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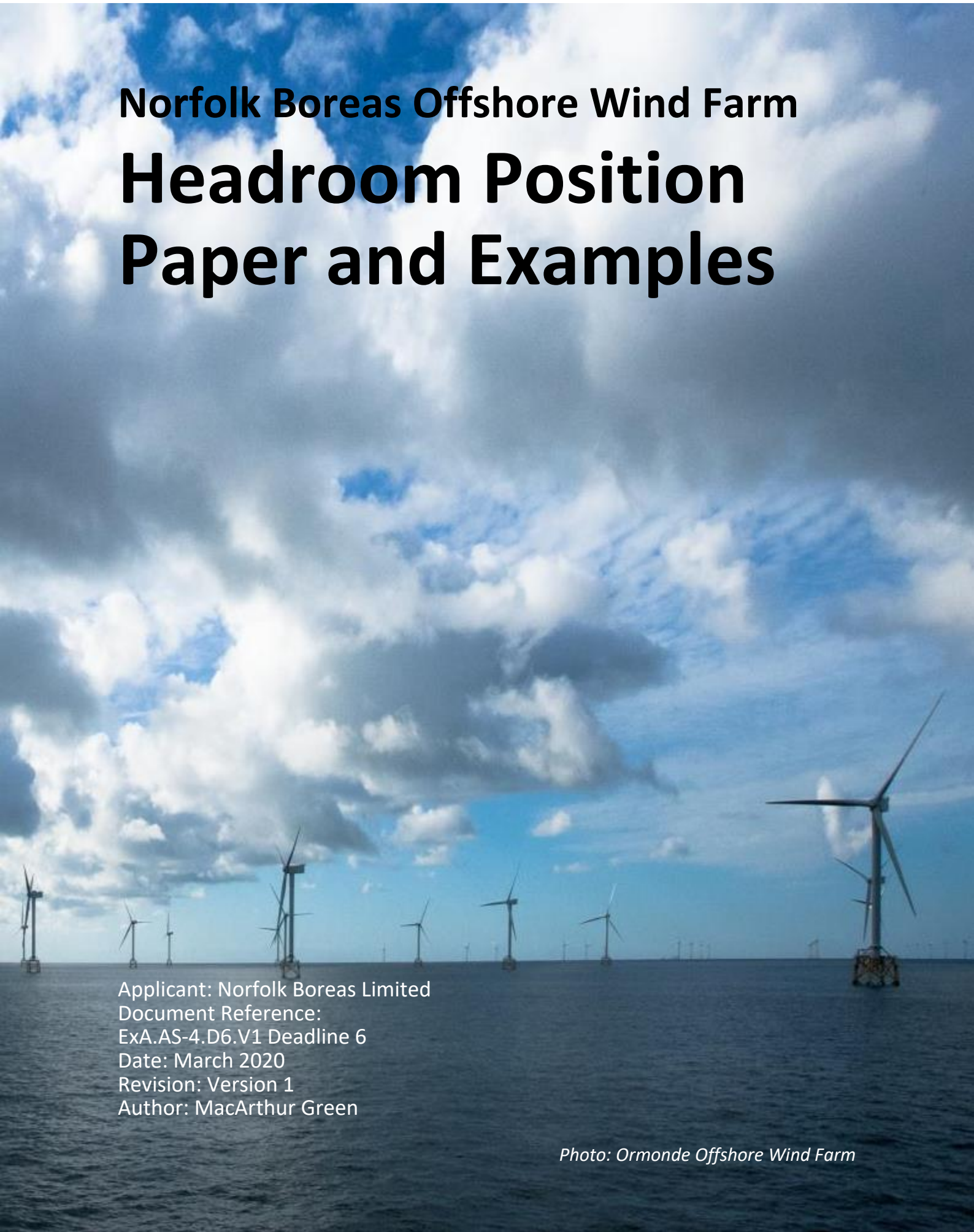

Norfolk Boreas Offshore Wind Farm

Headroom Position Paper and Examples

Applicant: Norfolk Boreas Limited
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Glossary of Acronyms

CRM	Collision Risk Model
EIA	Environmental Impact Assessment
ES	Environmental Statement
FFC	Flamborough and Filey Coast
MW	Megawatt
NMC	Non-material Change
SPA	Special Protection Area

1 Introduction

1. At Issue Specific Hearing 4 (Offshore effects including the draft Development Consent Order) and in the corresponding Written Submission [REP4-014], Norfolk Boreas Limited (the Applicant) presented submissions on 'headroom'.

2. The Applicant has prepared this paper to draw the submissions on headroom together in one place as well as to provide a further worked example at Annex 1 in relation to Triton Knoll.

2 Headroom Overview

3. Cumulative and in-combination collision estimates are made up of the worst case mortality for each contributory wind farm, taken either from the relevant wind farm Environmental Statement (ES) or consent document (i.e. the Development Consent Order (DCO)). Wind farm applications are submitted at an early stage in the process of the project design, at which time the developers may not know the precise nature and arrangement of turbines and associated infrastructure that make up the proposed development. Assessments are therefore typically presented using a 'Rochdale Envelope' approach to ensure impact assessment encompasses the worst case project design.

4. However, constructed wind farms, particularly more recent ones, rarely use the maximum number, or precise model, of turbines which were used in setting the parameters for the Rochdale Envelope or which are therefore secured in the consent. Technological developments mean that generating capacities can be attained with fewer, larger dimension turbines. This is highly relevant for cumulative collision estimations since collision mortalities are almost always lower for these 'as-built' developments when compared with those for the consented designs. The design revisions made by Norfolk Boreas provide a prime example of this process, albeit crucially these changes have been made prior to the design being fixed in place, as happens when a project is consented. For most recent wind farms, much less project design revision has occurred prior to consent, with the remainder occurring post-consent. The consequence of this is that much of the reduction in impacts which these post-consent design revisions represents is not reflected in the figures used by other wind farms in their cumulative assessments. The use of collision risk estimates based on worst case scenarios is therefore likely to lead to a potential over-estimate. This difference between impact magnitude for a consented design and that for the actually built wind farm is referred to as 'headroom'.

3 Headroom and Precaution

5. The Applicant maintains that there will be no Adverse Effect on Integrity (AEoI) for the qualifying kittiwake feature of the Flamborough and Filey Coast Special

Protection Area (SPA) and the qualifying lesser black-backed gull feature of the Alde-Ore Estuary SPA. The Applicant is not reliant on headroom to reach these conclusions; nevertheless, the Applicant considers that it is another important source of over-precaution in the cumulative and in-combination assessment.

6. The view that consented values must be used in cumulative and in-combination assessments, as opposed to as built reductions following revisions to a wind farm design's worst case Rochdale envelope, does not reflect the reality of seabird collision risks. The Applicant understands that Natural England accepts that there is 'headroom' in this respect. There is a risk that continuing to adopt this precautionary approach will unnecessarily prevent further wind farm development, delaying efforts to reduce carbon emissions to meet the climate emergency.

7. When assessing collision risk, the figures used in the collision risk model are either derived from the figures used in the worst case assessment, or the figures relevant to the consented schemes. Therefore there are two tiers to the headroom argument:

   - Assessed versus consented; and
   - Consented versus as-built.

8. On the matter of assessed versus consented, the Applicant has identified projects where the figures used in the collision risk model are derived from the worst case assessed, as opposed to the final scheme consented. In each case either the original DCO, or a non-material change, or a section 36 variation has reduced the parameters in the consent from what was originally assessed as the worst case. Therefore as with the East Anglia ONE decision, it must be without doubt that headroom has been created by those projects and that such headroom is "legally secured".

9. On consented versus as-built, there are a number of reasons why the Applicant considers that the as-built scheme (and its associated parameters) is "legally secured". This is partly due to the way in which the deemed marine licence (DML) conditions require approval of final layouts and certification of final layouts on completion of construction. In essence the Applicant's submission is no different to the MMO's and Natural England's advice on cable protection, that new areas of cable protection cannot be installed following certification that construction has completed. This is not least because, in a number of cases which the Applicant has so far considered, the age of the environmental information is now in excess of seven years. As Natural England state in their recent position statement on new areas of cable protection, environmental information which is more than five years old would be considered out of date and updated environmental information would be required. This includes any requirement for a further Habitats Regulation

Assessment, which would therefore amount to a material change requiring a new consent.

10. To illustrate this point further, in February 2017, The Crown Estate launched a process to apply for wind farm extensions. Some of the extensions relate to projects which the Applicant has identified as having headroom between the consented and as-built figures. However there is no suggestion that those projects will extend under an existing consent. In fact, the Crown Estate's plan level appropriate assessment noted that a separate appropriate assessment, and therefore a new application, would need to be undertaken for each project.

11. In summary, the Applicant's position is that it is without doubt that there is legally secured headroom between the assessed and consented figures. In addition, the Applicant's position is that further "legally secured" headroom exists between the consented and the as-built projects, and this is supported by the MMO and NE's recent positions and previous advice on deployment of new areas of cable protection.

4 Headroom worked examples

12. To illustrate the effect on collision estimates of using built vs. assessed or consented wind farm designs, the following comparison has been conducted for the Hornsea Project One wind farm using kittiwake as an example. Calculations for updating the Triton Knoll kittiwake collision risk estimates are also presented.

13. The original Hornsea Project One application (ES) was based on 332 3.6MW turbines, and consent was granted for up to 240 5MW turbines. It was stated by Smart Wind (2014)[1] that the consented design reduced collision risks for gannet and kittiwake by 13% compared with the original ES design, however as far as the Applicant has been able to determine, no updated collision modelling was submitted in to the Hornsea Project One examination. In 2016, a Non-material change (NMC) application[2] was submitted (and subsequently approved) which proposed maximum turbine numbers of either 203 (6MW), 174 (7MW) or 152 (8MW), depending on which turbine was selected. Each of these achieved the generating limit of 1200MW (amended to 1218MW, as set out in the NMC). The wind farm has now completed construction using 7MW turbines, and therefore 174 turbines have been installed.

[1] Smart Wind (2014) Hornsea Offshore Wind Farm Project One The Applicant's Written Response to Deadline V Application Reference: EN010033 14 May 2014

[2] Hornsea Project One Name Plate Capacity And Limit Of Deviation Work Area Dco Amendments Supporting Statement. https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010033/EN010033-002874-DONG%20Energy%20HOW01%20DCO%20Amendments%20Supporting%20Statement

14. Using the collision modelling update method developed by MacArthur Green for The Crown Estate[3] it is straightforward to update the original collision predictions using the 'common currency' excel spreadsheet. This tool recalculates collision mortality using three pieces of information: the assessed (or consented) wind farm parameters and associated collision mortalities and the revised (consented or built) turbine parameters. This process avoids the requirement to re-run the collision model and therefore removes the need to obtain the complete set of input data (seabird densities, etc.) from the wind farm applications.

15. Table 1 below presents a summary of the collision estimates which demonstrate that the Hornsea Project One kittiwake collisions to be used in cumulative and in-combination assessments should be reduced to correspond with the built wind farm (174 x 7MW turbines) rather than the current figures which corresponds to the assessed design (332 x 3.6MW). The reduction in annual kittiwake EIA collisions obtained for Hornsea Project One from the assessed to consented designs is 13% and from assessed to as built is 43%, a reduction in mortality of 52, from 123 to 71. The equivalent reduction for birds apportioned to the Flamborough and Filey Coast (FFC) Special Protection Area (SPA) from Hornsea Project One is from 41 to 24.

16. Equivalent figures for the Triton Knoll wind farm are also summarised in Table 1. For this project the method developed for The Crown Estate was used (see Annex 1) with updated turbine parameters provided by the developer and made available on the Marine Data Exchange[4]. The reduction in total kittiwake collisions for this site is 64%, from 209 to 76 and for birds apportioned to the FFC SPA from Triton Knoll is from 35 to 13.

Table 1 Assessed versus built Hornsea Project One and Triton Knoll Wind Turbine Generators (WTGs) and impact on kittiwake

Wind farm	Impact scale	Assessed WTGs	Consented WTGs	Built WTGs	Assessed kittiwake CRM	Consented kittiwake CRM	Built kittiwake CRM	Headroom (reduction from assessed to built), number and percentage
Hornsea Project One	EIA	332	240	174	123	107	71	52 (43%)
	HRA				41	36	24	17 (41%)

[3] Trinder, M 2017. Estimates of Ornithological Headroom in Offshore Wind Farm Collision Mortality. Unpublished report to The Crown Estate (submitted as Appendix 43 to Deadline I submission Hornsea Project Three: https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010080/EN010080-001095-DI_HOW03_Appendix%2043.pdf)

[4] http://marinedataexchange.co.uk/search?q=#fq=fq%3DProject%253Amde1tceea3651

Wind farm	Impact scale	Assessed WTGs	Consented WTGs	Built WTGs	Assessed kittiwake CRM	Consented kittiwake CRM	Built kittiwake CRM	Headroom (reduction from assessed to built), number and percentage
Triton Knoll	EIA	333	288	90	209	Not available	75.9	133.1 (64%)
	HRA				35.4	Not available	12.9	22.5 (63%)
EIA Total Difference								185.1
HRA Total Difference								39.5

17. The total headroom for these two projects amounts to 39.5 collisions at the HRA scale. The current number of kittiwake collisions for Norfolk Boreas is 14 using Natural England's preferred methods and 6.1 using the Applicant's preferred methods. The reduction in mortality sums from Hornsea Project One and Triton Knoll (Table 1) of 39.5 exceeds the revised kittiwake collision risks (using Natural England methods) for Norfolk Boreas (14) and Norfolk Vanguard (21) combined. If this level of headroom was applied to the Norfolk Boreas project the effect on collision risk would be to reduce the potential in-combination impacts on kittiwake to levels that were previously considered acceptable to avoid adverse effect on integrity (using a building block approach including Norfolk Vanguard but excluding Hornsea Project Three).

18. Furthermore, similar declines can be obtained for other wind farms, and these can be calculated with readily available data on turbine designs and mortality estimates using the tool developed for this purpose (the validity of this method is demonstrated in Annex 1), rather than needing to extract the original input parameters which can be difficult to obtain for older wind farm projects (and sometimes were not included).

19. The Crown Estate maintains a database of wind farm designs, consented and actual, and a copy of the tool which automatically updates collision predictions. When this tool was developed it was estimated that cumulative kittiwake collisions were over-estimated by around 17%, which equated to a total headroom of around 500 individuals at the North Sea scale and 40 individuals for Flamborough and Filey Coast SPA, from an in-combination total of 319 (Trinder 2017). For lesser black-backed gull collisions were over-estimated by up to 40% at the North Sea scale, equating to a headroom of 200 individuals (no Alde-Ore Estuary SPA estimate was presented).

20. In addition to revised wind farm designs post-consent, there are now also several wind farms which have submitted revised applications and for which the developers now have two consents (e.g. Inch Cape, Neart Na Gaoithe) with very different impact predictions; the earlier consents are based on wind farm designs with large numbers of small turbines with associated high collision risk estimates, while the later consents have fewer turbines and much lower collision estimates. For example, Inch Cape had a total kittiwake collision estimate of 301 on it original application and on its later one this figure is 72 (a reduction of 229). Neart Na Gaoithe had an original kittiwake collision estimate of 93 and 28 on its later one (a reduction of 65). Thus, these two projects alone represent an over-estimate in kittiwake collisions of almost 300 at the North Sea scale. Their summed (original) contribution to the Flamborough and Filey Coast SPA kittiwake mortality was 20, which is 5 for the second consent designs, a reduction of 15.

21. However, Natural England has stated that the higher collision estimates must be used for these wind farms, despite the virtual certainty that the earlier consented designs will not be built.

22. In conclusion, the Applicant considers that evidence has been presented in support of both the legal case (as to the parameters that are "legally secured") and the calculation methods and that the datasets required are available in many instances and are, to all intents, the same as those currently used in cumulative and in-combination assessment. Whilst the Applicant is in no way reliant on the headroom argument to rule out AEoI for the Project, what this demonstrates is that the current cumulative and in-combination estimates, which do not account for project updates, are in themselves precautionary (which Natural England has agreed) and that this is an entirely separate and additional source of precaution over and above those other sources of precaution (e.g. precautionary collision model parameters and breeding season durations).

5 Annex 1

Hornsea 1 CRM calculations – demonstration of revisions to collision estimates

23. To demonstrate the difference in collision mortality obtained for a wind farm's built design compared to its assessed one, data and calculations for the Hornsea Project One wind farm are presented below. This has focussed on EIA kittiwake, but similar results are obtained for all species. The source data from SmartWind (2013)[5] were obtained from application documents (copied below) and used as inputs to the Band collision model.

24. Seabird density data are presented in Table C.164, assessed wind farm data in Table C.133 and the associated collision predictions for the assessed wind farm in Table C.169.

[5] Hornsea Offshore Wind Farm Project One Environmental Statement Volume 5 – Offshore Annexes Chapter 5.5.1 Ornithology Technical Report PINS Document Reference: 7.5.5.1 APFP Regulation 5(2)(a) July 2013
https://infrastructure.planninginspectorate.gov.uk/wp-content/ipc/uploads/projects/EN010033/EN010033-000566-7.5.5.1%20Ornithology%20Technical%20Report.pdf

Results Years 1 and 2 sub-zone 1

Table C.164 Densities of flying birds at Hornsea sub-zone 1 development area between March 2010 and February 2012. Data gathered during ship-based surveys.

Species	Density (birds/km2) Jan	Density (birds/km2) Feb	Density (birds/km2) Mar	Density (birds/km2) Apr	Density (birds/km2) May	Density (birds/km2) Jun	Density (birds/km2) Jul	Density (birds/km2) Aug	Density (birds/km2) Sep	Density (birds/km2) Oct	Density (birds/km2) Nov	Density (birds/km2) Dec
Fulmar	0.19	0.07	0.29	0.04	0.24	0.41	0.23	0.11	0.10	0.04	0.04	0.00
Gannet	0.24	0.07	0.43	0.07	0.03	0.02	0.07	0.14	0.18	0.35	0.55	0.04
Kittiwake	0.34	0.36	0.49	0.19	0.07	0.71	1.27	0.69	0.77	0.34	0.88	0.24
Little Gull	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	2.62	0.25	0.00
Common Gull	0.02	0.03	0.01	0.03	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01
Great Black-backed Gull	0.22	0.11	0.13	0.05	0.04	0.01	0.05	0.05	0.22	0.03	0.13	0.15
Lesser Black-backed Gull	0.02	0.00	0.00	0.03	0.07	0.07	0.11	0.10	0.02	0.00	0.00	0.03
Herring Gull	0.01	0.02	0.04	0.01	0.01	0.00	0.00	0.00	0.00	0.00	0.02	0.09
Large gulls combined	0.25	0.13	0.17	0.09	0.12	0.07	0.16	0.15	0.24	0.03	0.16	0.27
Common Tern	0.00	0.00	0.00	0.00	0.00	0.02	0.00	0.01	0.33	0.06	0.00	0.00
Arctic Tern	0.00	0.00	0.00	0.00	0.10	0.00	0.00	0.06	0.00	0.01	0.00	0.00
Guillemot	0.57	0.23	0.38	0.03	0.07	0.04	0.10	0.00	0.07	0.07	0.13	0.33
Razorbill	0.27	0.03	0.22	0.09	0.01	0.05	0.08	0.00	0.02	0.16	0.08	0.03
Guillemot/Razorbill	0.84	0.26	0.60	0.12	0.08	0.09	0.18	0.00	0.09	0.22	0.21	0.36
Common/Arctic Terns combined	0.00	0.00	0.00	0.00	0.10	0.02	0.00	0.07	0.33	0.07	0.00	0.00
Arctic Skua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	0.00	0.00
Great Skua	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.01	0.01	0.00	0.00	0.00

Table C.133 Parameters used in collision rate modelling, for two wind farm variants at Hornsea project 1.

Variant	Number of blades	Rotation speed (rpm)	Rotor radius (m)	Minimum rotor height	Maximum blade width (m)	Pitch (°)	Number of turbines	Latitude (DD)
332 x 3.6MW	3	13.0	60	22	4.2	15[1]	332	53.89
150 x 8MW	3	11.9	89	22	5.9	15[1]	150	53.89

[1] *Data based on nominal value.*

Table C.169 Results of collision rate monitoring for Hornsea sub-zone 1 development area between March 2010 and February 2012. Potential number of collisions assuming an avoidance rate of 99%.

332 x 3.6MW

Species	Collisions per month with avoidance rate 0.99 Jan	Collisions per month with avoidance rate 0.99 Feb	Collisions per month with avoidance rate 0.99 Mar	Collisions per month with avoidance rate 0.99 Apr	Collisions per month with avoidance rate 0.99 May	Collisions per month with avoidance rate 0.99 Jun	Collisions per month with avoidance rate 0.99 Jul	Collisions per month with avoidance rate 0.99 Aug	Collisions per month with avoidance rate 0.99 Sep	Collisions per month with avoidance rate 0.99 Oct	Collisions per month with avoidance rate 0.99 Nov	Collisions per month with avoidance rate 0.99 Dec	TOTAL COLLISIONS PER YEAR WITH AVOIDANCE RATE OF 0.99
Fulmar	0	0	0	0	0	0	0	0	0	0	0	0	0
Gannet	6	2	12	2	1	1	2	5	5	10	13	1	60
Kittiwake	5	5	9	3	1	14	25	13	13	6	14	4	112
Little Gull	0	0	0	0	0	0	0	0	0	4	0	0	5
Common Gull	1	1	0	1	0	0	0	0	0	0	0	0	3
Great Black-backed Gull	33	15	22	9	8	2	9	9	37	4	20	22	188
Lesser Black-backed Gull	2	0	0	3	7	7	11	10	2	0	0	3	45
Herring Gull	1	4	7	1	2	0	0	0	0	0	4	14	32
Large gulls combined	27	13	21	11	16	10	21	19	29	3	17	29	216
Common Tern	0	0	0	0	0	0	0	0	0	0	0	0	0
Arctic Tern	0	0	0	0	0	0	0	0	0	0	0	0	0
Guillemot	0	0	0	0	0	0	0	0	0	0	0	0	0
Razorbill	0	0	0	0	0	0	0	0	0	0	0	0	0
Guillemot/Razorbill	0	0	0	0	0	0	0	0	0	0	0	0	0
Common/Arctic Terns combin	0	0	0	0	0	0	0	0	0	0	0	0	0
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	0	0	0	0

150 x 8MW

TOTAL

25. It can be seen that the assessed annual collision prediction for kittiwake (Table C.169) at an avoidance rate of 99% was 112 (note that the current kittiwake avoidance rate of 98.9% was not presented, but multiplying 112 by ((1-0.0989)/(1-0.99)) updates this to an avoidance rate of 98.9% = 123).

26. Using the input data in Tables C.133 and C.164 the following values were entered into the Band excel collision model.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**COLLISION RISK ASSESSMENT**			used in overall collision risk sheet								used in available hours sheet				
2	**Sheet 1 – Input data**			used in migrant collision risk sheet								used in large array correction sheet				
3				used in single transit collision risk sheet or extended model								not used in calculation but stated for reference				
4																
5		**Units**	**Value**		**Data sources**											
6	**Bird data**															
7	Species name		**Kittiwake**													
8	Bird length	m	0.39													
9	Wingspan	m	1.08													
10	Flight speed	m/sec	13.1													
11	Nocturnal activity factor (1-5)		3													
12	Flight type, flapping or gliding		flapping													
13					**Data sources**											
14	**Bird survey data**			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
15	Daytime bird density	birds/sq km		0.34	0.36	0.49	0.19	0.07	0.71	1.27	0.69	0.77	0.34	0.88	0.24	
16	Proportion at rotor height	%	3.7%													
17	Proportion of flights upwind	%	50.0%													
18					**Data sources**											
19	**Birds on migration data**															
20	Migration passages	birds		0	0	0	0	0	0	0	0	0	0	0	0	
21	Width of migration corridor	km	8													
22	Proportion at rotor height	%	75%													
23	Proportion of flights upwind	%	50.0%													
24		**Units**	**Value**		**Data sources**											
25	**Windfarm data**															
26	Name of windfarm site		**H1**													
27	Latitude	degrees	53.89													
28	Number of turbines		332													
29	Width of windfarm	km	38													
30	Tidal offset	m	0													
31		**Units**	**Value**		**Data sources**											
32	**Turbine data**															
33	Turbine model		**5MW turbine**													
34	No of blades		3													
35	Rotation speed	rpm	13													
36	Rotor radius	m	60													
37	Hub height	m	82	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
38	Monthly proportion of time operational	%		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	
39	Max blade width	m	4.200													
40	Pitch	degrees	15													
41																
42																
43	**Avoidance rates used in presenting results**		95.00%													
44			98.90%													
45			99.00%													
46			99.50%													
47																
48																

27. Collision results were obtained as below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	**COLLISION RISK ASSESSMENT**																		
2	**Sheet 2 – Overall collision risk**			**All data input on Sheet 1:**						from Sheet 1 – input data									
3				**no data entry needed on this sheet!**						from Sheet 6 – available hours									
4	Bird details:									from Sheet 3 – single transit collision risk									
5		Species		Kittiwake						from survey data									
6		Flight speed	m/sec	13.1						calculated field									
7		Nocturnal activity factor (1-5)		3															
8		Nocturnal activity (% of daytime)		50%															
9	Windfarm data:																		
10		Latitude	degrees	53.9															
11		Number of turbines		332															
12		Rotor radius	m	60															
13		Minimum height of rotor	m	82															
14		Total rotor frontal area	sq m	3754832															
15					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		**year average**	
16		Proportion of time operational	%		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%		85.0%	
17																			
18	**Stage A – flight activity**																		
19		Daytime areal bird density	birds/sq km		0.34	0.36	0.49	0.19	0.07	0.71	1.27	0.69	0.77	0.34	0.88	0.24			
20		Proportion at rotor height	%	3.7%															
21		Total daylight hours per month	hrs		249	272	366	420	494	510	513	461	383	329	259	233			
22		Total night hours per month	hrs		495	400	378	300	250	210	231	283	337	415	461	511			
23		Flux factor			249122	250861	401373	#####	63929	644562	1177903	613278	626636	269139	635672	172966			
24																			
25	**Option 1 –Basic model – Stages B, C and D**																	**per annum**	
26		Potential bird transits through rotors			9218	9282	14851	5911	2365	23849	43582	22691	23186	9958	23520	6400		**194813**	
27		Collision risk for single rotor transit	(from sheet 3)	6.7%															
28		Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**525**	**529**	**846**	**337**	**135**	**1359**	**2484**	**1293**	**1321**	**568**	**1340**	**365**		**11103**	
29																			
30	**Option 2–Basic model using proportion from flight distribution**				**1373**	**1383**	**2213**	**881**	**352**	**3554**	**6494**	**3381**	**3455**	**1484**	**3505**	**954**		**29028**	
31																			
32	**Option 3–Extended model using flight height distribution**			Gannet															
33		Proportion at rotor height	(from sheet 4)	9.7%															
34		Potential bird transits through rotors	Flux integral	0.0516	12847	12937	20699	8239	3297	33240	60744	31627	32315	13879	32781	8920		**271525**	
35		Collisions assuming no avoidance	Collision integral	0.00194	**411**	**414**	**662**	**264**	**106**	**1064**	**1944**	**1012**	**1034**	**444**	**1049**	**285**		**8689**	
36		Average collision risk for single rotor transit		3.8%															
37																			
38	**Stage E – applying avoidance rates**																		
39		Using which of above options?	**Option 1**	0.00%	525	529	846	337	135	1359	2484	1293	1321	568	1340	365		**11103**	
40																			
41	Collisions assuming avoidance rate		birds per month or year	95.00%	26	26	42	17	7	68	124	65	66	28	67	18		**555**	
42				98.90%	6	6	9	4	1	15	27	14	15	6	15	4		**122**	
43				99.00%	5	5	8	3	1	14	25	13	13	6	13	4		**111**	
44				99.50%	3	3	4	2	1	7	12	6	7	3	7	2		**56**	
45																			
46	Collisions after applying large array correction			95.00%	26	26	42	17	7	68	124	65	66	28	67	18		**555**	
47				98.90%	6	6	9	4	1	15	27	14	15	6	15	4		**122**	
48				99.00%	5	5	8	3	1	14	25	13	13	6	13	4		**111**	
49				99.50%	3	3	4	2	1	7	12	6	7	3	7	2		**56**	
50																			
51																			

28. As can be seen above, the annual kittiwake collisions at an avoidance rate of 99% (cell R43 above) is 111, which compares with the assessed figure of 112 above (this difference is expected to be due to rounding variations, since the input data were only presented to two decimal places) and at 98.9% (cell R42) the mortality is 122.

29. To estimate the built wind farm collisions, the Band spreadsheet was then updated using the turbine parameters presented in the Hornsea Project One NMC which correspond to the built wind farm (174 x 7 MW); Table 1.3 below.

Table 1.2: The three defined turbine scenarios based upon the numbers allowed under the DCO and the parameters that would have been used at the time of the DCO (note, of these options only the 8MW turbine was actually presented for the purposes of the DCO)

Parameter	6 MW	7 MW	8 MW
No. of turbines	200	171	150
Rotation speed (m/s)	11	10.5	10.2
Rotor radius (m)	77	86	89
Hub height (m)	98.45 (HAT)	107.45 (HAT)	110.45 (HAT)
Monthly proportion of time operational (%) (all months)	85	85	85
Blade width (m)	5	5.4	5.4
Pitch (°)	10	3	3

Table 1.3: Updated turbine parameters for the three defined turbine scenarios (bold text indicates where parameters differ from those presented in Table 1.2)

Parameter	6 MW	7 MW	8 MW
No. of turbines with the increase in name plate capacity	**203**	**174**	**152**
Rotation speed (m/s)	11	10.5	10.2
Rotor radius (m)	77	**77**	89
Hub height (m)	**98.35 (HAT)**	**113.99 (HAT)**	**110.35 (HAT)**
Monthly proportion of time operational (%) (all months)	85	85	85
Blade width (m)	5	**5**	5.4
Pitch (°)	**3**	3	3

30. The updated Band spreadsheet calculation, using the 7MW turbine parameters from table 1.3 above are presented below.

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P
1	**COLLISION RISK ASSESSMENT**			used in overall collision risk sheet								used in available hours sheet				
2	**Sheet 1 – Input data**			used in migrant collision risk sheet								used in large array correction sheet				
3				used in single transit collision risk sheet or extended model								not used in calculation but stated for reference				
4																
5		**Units**	**Value**		**Data sources**											
6	**Bird data**															
7	Species name		**Kittiwake**													
8	Bird length	m	0.39													
9	Wingspan	m	1.08													
10	Flight speed	m/sec	13.1													
11	Nocturnal activity factor (1-5)		3													
12	Flight type, flapping or gliding		flapping													
13					**Data sources**											
14	**Bird survey data**			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
15	Daytime bird density	birds/sq km		0.34	0.36	0.49	0.19	0.07	0.71	1.27	0.69	0.77	0.34	0.88	0.24	
16	Proportion at rotor height	%	3.7%													
17	Proportion of flights upwind	%	50.0%													
18					**Data sources**											
19	**Birds on migration data**															
20	Migration passages	birds		0	0	0	0	0	0	0	0	0	0	0	0	
21	Width of migration corridor	km	8													
22	Proportion at rotor height	%	75%													
23	Proportion of flights upwind	%	50.0%													
24		**Units**	**Value**		**Data sources**											
25	**Windfarm data**															
26	Name of windfarm site		**H1**													
27	Latitude	degrees	53.89													
28	Number of turbines		174													
29	Width of windfarm	km	38													
30	Tidal offset	m	0													
31		**Units**	**Value**		**Data sources**											
32	**Turbine data**															
33	Turbine model		**7MW**													
34	No of blades		3													
35	Rotation speed	rpm	10.5													
36	Rotor radius	m	77													
37	Hub height	m	113.99	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	
38	Monthly proportion of time operational	%		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	
39	Max blade width	m	5.000													
40	Pitch	degrees	3													
41																
42																
43	**Avoidance rates used in presenting results**		95.00%													
44			98.90%													
45			99.00%													
46			99.50%													

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S
1	**COLLISION RISK ASSESSMENT**																		
2	**Sheet 2 – Overall collision risk**			**All data input on Sheet 1:**						from Sheet 1 - input data									
3				**no data entry needed on this sheet!**						from Sheet 6 - available hours									
4	Bird details:									from Sheet 3 - single transit collision risk									
5		Species		Kittiwake						from survey data									
6		Flight speed	m/sec	13.1						calculated field									
7		Nocturnal activity factor (1-5)		3															
8		Nocturnal activity (% of daytime)		50%															
9	Windfarm data:																		
10		Latitude	degrees	53.9															
11		Number of turbines		174															
12		Rotor radius	m	77															
13		Minimum height of rotor	m	113.99															
14		Total rotor frontal area	sq m	3241011															
15					Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec		**year average**	
16		Proportion of time operational	%		85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%	85%		85.0%	
17																			
18	**Stage A – flight activity**																		
19		Daytime areal bird density	birds/sq km		0.34	0.36	0.49	0.19	0.07	0.71	1.27	0.69	0.77	0.34	0.88	0.24			
20		Proportion at rotor height	%	3.7%															
21		Total daylight hours per month	hrs		249	272	366	420	494	510	513	461	383	329	259	233			
22		Total night hours per month	hrs		495	400	378	300	250	210	231	283	337	415	461	511			
23		Flux factor			167557	168727	269959	#####	42998	433526	792246	412485	421469	181020	427547	116335			
24																			
25	**Option 1 –Basic model – Stages B, C and D**																	**per annum**	
26		Potential bird transits through rotors			6200	6243	9989	3976	1591	16040	29313	15262	15594	6698	15819	4304		**131029**	
27		Collision risk for single rotor transit	(from sheet 3)	5.8%															
28		Collisions for entire windfarm, allowing for non-op time, assuming no avoidance	birds per month or year		**306**	**308**	**493**	**196**	**79**	**792**	**1447**	**753**	**770**	**331**	**781**	**212**		**6466**	
29																			
30	**Option 2–Basic model using proportion from flight distribution**				**135**	**136**	**218**	**87**	**35**	**350**	**640**	**333**	**341**	**146**	**346**	**94**		**2863**	
31																			
32	**Option 3–Extended model using flight height distribution**			Gannet															
33		Proportion at rotor height	(from sheet 4)	1.6%															
34		Potential bird transits through rotors	Flux integral	0.0516	8641	8701	13922	5542	2217	22357	40856	21272	21735	9335	22048	5999		**182625**	
35		Collisions assuming no avoidance	Collision integral	0.00194	**277**	**278**	**446**	**177**	**71**	**715**	**1307**	**681**	**696**	**299**	**706**	**192**		**5844**	
36		Average collision risk for single rotor transit		3.8%															
37																			
38	**Stage E – applying avoidance rates**																		
39		Using which of above options?	**Option 1**	0.00%	306	308	493	196	79	792	1447	753	770	331	781	212		**6466**	
40																			
41	Collisions assuming avoidance rate		birds per month or year	95.00%	15	15	25	10	4	40	72	38	38	17	39	11		**323**	
42				98.90%	3	3	5	2	1	9	16	8	8	4	9	2		**71**	
43				99.00%	3	3	5	2	1	8	14	8	8	3	8	2		**65**	
44				99.50%	2	2	2	1	0	4	7	4	4	2	4	1		**32**	
45																			
46	Collisions after applying large array correction			95.00%	15	15	25	10	4	40	72	38	38	17	39	11		**323**	
47				98.90%	3	3	5	2	1	9	16	8	8	4	9	2		**71**	
48				99.00%	3	3	5	2	1	8	14	8	8	3	8	2		**65**	
49				99.50%	2	2	2	1	0	4	7	4	4	2	4	1		**32**	
50																			

31. As can be seen above, the Band derived total kittiwake annual collisions at 99% for the built scenario (174 x 7MW) are reduced to 65 (cell R43). Adjusting this figure from the avoidance rate of 99% to the current advised kittiwake rate of 98.8% gives a value of 71 (obtained as follows: 65 x ((1-0.989)/(1-0.99))). This is the appropriate kittiwake annual collision estimate for the built Hornsea Project One wind farm which should be used in cumulative assessments in place of the 123, derived from the assessed design, which is currently used.

32. The process outlined above requires that all the necessary input parameters are provided in the project assessment which has not always been the case. An alternative method, which only requires the old and new turbine parameters and original collision estimates was developed for The Crown Estate by MacArthur Green. Snapshots from the excel file that undertakes these updates are presented below. The collision values used were those for an avoidance rate of 98.9%, 123.

33. The table below contains the input turbine parameters for the assessed turbine inputs (332 x 5MW) and the built ones, as presented in the NMC (174 x 7MW).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
1							OLD					NEW						
2	Wind farm	Status	Date of consent	Consented no. turbines (max.)	Assessed no. turbines	Assessed turbine capacity (MW)	Rotor radius (m)	Hub height (m)	Average RPM	Max blade width (m)	Average blade pitch (deg.)	Actual no. turbines	Built turbine capacity (MW)	Rotor radius (m)	Hub height (m)	Average RPM	Max blade width (m)	Average blade pitch (deg.)
22	Hornsea 1	Consented	31/12/2014	240	332	3.6	60	82	13	4.2	15	174	7	77	113.99	10.5	5	3

34. The table below shows the parameters used and the calculated 'CRM adjustment' figure (0.5824, column L) which indicates the proportional adjustment to be made to the old collisions (123) to obtain the updated mortality of 71.6.

A	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q
		OLD (application)				NEW (actual)					ANNUAL CRM				
wind farm	species	no. turbines	Radius	TRF	Pcollision	no. turbines	Radius	TRF	Pcollision	CRM adjustment	old CRM	model	AR	new CRM	headroom
Hornsea 1	Kittiwake	332	60	3754831.5	0.0671	174	77	3241011.5	0.0581	0.5824	123	1	98.9	71.6	51.4

35. As demonstrated here, this figure (71.6), was obtained with much fewer data requirements and is the same as that obtained through recalculation from the original dataset (using the Band spreadsheets), thereby demonstrating the validity of this method for the purpose of updating collision estimates.

Triton Knoll CRM calculations – demonstration of revisions to collision estimates

36. The collision estimate for the Triton Knoll wind farm have been updated using the method developed for The Crown Estate by MacArthur Green. Snapshots from the excel file that undertakes these updates are presented below.

37. The table below contains the input turbine parameters for the assessed turbine inputs (333 x 3.6MW) and the built ones, obtained from The Crown Estate Marine Data Exchange[6] (90 x 9.525MW).

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
							OLD					NEW						
	Wind farm	Status	Date of consent	Consented no. turbines (max.)	Assessed no. turbines	Assessed turbine capacity (MW)	Rotor radius (m)	Hub height (m)	Average RPM	Max blade width (m)	Average blade pitch (deg.)	Actual no. turbines	Built turbine capacity (MW)	Rotor radius (m)	Hub height (m)	Average RPM	Max blade width (m)	Average blade pitch (deg.)
1	Triton Knoll	Consented	11/07/2013	288	333	3.6	62.5		9.47	4.2	6	90	9.525	82	110.2	10.8	5.4	15

38. The table below shows the parameters used and the calculated 'CRM adjustment' figure (0.3633, column L) which indicates the proportional adjustment to be made to the old collisions (209, column M) to obtain the updated mortality of 75.9 (column P) and a headroom of 133.1 (column Q).

	A	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R
			OLD (application)				NEW (actual)					ANNUAL CRM					
	wind farm	species	no. turbines	Radius	TRF	Pcollision	no. turbines	Radius	TRF	Pcollision	CRM adjustment	old CRM	model	AR	new CRM	headroom	New CRM / MW
1	Triton Knoll	Kittiwake	333	62.5	4086524.8	0.0604	90	82	1901166.2	0.0618	0.3633	209	1	98.9	75.9	133.1	0.08

[6] http://marinedataexchange.co.uk/search?q=#fq=fq%3DProject%253Amde1tceea3651