of State (SoS) for Business, Energy and Industrial Strategy (BEIS) received by the Applicant on the 22nd September 2021.

1.1 Updated Collision Risk Modelling

2. With respect to the CRM, the SoS requested that the Applicant should use Natural England's latest advised avoidance rates, with a reference to a recent publication by the British Trust for Ornithology (BTO), Cook (2021). This work, commissioned by Natural England, updates the previous avoidance rate review (Cook et al. 2014) and presents a review and analysis of data collected by a range of studies from which it is possible to estimate wind turbine collision avoidance rates.

3. The Applicant was only made aware of this work, via email from Natural England on the 28th July 2021, shortly before the report was due to be made available (although it in fact was only published on the 20th August 2021). Natural England has advised the Applicant that they are producing a guidance document on the use of the information in Cook (2021) jointly with the other statutory nature conservation bodies (SNCBS). In the meantime, as stated in Natural England's submission of the 20th August 2021[1]:

'*Natural England is likely to recommend the revised AR going forwards*' (i.e. the rates recommended in Cook 2021).

4. The Applicant's ornithology consultant reviewed Cook (2021) and, assisted by the fact that the data and analysis scripts were also provided on the BTO website, has been able to examine the methods and results closely. A detailed report of this review is provided in Appendix 2 of The Applicant's Response to the Request for Additional Information (ExA.PDR.D22.V1) submitted on 21st October 2021, but in summary the Applicant is concerned that the analysis and conclusions contained in Cook (2021) are flawed for the following reasons:

- There is considerable variation in the suitability and robustness of the individual studies which underpin the analysis;
- Examination of the contribution from each study to the overall outputs has identified one study in particular which exerts a very strong influence on the

1 [redacted]

average avoidance rate estimates (this point clearly meets the definition of a statistical outlier);

- There are strong evidential reasons why this study should not be included, due to a very short and unrepresentative period of study, and in fact this study was rejected for inclusion in Cook et al. (2014) on these grounds. There is no explanation provided in Cook (2021) for its subsequent inclusion; and,
- Removal of this one study (1 row of data from 415 appropriate to the all gull avoidance rate) increases the avoidance rate advised for use with kittiwake from 98.74% to 99.13%. Compared with the current kittiwake avoidance rate (98.9%) a rate of 99.13% would reduce predicted collisions by 23%, while including this data point would increase predicted collisions by 14%.

5. For these reasons the Applicant does not consider the avoidance rate recommendations in Cook (2021) to be based on robust considerations of the available data. The Applicant also notes that no official Natural England guidance on the use of these rates has been made available. It is therefore considered premature for collision modelling to be undertaken using the revised rates.

6. The above concerns notwithstanding, due to the way the rates were calculated it is also not possible to update the collision estimates for other wind farms included in the cumulative and in-combination assessments using the Cook (2021) recommended avoidance rates. This is because to obtain avoidance rates Cook (2021) first estimated the predicted collision rate (to compare with actual collision observations) and in doing so used a different nocturnal activity rate (25%) than has been advised until relatively recently by Natural England (50%). Because the avoidance rate is obtained as the comparison between CRM predictions and observed mortalities, the resulting avoidance rate is specific to the suite of model input parameters used. For this reason the Cook (2021) avoidance rates cannot be applied retrospectively to other wind farms.

7. The above notwithstanding, in order for the SoS to have all the requested information on which to base conclusions, collision risks have been recalculated for Norfolk Boreas using the alternative avoidance rates (and nocturnal activity rates) in Cook (2021). However, for the above reasons, the estimates for other wind farms presented in the in-combination table are the same as provided previously (e.g. REP8-025).

1.2 Updated Population Viability Analysis

8. The SoS request was to provide updated PVA for kittiwake and gannet, comparing the counterfactual FFC SPA population sizes after 30 years and the in-combination assessments should include all projects up to and including Hornsea Project 3. The

Applicant sought clarification on the list of projects to include, and was informed that:

'*the in-combination assessment to include Hornsea Project 3, Norfolk Vanguard and Norfolk Boreas. For the avoidance of doubt, the in-combination assessment should not include East Anglia ONE North, East Anglia Two, Hornsea Project 4, or the Dudgeon and Sheringham extension projects*.'

2 Methods – Density Dependence

9. The Natural England PVA tool includes an option to switch the model to run as either density independent, with no connection between population size and the demographic rates (survival and productivity) or density dependent, which includes a feedback link between population size and one or more demographic rates. For example, this could take the form of a negative relationship between population size and productivity, such that as the population increases productivity decreases, and vice versa. In this manner the simulated population in the model is maintained around a stable level. Such feedback responses often occur in real populations due to competition between individuals for limited resources such as breeding space, breeding partners or food. There is a large amount of theoretical and empirical evidence for such population regulation, including for seabirds, although it must be acknowledged that the mechanisms and strength for how this operates in seabirds is less well understood, primarily due to the challenges of collecting the necessary data.

10. The Applicant has reviewed the Natural England PVA guidance on how density dependence is included in the online version of the tool. The density dependent function provided has been set to operate in a very weak manner, scaled to operate with a 10-fold change in population size. Comparted within the extent to which seabird populations change across periods of 30 years (as simulated here) changes of this size would be the exception rather than the norm (e.g. a population would need to increase from 10,000 individuals to 100,000, or decrease by this amount, for the full effect of density dependence to be observed). The practical consequence of this for the PVA tool is that density dependent model runs produce outputs which are largely indistinguishable from density independent outputs and little insight is gained as to how the population response to an impact varies with and without density dependence. This approach to modelling density dependence differs from that used in previous PVA for the FFC SPA (e.g. MacArthur Green 2018 as referenced in APP-201) which applied density dependence in a manner consistent with seabird populations (e.g. Cury et al. 2013). Indeed, the version of the Natural England PVA tool which can be run within the R programming environment[2] (rather than online)

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offers greater flexibility in this regard, with options to select different forms of density dependence which are better supported by the, albeit limited, empirical evidence. It is not explained why these options were not included in the online version (which Natural England has advised the Applicant should use).

11. Hence, while the Applicant had intended to run the PVA models using the Natural England PVA tool under both density dependent and density independent options and provide the results for comparison, due to the way the PVA tool is currently set up it was determined that there was little additional insight to be gained from doing so. It is acknowledged that care must be taken when setting the form and strength of density dependent regulation in a population model. However, it remains the case that density independent PVA predictions are, with very few exceptions, less realistic than density dependent ones which have been based on life history theory and evidence of how seabird populations are regulated. Indeed, if density dependence is considered as a continuum, from fully density independent to strongly density dependent, density independent predictions can be considered to have the least scientific support and to provide the least reliable predictions. While this could be justified on the basis of being precautionary and basing decisions on an assessment of the worst case outcomes, the Applicant considers that such an interpretation is overly simplistic for two reasons. Firstly, density dependent PVA undertaken in an appropriate manner is still precautionary. Secondly, density independent PVA is Natural England’s preferred approach not because there is supporting evidence for density independent growth but because of the challenges in estimating how density dependence operates in natural populations. In almost all instances a density independent model will be over-precautionary and will provide unrealistic predictions.

12. Inclusion of density dependence also influences consideration of which counterfactual outputs are more appropriate. PVA counterfactuals are relative measures of population metrics, derived as the impacted value divided by the unimpacted (or baseline) value. Thus, if the impact has no effect on (for example) population size, the counterfactual metric will have a value of 1, while any reduction in the metric caused by the impact will result in a counterfactual with a value less than 1. These are often presented interchangeably on both a proportional scale (i.e. between 0 and 1) and also converted into percentages.

13. The SoS requested comparisons of the SPA population sizes for gannet and kittiwake after 30 years with and without the development (Norfolk Boreas). This metric is referred to as the counterfactual of population size (CPS). A second informative metric from PVA analysis is the counterfactual of the population growth rate (CPGR) which compares the population’s rate of annual growth with and without the impact (averaged across a period of years).

14. Although both counterfactual measures (CPS and CPGR) are provided in this report, the Applicant considers that they are not equally appropriate for model interpretation in all cases, due to the role of density dependence. As discussed above, a density independent population has no constraint on growth. Thus, a density independent population with a positive growth rate will grow exponentially and the baseline and impacted populations will diverge by an increasing amount as the duration increases. In other words, the CPS is sensitive to the period it is measured over. But neither the baseline nor impacted population projections are likely to be credible since seabird populations are constrained by factors such as nest site availability, prey availability etc., as explained above (i.e. aspects which lead to density dependence). Hence a density independent CPS is a comparison of two unrealistic population predictions. In contrast, the CPGR is time invariant; the value is the same whether the simulation runs for 20 years, 30 years or 100 years (while the CPS for these would be very different). All else being equal, a measure with lower sensitivity to input parameters is to be preferred, which in the case of density independent PVA is the CPGR.

15. The stable state for a density dependent population is a growth rate of 1. Therefore, if the PVA model is run with density dependence then the population growth of both the baseline and impacted runs will stabilise to 1 (i.e. zero net growth), but the impacted population will have a lower (average) stable population size. In this case the CPGR is of limited utility since it will have a value of around 1 irrespective of the impact magnitude, but the CPS will provide a measure of how much smaller the impacted population is predicted to be.

16. Thus, in summary if the PVA is density independent (as presented here for reasons outside the Applicant’s control) then the CPGR is considered more robust and informative, while if the PVA is density dependent then the CPS is considered more robust and informative.

17. For these reasons, while both CPS and CPGR are provided, the interpretation of the density independent PVA outputs focusses on the CPGR. In all cases models were run for 5,000 simulations, as advised by Natural England. The full model inputs are provided in Appendix 2 PVA parameter logs.

3 Norfolk Boreas Alone Collision Risk Modelling

3.1 Gannet

18. The updated parameters used to date in the gannet collision risk assessment and those used for the updated modelling are provided in Table 3.1. All other parameters in the model remain as provided in REP5-059, REP2-035 and APP-566.

Table 3.1 Collision modelling parameter values for the rates which have been updated.

Parameter	Original value (used in assessment to date)	Updated value (Cook 2021)	Updated value (MacArthur Green 2021[3])
Avoidance rate	98.9%	98.6%	99.4%
Nocturnal activity rate	50%	25%	25%
Macro displacement	0%	60-80%	60-80%

19. It should be noted that Cook (2021) do not estimate a gannet avoidance rate directly (owing to insufficient data) and recommend use of the ‘all gull’ rate (98.6%) together with an additional reduction in the seabird density estimate of 60-80% in acknowledgement of the marked macro-avoidance behaviour (i.e. very few gannets enter wind farms) recorded at multiple sites. Since seabird density has a 1:1 link to collision mortality estimates it is straightforward to apply this adjustment to both the current project and also retrospectively to older wind farm estimates (i.e. the collision mortality is simply multiplied by 0.4 for 60% macro avoidance or 0.2 for 80% macro avoidance).

20. The recommended avoidance rate for gannet is the ‘all gull’ rate, which was estimated by Cook (2021) using a nocturnal activity rate (25%) which is lower than that recommended for use in gull collision assessments to date (50%). This means that the Cook (2021) avoidance rate cannot be applied retrospectively to older collision estimates for gull species such as kittiwake (i.e. the CRM needs to be rerun using both the alternative avoidance rate and the lower nocturnal activity rate). However, because the nocturnal rate already advised for gannet assessments is 25%, the Cook (2021) avoidance rate can be straightforwardly applied to older collision predictions (i.e. the existing mortality can be adjusted for the difference between the old and new avoidance rate). However, as noted above, the Cook (2021) all gull avoidance rate is not considered to be robust due to the inclusion of a highly questionable study (see Appendix 2 of The Applicant's Response to the Request for Additional Information (ExA.PDR.D22.V1)). Removing this single data point (1 of 415) increases the all gull avoidance rate from 98.74% to 99.13%. Collisions estimated using this rate are also provided in Table 3.2.

21. This includes total collisions at the wind farm and those apportioned to the Flamborough and Filey Coast (FFC) SPA.

[3] Appendix 2 of The Applicant's Response to the Request for Additional Information (ExA.PDR.D22.V1) submitted on 21st October 2021.

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Table 3.2 Original and updated collision mortality estimates for Norfolk Boreas. Mean values and 95% confidence intervals.

Parameter	Original mortality (used in assessment to date; REP5-059)		Alternative mortality (Cook 2021)				Updated mortality (MacArthur Green 2021)			
	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Macro-avoidance	**0%**		**60%**		**80%**		**60%**		**80%**	
Avoidance rate	**98.9%**		**98.74%**		**98.74%**		**99.13%**		**99.13%**	
Jan	0.2 (0-0.9)	0 (0-0)	0.1 (0-0.4)	0 (0-0)	0 (0-0.2)	0 (0-0)	0.1 (0-0.3)	0 (0-0)	0 (0-0.1)	0 (0-0)
Feb	0.4 (0-1)	0 (0-0)	0.2 (0-0.5)	0 (0-0)	0.1 (0-0.2)	0 (0-0)	0.1 (0-0.3)	0 (0-0)	0.1 (0-0.2)	0 (0-0)
Mar	0.5 (0-1.5)	0.5 (0-1.5)	0.2 (0-0.7)	0.2 (0-0.7)	0.1 (0-0.3)	0.1 (0-0.3)	0.2 (0-0.5)	0.2 (0-0.5)	0.1 (0-0.2)	0.1 (0-0.2)
Apr	0.2 (0-0.9)	0.2 (0-0.9)	0.1 (0-0.4)	0.1 (0-0.4)	0.1 (0-0.2)	0.1 (0-0.2)	0.1 (0-0.3)	0.1 (0-0.3)	0 (0-0.1)	0 (0-0.1)
May	1 (0.3-2)	1 (0.3-2)	0.5 (0.1-0.9)	0.5 (0.1-0.9)	0.2 (0.1-0.5)	0.2 (0.1-0.5)	0.3 (0.1-0.6)	0.3 (0.1-0.6)	0.2 (0-0.3)	0.2 (0-0.3)
Jun	0.4 (0-1.5)	0.4 (0-1.5)	0.2 (0-0.7)	0.2 (0-0.7)	0.1 (0-0.4)	0.1 (0-0.4)	0.1 (0-0.5)	0.1 (0-0.5)	0.1 (0-0.2)	0.1 (0-0.2)
Jul	0.3 (0-1)	0.3 (0-1)	0.1 (0-0.5)	0.1 (0-0.5)	0.1 (0-0.2)	0.1 (0-0.2)	0.1 (0-0.3)	0.1 (0-0.3)	0 (0-0.2)	0 (0-0.2)
Aug	10 (0-24)	10 (0-24)	4.6 (0-11)	4.6 (0-11)	2.3 (0-5.5)	2.3 (0-5.5)	3.2 (0-7.6)	3.2 (0-7.6)	1.6 (0-3.8)	1.6 (0-3.8)
Sep	1.7 (0.4-3.6)	1.7 (0.4-3.6)	0.8 (0.2-1.7)	0.8 (0.2-1.7)	0.4 (0.1-0.8)	0.4 (0.1-0.8)	0.5 (0.1-1.2)	0.5 (0.1-1.2)	0.3 (0.1-0.6)	0.3 (0.1-0.6)
Oct	2.2 (0.2-5.2)	0.1 (0-0.3)	1 (0.1-2.4)	0.1 (0-0.1)	0.5 (0-1.2)	0 (0-0.1)	0.7 (0.1-1.6)	0 (0-0.1)	0.3 (0-0.8)	0 (0-0)
Nov	10.5 (5.7-15.9)	0.7 (0.4-1)	4.8 (2.6-7.3)	0.3 (0.2-0.5)	2.4 (1.3-3.6)	0.1 (0.1-0.2)	3.3 (1.8-5)	0.2 (0.1-0.3)	1.7 (0.9-2.5)	0.1 (0.1-0.2)
Dec	3.3 (1.9-5)	0.2 (0.1-0.3)	1.5 (0.9-2.3)	0.1 (0.1-0.1)	0.8 (0.4-1.1)	0 (0-0.1)	1 (0.6-1.6)	0.1 (0-0.1)	0.5 (0.3-0.8)	0 (0-0)
Annual	**30.7 (8.5-62.5)**	**15.2 (1.2-36.2)**	**14.1 (3.9-28.8)**	**6.9 (0.5-16.7)**	**7 (1.9-14.2)**	**3.5 (0.3-8.3)**	**9.7 (2.7-19.8)**	**4.8 (0.4-11.5)**	**4.9 (1.3-9.8)**	**2.4 (0.2-5.7)**

22. Using the previously agreed avoidance rate (98.9%) with no additional macro-avoidance, the total gannet collision mortality is 30.7 and the mortality apportioned to the FFC SPA is 15.2.

23. Using the alternative rates in Cook (2021) and a macro avoidance rate of 60%, these values are 14.1 and 6.9 respectively. Using a macro avoidance rate of 80%, these values are 7.0 and 3.5, respectively.

24. Using the Applicant’s rates estimated from the Cook (2021) data and analysis but with the statistical outlier data point omitted, at a macro avoidance rate of 60% these values are 9.7 and 4.8 and at 80% macro avoidance 4.9 and 2.4, respectively.

25. Thus, using the alternative avoidance rates the collision estimates for gannet are reduced by at least 55% (Cook 2021 rates and 60% macro avoidance) and by up to 84% (with the statistical outlier in Cook 2021 omitted and 80% macro avoidance).

3.1.1 In-combination collision risk Assessment

26. The summary cumulative and in-combination gannet collision estimates are provided in Table 3.3. The previous total, up to and including Hornsea Project Three, is provided along with updated estimates which bracket the range of alternative avoidance rates considered. The upper estimate uses the Cook (2021) recommended avoidance rate of 98.74% with 60% macro avoidance and the lower estimate uses the revised Cook (2021) estimate (Appendix 2 of The Applicant's Response to the Request for Additional Information (ExA.PDR.D22.V1)) obtained with the outlying data point omitted with a macro avoidance rate of 80%.

27. The in-combination total apportioned to the FFC SPA is reduced from 257 obtained with the previous methods to an upper estimate of 118 and a lower estimate of 41, a 54% to 84% reduction in predicted collisions.

Table 3.3 Gannet cumulative and in-combination collisions apportioned to the FFC SPA. The 'Previous OWFs' is a summed total including all wind farms in the assessment up to Hornsea Project Three in England and Moray West in Scotland (full table in Appendix 1 Cumulative and in-combination collisions). The updated mortality estimates have been calculated using the collision avoidance rates and macro avoidance rates indicated.

Wind farms	Avoidance rate	Macro avoidance	Breeding		Autumn		Spring		Annual	
			Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Previous OWFs (as per REP8-025)	98.9	0%	1744.8	185.7	757.4	36.15	310.7	19.04	2813	241.7
Previous OWF (update)	98.74	60%	799.4	85.1	347.0	16.6	142.4	8.7	1288.9	110.7
	99.13	80%	276.0	29.4	119.8	5.7	49.1	3.0	445.0	38.2
Norfolk Boreas (REP5-059)	98.9	0%	14.1	14.2	12.7	0.61	3.9	0.24	30.7	15.1
Norfolk Boreas (update)	98.74	60%	6.5	6.5	5.8	0.3	1.8	0.1	14.1	6.9
	99.13	80%	2.2	2.2	2.0	0.1	0.6	0.0	4.9	2.4
Total with Norfolk Boreas (as per REP8-025)	98.9	0%	1758.9	199.9	770.1	36.8	314.6	19.3	2843.7	256.8
Total with Norfolk Boreas (update)	**98.74**	**60%**	**805.9**	**91.6**	**352.8**	**16.8**	**144.1**	**8.8**	**1302.9**	**117.7**
	99.13	**80%**	**278.2**	**31.6**	**121.8**	**5.8**	**49.8**	**3.0**	**449.8**	**40.6**

3.1.2 In-combination displacement risk

28. For the updated gannet PVA it is also necessary to include displacement. Table 3.4 provides the population abundance estimate from which displacement mortality has been estimated (using 80% displacement and 1% mortality) for inclusion in the PVA.

Table 3.4 Gannet cumulative and in-combination population abundance apportioned to the FFC SPA. The 'Previous OWFs' is a summed total including all wind farms in the assessment up to Hornsea Project Three in England and Moray West in Scotland (full table in Appendix 1 Cumulative and in-combination collisions).

Wind Farm	Breeding		Autumn		Spring		Annual	
	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Previous OWFs	18526	4651	15009	720	3812	236.3	37347	5607.3
Displacement mortality (80% displaced x 1% mortality)	148.2	37.2	120.1	5.8	30.5	1.9	298.8	44.9
Norfolk Boreas	1229	1229	1723	82.7	526	32.6	3478	1344.3
Displacement mortality (80% displaced x 1% mortality)	9.8	9.8	13.8	0.7	4.2	0.3	27.8	10.8
Updated total	**19755**	**5880**	**16732**	**802.7**	**4338**	**268.9**	**40825**	**6951.6**
Displacement mortality (80% displaced x 1% mortality)	**158.0**	**47.0**	**133.9**	**6.4**	**34.7**	**2.2**	**326.6**	**55.6**

3.1.3 PVA for in-combination collision and displacement mortality

The figures in the final column of Table 3.3 were combined with the FFC SPA total displacement (55.6) from Table 3.4 to give the range of additional mortalities to use as inputs to the Natural England PVA tool (see Appendix 2 PVA parameter logs) The CPS and CPGR for each mortality are provided in Table 3.5.

Table 3.5 Gannet FFC SPA mortalities and population modelling results using the Natural England PVA tool

Scenario	Norfolk Boreas collision mortality	Norfolk Boreas displacement mortality	Other wind farm collision mortality	Other wind farm displacement mortality	Total additional in-combination adult mortality	Density independent counterfactual metric (after 30 years)	
						Growth rate	Population size
In-combination displacement and collision exc. Norfolk Boreas (@98.74% and 60% macro)	0	0	110.7	44.9	155.6	0.9931	0.8062
In-combination displacement and collision inc. Norfolk Boreas (@99.13% and 80% macro)	2.4	10.8	110.7	44.9	168.8	0.9925	0.7914
In-combination displacement and collision inc. Norfolk Boreas (@98.74% and 60% macro)	6.9	10.8	110.7	44.9	173.3	0.9923	0.7867
In-combination displacement and collision exc. Norfolk Boreas (@99.13% and 80% macro)	0	0	38.20	44.9	83.1	0.9963	0.8914
In-combination displacement and collision inc. Norfolk Boreas (@99.13% and 80% macro)	10.8	2.4	38.20	44.9	96.3	0.9957	0.8754
In-combination displacement and collision inc. Norfolk Boreas (@98.74% and 60% macro)	10.8	6.9	38.20	44.9	100.8	0.9955	0.8699

29. Using the Cook (2021) avoidance rate (98.74%) and 60% macro avoidance for all wind farms (including Norfolk Boreas), giving an in-combination collision and displacement mortality of 173.3, the density independent PVA results indicated that the maximum reduction in growth rate was 0.77% (0.9923). At this mortality the CPS indicated the gannet population would be 79% (0.7867) of the baseline (unimpacted) size after 30 years.

30. Comparing the in-combination collision and displacement mortality results, the addition of Norfolk Boreas reduced the population growth rate by 0.09% (0.9931-0.9923) using the Cook (2021) avoidance rates and 0.07% (0.9931-0.9925) using the Cook (2021) avoidance rate with the outlying study omitted and 80% macro avoidance. The equivalent reductions in population size were 1.9% and 1.5%, however as noted above the CPS is considered a less reliable metric for density independent simulations.

31. These PVA results compare to the observed rate at which the FFC SPA population has grown over the last 25 years, which has been at least 10% per year. A reduction of less than 1% in this rate represents a negligible risk for the population. Natural England (2019) suggested that, if the SPA population follows a similar pattern of growth to those observed at colonies of a similar age, the observed rate of growth is likely to decrease over the coming decades. Natural England (2019) does not discuss the reasons for this apparent pattern in other colonies, however it is reasonable to assume that this would occur due to increasing levels of competition for resources, in other words a *density dependent* response. On this basis it would be expected that the results from a *density dependent* PVA would be more appropriate to consider, however as discussed above there is no means at present for realistic levels of density dependence to be simulated using the Natural England PVA tool.

32. The gannet breeding numbers at the FFC SPA have continued to increase in all counts conducted to date and the gannet population is therefore clearly in favourable conservation status. The relevant conservation objective is to maintain favourable conservation status of the gannet population, subject to natural change.

33. On the basis of the population model predictions the number of predicted collision and displacement mortalities at Norfolk Boreas in-combination with other North Sea wind farms with potential connectivity to the FFC SPA is not at a level which would trigger a risk of population decline but would only result in a slight reduction in the growth rate currently seen at this colony.

34. The contribution of Norfolk Boreas to the in-combination totals is also very small, making an additional reduction to the growth rate of no more than 0.09% and an additional reduction in CPS of 1.9%, which means that the population size would be 1.9% below the size it would reach without the wind farm.

35. Therefore, since the gannet population has very favourable status and even when assessed using precautionary methods the impacts will only slightly reduce the population growth rate, which will remain positive, it can be concluded that, even with the high degree of precaution in the assessment (see [REP2-035] and [REP6-021]), there will be no adverse effect on the integrity of FFC SPA from impacts on gannet due to in-combination collision mortality, in-combination displacement mortality and the two sources of impact combined.

3.2 Kittiwake

36. The updated parameters used to date in the kittiwake collision risk assessment and those used for the updated modelling are provided in Table 3.6. All other parameters in the model remain as provided in REP5-059, REP2-035 and APP-566.

Table 3.6 Kittiwake collision modelling parameter values for the rates which have been updated.

Parameter	Original value (used in assessment to date)	Updated value (Cook 2021)	Updated value (MacArthur Green 2021)
Avoidance rate	98.9%	98.74%	99.13%
Nocturnal activity rate	50%	25%	25%

37. The collision estimates are provided in Table 3.7. This includes total collisions at the wind farm and those apportioned to the FFC SPA.

Table 3.7 Kittiwake original and updated collision mortality estimates. Mean values and 95% confidence intervals.

Parameter	Original mortality (used in assessment to date)		Alternative mortality (Cook 2021)		Updated mortality (MacArthur Green 2021)	
	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Avoidance rate	**98.9%**		**98.74%**		**99.13%**	
Nocturnal activity rate	**50%**		**25%**		**25%**	
Jan	9.2 (3.1-16.3)	0.7 (0.2-1.2)	8 (2.7-14.1)	0.6 (0.2-1)	5.5 (1.9-9.7)	0.4 (0.1-0.7)
Feb	2.7 (0.8-5)	0.2 (0.1-0.4)	2.5 (0.8-4.6)	0.2 (0.1-0.3)	1.7 (0.5-3.2)	0.1 (0-0.2)
Mar	1.5 (0-3.7)	1.3 (0-3.2)	1.4 (0-3.5)	1.2 (0-3)	1 (0-2.4)	0.8 (0-2.1)
Apr	2.5 (1.3-4.3)	2.2 (1.1-3.7)	2.5 (1.2-4.3)	2.2 (1-3.7)	1.7 (0.9-2.9)	1.5 (0.8-2.5)
May	3.5 (1.6-5.5)	3 (1.4-4.7)	3.6 (1.7-5.6)	3.1 (1.5-4.8)	2.5 (1.2-3.9)	2.1 (1-3.4)
Jun	1.9 (0-4.9)	1.6 (0-4.2)	2 (0-5.1)	1.7 (0-4.4)	1.4 (0-3.5)	1.2 (0-3)
Jul	3.1 (0.6-6.6)	2.6 (0.5-5.7)	3.2 (0.6-6.9)	2.7 (0.5-5.9)	2.2 (0.4-4.8)	1.9 (0.3-4.1)
Aug	0.8 (0-2.4)	0.7 (0-2.1)	0.8 (0-2.4)	0.7 (0-2.1)	0.6 (0-1.7)	0.5 (0-1.5)
Sep	1.1 (0-2.9)	0.1 (0-0.2)	1.1 (0-2.8)	0.1 (0-0.2)	0.7 (0-2)	0 (0-0.1)
Oct	2.9 (0-7.6)	0.2 (0-0.4)	2.6 (0-7.1)	0.1 (0-0.4)	1.8 (0-4.9)	0.1 (0-0.3)
Nov	8.6 (4.1-14)	0.5 (0.2-0.8)	7.6 (3.6-12.3)	0.4 (0.2-0.7)	5.2 (2.5-8.5)	0.3 (0.1-0.5)
Dec	19.7 (12.8-27.1)	1.1 (0.7-1.5)	16.7 (10.9-23)	0.9 (0.6-1.2)	11.5 (7.5-15.9)	0.6 (0.4-0.9)
Annual	**57.5 (24.3-100.3)**	**14 (4.2-27.9)**	**51.9 (21.5-91.7)**	**13.9 (4-27.7)**	**35.9 (14.9-63.4)**	**9.6 (2.9-19.1)**

38. Using the previously agreed avoidance rate (98.9%) and nocturnal activity rate (50%) the total kittiwake collision mortality is 57.5 and the mortality apportioned to the FFC SPA is 14.0.

39. Using the rates in Cook (2021) these values are 51.9 and 13.9 respectively. Using the Applicant’s rates estimated from the Cook (2021) data and analysis but with the statistical outlier data point omitted the values are 35.9 and 9.6 respectively.

40. As set out in Appendix 2 of The Applicant's Response to the Request for Additional Information (ExA.PDR.D22.V1),the Applicant does not consider the Cook (2021) avoidance rate to be robust due to the inclusion of one unreliable outlying study. When this data point is removed, and the lower nocturnal rate applied, the kittiwake collision estimate apportioned to the FFC SPA is reduced by 31% from 14 to 9.6.

41. As discussed above, it is not appropriate to apply the updated avoidance rates in Cook (2021) or the adjusted rate with the outlying data point omitted because these were estimated using a different nocturnal activity rate than has been recommended by Natural England to date. However, it is likely that similar magnitudes of reduction in collisions would be obtained for other wind farms as for Norfolk Boreas. Thus reductions of around 30% (as obtained for Norfolk Boreas) could be expected for the in-combination total. However, it must be stressed that the actual reduction will vary, depending on the seasonal patterns of kittiwake abundance at each wind farm and its latitude, as these both affect the change in collision risk.

3.2.1 In-combination collision risk assessment

The summary cumulative and in-combination kittiwake collision estimates are provided in Table 3.8.

Table 3.8 Kittiwake summary cumulative and in-combination collisions apportioned to the FFC SPA. The 'Previous OWFs' is a summed total including all wind farms in the assessment up to Hornsea Project Three in England and Moray West in Scotland (full table in Appendix 1 Cumulative and in-combination collisions).

Wind Farm	Avoidance rate	Nocturnal activity rate	Breeding		Autumn		Spring		Annual	
			Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Previous OWFs (as per REP8-025)	98.9%	50%	1170.3	161.2	1484.2	78.1	1151	82.4	3805.5	321.6
Norfolk Boreas (as per REP5-059)	98.9%	50%	13.3	11.4	32.2	1.7	11.9	0.9	57.5	14
Norfolk Boreas (using Cook 2021)	98.74%	25%	13.5	11.6	28	1.5	10.4	0.8	51.9	13.9
Norfolk Boreas (using Cook 2021 adjusted)	99.13%	25%	9.3	8	19.3	1	7.2	0.5	35.9	9.6
Total (inc. Norfolk Boreas as per REP5-059)	**98.9%**	**50%**	**1183.6**	**172.6**	**1516.4**	**79.8**	**1162.9**	**83.3**	**3863**	**335.6**
Total (inc. Norfolk Boreas using Cook 2021)	**98.9% / 98.74%**	**50% / 25%**	**1183.8**	**172.8**	**1512.2**	**79.6**	**1161.4**	**83.2**	**3857.4**	**335.5**
Total (inc. Norfolk Boreas using adjusted Cook 2021)	**98.9% / 99.13%**	**50% / 25%**	**1179.6**	**169.2**	**1503.5**	**79.1**	**1158.2**	**82.9**	**3841.4**	**331.2**

3.2.2 PVA for in-combination collision mortality

42. The figures in the final column of Table 3.8 were entered as additional mortality into the Natural England PVA tool (see Appendix 2 PVA parameter logs). The CPS and CPGR for each mortality are provided in Table 3.9.

Table 3.9 Kittiwake FFC SPA mortalities and population modelling results using the Natural England PVA tool

Scenario	Norfolk Boreas (mortality included)	Total additional adult mortality	Density independent counterfactual metric (after 30 years)	
			Growth rate	Population size
Previous OWFs (as per REP8-025)	0	321.6	0.9963	0.8918
Total (inc. Norfolk Boreas using Cook 2021)	9.6	331.2	0.9962	0.8886
Total (inc. Norfolk Boreas using adjusted Cook 2021)	13.9	335.5	0.9962	0.8874

43. The density independent PVA results indicate that the maximum reduction in growth rate was 0.4% (0.9962) for an in-combination collision mortality of 335.5. At this mortality the CPS indicates the kittiwake population after 30 years would be 89% (0.8871) of the baseline (unimpacted) size.

44. Comparing the in-combination collision mortality results with and without Norfolk Boreas, the maximum population growth rate reduction was 0.016% (0.9963-0.9962). The equivalent reduction in population size was 0.44%, however as noted above the CPS is considered a less reliable metric for density independent simulations.

45. The kittiwake breeding numbers at the Flamborough and Filey Coast SPA have remained relatively stable with an average of almost 44,000 pairs over the last 20 years (Lloyd et al. 2019), although between 2008 and 2017 the population grew at over 2% per year. A maximum reduction of 0.4% in the growth rate would not trigger a population decline, and the contribution from Norfolk Boreas is only 0.016% (i.e. a difference between a growth rate reduction of 0.384% and 0.368%).

46. On the basis of the population model predictions, the number of predicted collision mortalities at Norfolk Boreas in-combination with other North Sea wind farms with potential connectivity to the FFC SPA is not at a level which would trigger a risk of population decline, since the population growth rate remains positive and would only result in a slight reduction in the growth rate currently seen at this colony.

47. The contribution of Norfolk Boreas to the in-combination totals is also very small, making an additional reduction to the growth rate of no more than 0.016% and an additional reduction in CPS of no more than 0.44%, which means that the population size would be 0.44% below the size it would reach without the wind farm.

48. Therefore, it can be concluded that, even with the high degree of precaution in the assessment (see [REP2-035] and [REP6-021]), there will be no adverse effect on the integrity of the FFC SPA from impacts on kittiwake due to in-combination collision mortality.

4 References

Cook, A S C P, Humphreys, E. M., Masden, E. A., & Burton, N. H. K. (2014). The Avoidance Rates of Collision Between Birds and Offshore Turbines. Edinburgh.

Cook, A (2021) Additional Analysis to Support SNCB Recommendations Regarding Collision Risk Modelling. BTO Research Report 739.

Cury P. M., Boyd I., Bonhommeau S., Anker-Nilssen T., Crawford R. J. M., Furness R. W., Mills J. A., et al. (2011). Global seabird response to forage fish depletion: one-third for the birds. Science 334: 1703–1706.

Lloyd, I., Aitken, D., Wildi, J. and O'Hara, D. (2019) Flamborough and Filey Coast SPA Seabird Monitoring Programme 2019 Report. RSPB unpubl. report.

MacArthur Green (2018). Flamborough and Filey Coast pSPA Seabird PVA Report Supplementary matched run outputs 2018. Submitted as Appendix 9 to Deadline 1 submission – PVA. Hornsea Project Three.

Natural England (2019) Natural England's Comments on Norfolk Vanguard Ltd. Deadline 7 and Deadline 7.5 submissions in relation to Offshore Ornithology Related Matters. 30 May 2019

MacArthur Green (2021). Avoidance Rates Note. Appendix 2 to the Response to the Request for Further Information (ExA.PDR.D22.V1) submitted 21st October 2021.

Appendix 1 Cumulative and in-combination collisions

Table A1.1 Gannet cumulative and in-combination collision risk. Wind farm estimates using 98.9% collision avoidance and 0% macro avoidance. Totals amended to reflect recommended collision avoidance and macro avoidance in Cook (2021) and the Applicant's review of Cook (2021).

Wind farm	Breeding season		Autumn migration		Spring migration		Annual	
	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Beatrice Demonstrator	0.6	0	0.9	0.04	0.7	0.05	2.2	0.1
Greater Gabbard	14	0	8.8	0.42	4.8	0.3	27.5	0.7
Gunfleet Sands	-	-	-	-	-	-	-	-
Kentish Flats	1.4	0	0.8	0.04	1.1	0.07	3.3	0.1
Kentish Flats Extension	-	-	-	-	-	-	-	-
Lincs	2.1	2.1	1.3	0.06	1.7	0.1	5	2.3
London Array	2.3	0	1.4	0.07	1.8	0.11	5.5	0.2
Lynn and Inner Dowsing	0.2	0.2	0.1	0.01	0.2	0.01	0.5	0.2
Scroby Sands	-	-	-	-	-	-	-	-
Sheringham Shoal	14.1	14.1	3.5	0.17	0	0	17.6	14.3
Teesside	4.9	2.4	1.7	0.08	0	0	6.7	2.5
Thanet	1.1	0	0	0	0	0	1.1	0
Humber Gateway	1.9	1.9	1.1	0.05	1.5	0.09	4.5	2
Westermost Rough	0.2	0.2	0.1	0.01	0.2	0.01	0.5	0.2
Hywind	5.6	0	0.8	0.04	0.8	0.05	7.2	0.1
Kincardine	3	0	0	0	0	0	3	0
Beatrice	37.4	0	48.8	2.34	9.5	0.59	95.7	2.9
Dudgeon	22.3	22.3	38.9	1.87	19.1	1.18	80.3	25.3
Galloper	18.1	0	30.9	1.48	12.6	0.78	61.6	2.3
Race Bank	33.7	33.7	11.7	0.56	4.1	0.25	49.5	34.5
Rampion	36.2	0	63.5	3.05	2.1	0.13	101.8	3.2
Hornsea Project One	11.5	11.5	32	1.54	22.5	1.4	66	14.4
Blyth Demonstration Project	3.5	0	2.1	0.1	2.8	0.17	8.4	0.3
Dogger Bank Creyke Beck Projects A and B	81.1	40.6	83.5	4.0	54.4	3.4	219.0	47.9
East Anglia ONE	3.4	3.4	131	6.3	6.3	0.4	140.7	10.1
European Offshore Wind Deployment Centre	4.2	0	5.1	0.25	0.1	0	9.3	0.3
Firth of Forth Alpha and Bravo	800.8	0	49.3	2.37	65.8	4.08	915.9	6.4
Inch Cape	336.9	0	29.2	1.4	5.2	0.32	371.3	1.7
Methil	6	0	0	0	0	0	6	0
Moray Firth (EDA)	80.6	0	35.4	1.7	8.9	0.55	124.9	2.3
Neart na Gaoithe	143	0	47	2.26	23	1.43	213	3.7
Dogger Bank Teesside Projects A and B	14.8	7.4	10.1	0.49	10.8	0.67	35.7	8.5
Triton Knoll	26.8	26.8	64.1	3.08	30.1	1.87	121	31.7
Hornsea Project Two	7	7	14	0.67	6	0.37	27	8
East Anglia THREE	6.1	6.1	33.3	1.6	9.6	0.6	49	8.3
Moray West	10	0	2	0.1	1	0.06	13	0.2
Hornsea Project Three	10	6	5	0	4	0	19	7
Total (above @98.9% and 0% macro)	1744.8	185.7	757.4	36.15	310.7	19.04	2813	241.7
Total (above @98.74% and 60% macro)	799.4	85.1	347.0	16.6	142.4	8.7	1288.9	110.7
Total (above @98.74% and 80% macro)	399.7	42.5	173.5	8.3	71.2	4.4	644.4	55.4
Total (above @99.13% and 60% macro)	552.0	58.7	239.6	11.4	98.3	6.0	889.9	76.5
Total (above @99.13% and 80% macro)	276.0	29.4	119.8	5.7	49.1	3.0	445.0	38.2

Wind farm	Breeding season		Autumn migration		Spring migration		Annual	
	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Norfolk Boreas (@98.9% and 0% macro; REP5-059)	14.1	14.2	12.7	0.61	3.9	0.24	30.7	15.1
Norfolk Boreas (x60% macro @98.74%)	6.5	6.5	5.8	0.3	1.8	0.1	14.1	6.9
Norfolk Boreas (x80% macro @98.74%)	3.2	3.3	2.9	0.1	0.9	0.1	7.0	3.5
Norfolk Boreas (x60% macro @99.13%)	4.5	4.5	4.0	0.2	1.2	0.1	9.7	4.8
Norfolk Boreas (x80% macro @99.13%)	2.2	2.2	2.0	0.1	0.6	0.0	4.9	2.4
Total (inc. Norfolk Boreas @98.9% and 0% macro; REP8-025)	**1758.9**	**199.9**	**770.1**	**36.8**	**314.6**	**19.3**	**2843.7**	**256.8**
Total (inc. Norfolk Boreas @98.74% and 60% macro)	**805.9**	**91.6**	**352.8**	**16.8**	**144.1**	**8.8**	**1302.9**	**117.7**
Total (inc. Norfolk Boreas @98.74% and 80% macro)	**402.9**	**45.8**	**176.4**	**8.4**	**72.1**	**4.4**	**651.5**	**58.8**
Total (inc. Norfolk Boreas @99.13% and 60% macro)	**556.5**	**63.2**	**243.6**	**11.6**	**99.5**	**6.1**	**899.6**	**81.2**
Total (inc. Norfolk Boreas @99.13% and 80% macro)	**278.2**	**31.6**	**121.8**	**5.8**	**49.8**	**3.0**	**449.8**	**40.6**

Table A1.2 Updated kittiwake cumulative and in-combination collision risk. Wind farm estimates using 98.9% collision avoidance. Totals include Norfolk Boreas amended to reflect recommended collision avoidance and macro avoidance in Cook (2021) and the Applicant's review of Cook (2021).

Wind farm	Breeding season		Autumn migration		Spring migration		Annual	
	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Beatrice Demonstrator	0.0	0.0	2.1	0.1	1.7	0.1	3.8	0.2
Greater Gabbard	1.1	0.0	15.0	0.8	11.4	0.8	27.5	1.6
Gunfleet Sands	-	-	-	-	-	-	-	
Kentish Flats	0.0	0.0	0.9	0.1	0.7	0.1	1.6	0.1
Kentish Flats Extension	0.0	0.0	0.0	0.0	2.7	0.2	2.7	0.2
Lincs	0.7	0.7	1.2	0.1	0.7	0.1	2.6	0.8
London Array	1.4	0.0	2.3	0.1	1.8	0.1	5.5	0.3
Lynn and Inner Dowsing	-	-	-	-	-	-	-	
Scroby Sands	-	-	-	-	-	-	-	
Sheringham Shoal	-	-	-	-	-	-	-	
Teesside	38.4	0.0	24.0	1.3	2.5	0.2	64.9	1.5
Thanet	0.2	0.0	0.5	0.0	0.4	0.0	1.1	0.1
Humber Gateway	1.9	1.9	3.2	0.2	1.9	0.1	7.0	2.2
Westermost Rough	0.1	0.1	0.2	0.0	0.1	0.0	0.5	0.1
Hywind	16.6	0.0	0.9	0.1	0.9	0.1	18.3	0.1
Kincardine	22.0	0.0	9.0	0.5	1.0	0.1	32.0	0.6
Beatrice	94.7	0.0	10.7	0.6	39.8	2.9	145.2	3.5
Dudgeon	-	-	-	-	-	-	-	
Galloper	6.3	0.0	27.8	1.5	31.8	2.3	65.9	3.8
Race Bank	1.9	1.9	23.9	1.3	5.6	0.4	31.4	3.6
Rampion	54.4	0.0	37.4	2.0	29.7	2.1	121.5	4.2
Hornsea Project One	44.0	36.5	55.9	3.0	20.9	1.5	120.8	41.0
Blyth Demonstration Project	1.7	0.0	2.3	0.1	1.4	0.1	5.4	0.2
Dogger Bank Creyke Beck Projects A and B	288.6	55.8	135.0	7.3	295.4	21.3	719.0	84.3
East Anglia ONE	1.8	0.0	160.4	8.7	46.8	3.4	209.0	12.0
European Offshore Wind Deployment Centre	11.8	0.0	5.8	0.3	1.1	0.1	18.7	0.4
Firth of Forth Alpha and Bravo	153.1	0.0	313.1	16.9	247.6	17.8	713.8	34.7
Inch Cape	13.1	0.0	224.8	12.1	63.5	4.6	301.4	16.7
Methil	0.4	0.0	0.0	0.0	0.0	0.0	0.4	0.0
Moray Firth (EDA)	43.6	0.0	2.0	0.1	19.3	1.4	64.9	1.5
Neart na Gaoithe	32.9	0.0	56.1	3.0	4.4	0.3	93.4	3.4
Dogger Bank Teesside Projects A and B	136.9	26.4	90.7	4.9	216.9	15.6	444.5	46.9
Triton Knoll	24.6	24.6	139.0	7.5	45.4	3.3	209.0	35.4
Hornsea Project Two	16.0	13.3	9.0	0.5	3.0	0.2	28.0	14.0
East Anglia THREE	6.1	0.0	69.0	3.7	37.6	2.7	112.7	6.4
Moray West	79.0	0.0	24.0	1.3	7.0	0.5	110.0	1.8
Hornsea Project Three	77	0 (72)	38	0 (2)	8	0 (1)	123	0 (65-74)*
Total (above @98.9% and 50% nocturnal)	1170.3	161.2	1484.2	78.1	1151	82.4	3805.5	321.6
Norfolk Boreas (@98.9% and 0% macro; REP5-059)	13.3	11.4	32.2	1.7	11.9	0.9	57.5	14
Norfolk Boreas (@98.74% and 25% nocturnal)	13.5	11.6	28	1.5	10.4	0.8	51.9	13.9

Wind farm	Breeding season		Autumn migration		Spring migration		Annual	
	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA	Total	FFC SPA
Norfolk Boreas (@99.13% and 25% nocturnal)	9.3	8	19.3	1	7.2	0.5	35.9	9.6
Total with Norfolk Boreas (as per REP5-059)	**1183.6**	**172.6**	**1516.4**	**79.8**	**1162.9**	**83.3**	**3863**	**335.6**
Total with Norfolk Boreas (using Cook 2021)	**1183.8**	**172.8**	**1512.2**	**79.6**	**1161.4**	**83.2**	**3857.4**	**335.5**
Total with Norfolk Boreas (using adjusted Cook 2021)	**1179.6**	**169.2**	**1503.5**	**79.1**	**1158.2**	**82.9**	**3841.4**	**331.2**

Appendix 2 PVA parameter logs

Gannet

Population Viability Analysis Parameter log

Set up

The log file was created on: 2021-10-04 08:49:34 using Tool version 2, with R version 3.5.1, PVA package version: 4.17 (with UI version 1.7)

```
##                Package         Version
## popbio         "popbio"        "2.4.4"
## shiny          "shiny"         "1.1.0"
## shinyjs        "shinyjs"       "1.0"
## shinydashboard "shinydashboard" "0.7.1"
## shinyWidgets   "shinyWidgets"  "0.4.5"
## DT             "DT"            "0.5"
## plotly         "plotly"        "4.8.0"
## rmarkdown      "rmarkdown"     "1.10"
## dplyr          "dplyr"         "0.7.6"
## tidyr          "tidyr"         "0.8.1"
```

Basic information

This run had reference name “Gannet DI FFC SPA”.
PVA model run type: simplescenarios.
Model to use for environmental stochasticity: betagamma.
Model for density dependence: nodd.
Include demographic stochasticity in model?: Yes.
Number of simulations: 5000.
Random seed: 50.
Years for burn-in: 0.
Case study selected: None.

Baseline demographic rates

Species chosen to set initial values: Northern Gannet.
Region type to use for breeding success data: Country.
Available colony-specific survival rate: National. Sector to use within breeding success region: England.
Age at first breeding: 5.
Is there an upper constraint on productivity in the model?: Yes, constrained to 1 per pair.
Number of subpopulations: 1.
Are demographic rates applied separately to each subpopulation?: No.
Units for initial population size: breeding.adults
Are baseline demographic rates specified separately for immatures?: Yes.

Population 1

Initial population values: Initial population 26782 in 2025

Productivity rate per pair: mean: 0.823 , sd: 0.038
Adult survival rate: mean: 0.919 , sd: 0.042
Immatures survival rates:
Age class 0 to 1 - mean: 0.424 , sd: 0.045 , DD: NA
Age class 1 to 2 - mean: 0.829 , sd: 0.026 , DD: NA
Age class 2 to 3 - mean: 0.891 , sd: 0.019 , DD: NA
Age class 3 to 4 - mean: 0.895 , sd: 0.019 , DD: NA
Age class 4 to 5 - mean: 0.919 , sd: 0.042 , DD: NA

Impacts

Number of impact scenarios: 6.

Are impacts applied separately to each subpopulation?: No
Are impacts of scenarios specified separately for immatures?: No
Are standard errors of impacts available?: No
Should random seeds be matched for impact scenarios?: No
Are impacts specified as a relative value or absolute harvest?: relative
Years in which impacts are assumed to begin and end: 2026 to 2056

Impact on Demographic Rates

Scenario A - Name: mort155.6

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.005809872 , se: NA

Scenario B - Name: mort168.8

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.006302741 , se: NA

Scenario C - Name: mort173.3

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.006470764 , se: NA

Scenario D - Name: mort83.1

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.00310283 , se: NA

Scenario E - Name: mort96.3

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.003595699 , se: NA

Scenario F - Name: mort100.8

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.003763722 , se: NA

Output:

First year to include in outputs: 2026
Final year to include in outputs: 2056
How should outputs be produced, in terms of ages?: whole.population
Target population size to use in calculating impact metrics: NA
Quasi-extinction threshold to use in calculating impact metrics: NA

Kittiwake

Population Viability Analysis Parameter log

The log file was created on: 2021-10-04 08:55:24 using Tool version 2, with R version 3.5.1, PVA package version: 4.17 (with UI version 1.7)

```
##                Package         Version
## popbio         "popbio"        "2.4.4"
## shiny          "shiny"         "1.1.0"
## shinyjs        "shinyjs"       "1.0"
## shinydashboard "shinydashboard" "0.7.1"
## shinyWidgets   "shinyWidgets"  "0.4.5"
## DT             "DT"            "0.5"
## plotly         "plotly"        "4.8.0"
## rmarkdown      "rmarkdown"     "1.10"
## dplyr          "dplyr"         "0.7.6"
## tidyr          "tidyr"         "0.8.1"
```

Basic information

This run had reference name “Kittiwake DI FFC SPA”.
PVA model run type: simplescenarios.
Model to use for environmental stochasticity: betagamma.
Model for density dependence: nodd.
Include demographic stochasticity in model?: Yes.
Number of simulations: 5000.
Random seed: 50.
Years for burn-in: 0.
Case study selected: None.

Baseline demographic rates

Species chosen to set initial values: Black-Legged Kittiwake.
Region type to use for breeding success data: Country.
Available colony-specific survival rate: National. Sector to use within breeding success region: England.
Age at first breeding: 4.
Is there an upper constraint on productivity in the model?: Yes, constrained to 2 per pair.
Number of subpopulations: 1.
Are demographic rates applied separately to each subpopulation?: No.
Units for initial population size: breeding.adults
Are baseline demographic rates specified separately for immatures?: Yes.

Population 1

Initial population values: Initial population 103070 in 2025

Productivity rate per pair: mean: 0.58 , sd: 0.096
Adult survival rate: mean: 0.854 , sd: 0.077
Immatures survival rates:

Age class 0 to 1 - mean: 0.79 , sd: 0.077 , DD: NA
Age class 1 to 2 - mean: 0.854 , sd: 0.077 , DD: NA
Age class 2 to 3 - mean: 0.854 , sd: 0.077 , DD: NA
Age class 3 to 4 - mean: 0.854 , sd: 0.077 , DD: NA

Impacts

Number of impact scenarios: 3.

Are impacts applied separately to each subpopulation?: No
Are impacts of scenarios specified separately for immatures?: No
Are standard errors of impacts available?: No
Should random seeds be matched for impact scenarios?: No
Are impacts specified as a relative value or absolute harvest?: relative
Years in which impacts are assumed to begin and end: 2026 to 2056

Impact on Demographic Rates

Scenario A - Name: mort321.6

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.00312021 , se: NA

Scenario B - Name: mort331.2

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.00321335 , se: NA

Scenario C - Name: mort335.5

All subpopulations

Impact on productivity rate mean: 0 , se: NA

Impact on adult survival rate mean: 0.003255069 , se: NA

Output:

First year to include in outputs: 2026
Final year to include in outputs: 2056
How should outputs be produced, in terms of ages?: whole.population
Target population size to use in calculating impact metrics: NA
Quasi-extinction threshold to use in calculating impact metrics: NA