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Norfolk Vanguard Offshore Wind Farm

Offshore Ornithology

Deterministic Collision Risk Modelling for revised layout scenarios

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EXECUTIVE SUMMARY

This note presents an update to the seabird collision risk estimates for the Norfolk Vanguard Offshore Wind Farm. Following requests from the Examining Authority (ExA), Natural England and the Royal Society for the Protection of Birds to explore options to mitigate potential seabird impacts from the Project, additional mitigation has been applied through a revision of the wind turbine layout within the offshore sites to further minimise collision risks.

The revised project design comprises the maximum proportion of turbines to be installed across Norfolk Vanguard East and West. The layout of the wind turbines will be based on the following maxima:

- No more than two-thirds of the turbines will be installed in Norfolk Vanguard West and no more than half in Norfolk Vanguard East (with the remainder installed in the other site in each case).

These replace the previous worst case assumption that all of the turbines would be installed in either the Norfolk Vanguard East or West sites.

The worst case collision prediction for each species is dependent on their relative abundance across the two sites, but in all cases significantly lower collisions are estimated than those presented in the Collision Risk Modelling Update submitted at Deadline 6 (Ex; AS; 10.D6.15). The average reduction in collision mortality is 34%. For fulmar, gannet, Arctic skua, great skua, kittiwake, little gull, herring gull and great black-backed gull the revised worst case scenario is based on half of the turbines in each site, and for red-throated diver, black-headed gull, common gull and lesser black-backed gull the worst case is based on two-thirds of the turbines in Norfolk Vanguard West (and one-third in Norfolk Vanguard East).

Full details are provided in this note, comprising monthly, seasonal and annual totals, estimates of the increases in background mortality for key species (gannet, kittiwake, lesser black-backed gull, herring gull and great black-backed gull) and collisions apportioned to relevant Special Protection Area (SPA) populations (gannet and kittiwake from Flamborough and Filey Coast SPA and lesser black-backed gull from Alde-Ore Estuary SPA).

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Glossary

CRM	Collision Risk model
BDMPS	Biologically Defined Minimum Population Scale
EIA	Environmental Impact Assessment
ES	Environmental Statement
HRA	Habitats Regulations Assessment
MW	Megawatt
NAF	Nocturnal Activity Factor
NE	Natural England
NV	Norfolk Vanguard
RPM	Revolutions per minute
SPA	Special Protection Area
WTG	Wind Turbine Generator

1 INTRODUCTION

1. This note provides an update to the collision risk modelling (CRM) for the Norfolk Vanguard Offshore Wind Farm (NV) for revised turbine layout options which are proposed to further mitigate collision risk. The CRM has been undertaken using the deterministic Band (2012) model, summed across Norfolk Vanguard East (NV East) and Norfolk Vanguard West (NV West) based on a revision to the worst case scenarios for the two sites resulting from the revised turbine layout options.

2. Collision mortalities were calculated using option 2 for the 10 MW turbine. Note that wind turbine parameters were identical to those used in the CRM update submitted at Deadline 6 (ExA; AS; 10.D6.15), with the exception of mean RPM (revolutions per minute), which has been reduced from 10 to 8.3, following an update on turbine specifications as part of the on-going detailed project design. The input parameters are included in Table 7 and Table 8 (Appendix 1).

3. In line with requests from Natural England (Natural England 2018), uncertainty in parameter values is presented by using specified upper and lower density values for model input parameters as well as the central point (e.g. mean). These provide indications of the outer limits within which the collision estimates would be expected to lie.

4. Collision estimates were calculated using the mean and 95% confidence intervals for density estimates, the mean species-specific avoidance rates (as per JNCC et al. 2014), maximum likelihood flight heights (Johnson et al. 2014a,b) and standard (i.e. higher) nocturnal activity rates.

5. Chapter 5 Project Description of the Environmental Statement (ES) provides information on the project design envelope for the wind turbine layout as included in the application. This notes that the detailed design of the layout will be completed during the post-consent phase of the project, however worst case scenarios were assumed for assessments. The worst case scenario in the ES assumed the following maxima:

    - 1,800MW in NV East, 0MW in NV West; or
    - 0MW in NV East, 1,800MW in NV West.

6. Previous modelling (as presented in ES Chapter 13 Offshore Ornithology and subsequent updates submitted during the examination) presented worst case mortalities estimated in line with these scenarios.

7. During the examination for the Project, requests have been made by Natural England and the Royal Society for the Protection of Birds to explore options to mitigate potential seabird impacts from the Project

8. In order to provide additional mitigation by means of the turbine layout within the site to further minimise collision risk (see NPS EN-3 para 2.6.108) the Project Design Envelope has undergone additional review. The wind turbine layout is now based on the following maximum proportion of turbines which could be installed in either site with two alternative scenarios, (a) and (b):

    a. The maximum proportion of turbines in NV West would be two-thirds (with one-third in NV East); or

    b. The maximum proportion of turbines in NV East would be half (with the other half in NV West).

9. Collision estimates are presented for both scenario (a) and (b) for each species in order to clearly identify the species-specific worst case design, which reflect differences in the densities of a particular species across NV East and NV West. The higher estimate in each case represents the worst case for assessment.

10. A comparison is provided with the mortality predictions submitted at Deadline 6 (ExA; AS; 10.D6.15) for both the total annual estimate (i.e. at the Environmental Impact Assessment scale) and for gannet, kittiwake and lesser black-backed gull the annual mortality apportioned to those Special Protection Areas (SPAs) for which connectivity is predicted.

2 RESULTS

11. The worst case annual collision estimates presented at Deadline 6 (ExA; AS; 10.D6.15) and those for the revised Project Design Envelope are compared in Table 1, including the percentage reduction in worst case annual mortality achieved for each species. The reductions vary between 12% (black-headed gull) and 54% (Arctic skua), with an average reduction of 34%. The variation between species reflects their relative abundance across the NV East and NV West sites.

Table 1. Comparison of annual mortality estimates between those presented at Deadline 6 (ExA; AS; 10.D6.15) and the revised Project Design Envelope.

Species	Deadline 6 Estimate		Revised Project Design Envelope (current assessment)		Percentage reduction for revised Project Design Envelope
	Worst case annual mortality	Scenario (100% turbines in either NV East or West)	Worst case annual mortality	Scenario (a=2/3 W, 1/3 E; b=1/2 W, 1/2 E)	
Red-throated diver	4.66 (0-15.83)	NV West	3.65 (0.14-9.28)	a	21.7
Fulmar	9.61 (0.27-27.94)	NV East	6.92 (2.18-13.24)	b	28.0
Gannet	177.08 (29.43-431)	NV East	111.66 (62.66-174.18)	b	37.0
Arctic skua	0.56 (0-3.37)	NV East	0.26 (0-0.66)	b	53.6
Great skua	1.97 (0-9.86)	NV East	1.29 (0.12-3.52)	b	34.5
Kittiwake	317.79 (34.52-837.99)	NV East	186.09 (107.89-281.79)	b	41.4
Black-headed gull	4.94 (0-20.1)	NV West	4.35 (0-11.58)	a	11.9
Little gull	15.76 (0-55.4)	NV East	8.26 (2.78-15.68)	b	47.6
Common gull	14.95 (0-51.81)	NV West	11.9 (1.81-27.75)	a	20.4
Lesser black-backed gull	39.62 (1.91-110.46)	NV West	31.7 (8.95-65.16)	a	20.0
Herring gull	37.45 (0-144.67)	NV East	17.93 (9.65-30.33)	b	52.1
Great black-backed gull	100.52 (2.07-339.63)	NV East	61.94 (29.99-103.25)	b	38.4

12. The increases in background mortality for the largest Biologically Defined Minimum Population Scale (BDMPS) and biogeographic populations resulting from the annual collisions for the revised layouts are presented for those species considered to be of primary concern for collisions at offshore wind farms (gannet, kittiwake, lesser black-backed gull, herring gull and great black-backed gull) in Table 2. For all five species, the worst case collision mortality, including precautionary estimates using the upper 95% confidence interval on densities, were assessed against the largest BDMPS populations and the biogeographic populations.

Table 2. Increases in background mortality for the largest BDMPS and biogeographic populations for key species due to predicted collisions at Norfolk Vanguard for scenario a (two-thirds of turbines in Norfolk Vanguard West and one-third in Norfolk Vanguard East) and scenario b (half turbines in each site). Annual collision estimates calculated using the mean density and 95% confidence intervals with mean avoidance rates (JNCC 2016), maximum likelihood flight heights (Johnson et al. 2014) and standard (upper) nocturnal activity rates (gannet: 25%, gulls: 50%). The worst case (highest) collision estimates are high-lighted grey.

Species	Scenario	Annual mortality			Reference population		Baseline mortality (%)	Baseline mortality		Increase in baseline mortality (%)					
										Largest BDMPS			Biogeographic		
		Mean	Lower 95%	Upper 95%	Largest BDMPS	Biogeo-graphic		Largest BDMPS	Biogeo-graphic	Mean	Lower 95%	Upper 95%	Mean	Lower 95%	Upper 95%
Gannet	a	94.9	50.8	151.9	456298	1180000	19.1	87153	225380	0.109	0.058	0.174	0.042	0.023	0.067
	b	111.7	62.7	174.2				87153	225380	0.128	0.072	0.2	0.05	0.028	0.077
Kittiwake	a	150.2	79.6	237.5	829937	5100000	15.6	129470	795600	0.116	0.062	0.183	0.019	0.01	0.03
	b	186.1	107.9	281.8				129470	795600	0.144	0.083	0.218	0.023	0.014	0.035
Lesser black-backed gull	a	31.7	9.0	65.2	209007	864000	12.6	26335	108864	0.12	0.034	0.247	0.029	0.008	0.06
	b	28.5	7.4	60.0				26335	108864	0.108	0.028	0.228	0.026	0.007	0.055
Herring gull	a	12.6	6.4	22.4	466511	1098000	17.4	81173	191052	0.016	0.008	0.028	0.007	0.003	0.012
	b	17.9	9.6	30.3				81173	191052	0.022	0.012	0.037	0.009	0.005	0.016
Great black-backed gull	a	52.0	21.3	92.5			18.5	16909	43475	0.307	0.126	0.547	0.12	0.049	0.213
	b	61.9	30.0	103.2	91399	235000		16909	43475	0.366	0.177	0.611	0.142	0.069	0.237

13. Even when considering the precautionary estimates derived using the upper 95% confidence interval on density, no species exceeded the 1% threshold used as the measure below which such effects are considered undetectable against natural variations.

14. Natural England presented similar results to those in Table 2 in their response to the Applicant's Collision risk modelling update and clarification (Table 1 of REP3-051, although the collision estimates in that table were higher than those presented here as they were calculated for the 9 MW turbine and used the previous worst case scenario with all turbines in either NV East or NV West). Natural England concluded that '*on the basis of these figures collision risk for Norfolk Vanguard alone would have no significant impact at the EIA scale for all species, although this conclusion can only be made with low confidence regarding impacts on great black-backed gull at Norfolk Vanguard East'* (for the reasons noted above).

15. Therefore, with the significantly lower collisions presented in this note, with reductions of up to 54%, the same conclusion applies: no significant impacts due to collisions at the Project alone at the EIA scale. Furthermore, Natural England's caveat regarding great black-backed gull ('*this conclusion can only be made with low confidence regarding impacts on great black-backed gull at Norfolk Vanguard East'*) is no longer applicable since, even when assessed using the precautionary upper 95% density estimate, the increase in background mortality for this species remains below 1%.

16. For those species assessed against Special Protection Area (SPA) populations for collision risk, gannet, kittiwake (Flamborough and Filey Coast SPA) and lesser black-backed gull (Alde-Ore Estuary SPA), similar reductions in worst case annual mortality were calculated (Table 3). The seasonal percentage values used for apportioning collisions to the relevant SPAs were the same as those used in the updated Habitats Regulations Assessment (HRA) submitted at Deadline 6 (ExA; AS; 10.D6.17):

- Gannet: spring – 6.2%, breeding - 100%, autumn – 4.8%;
- Kittiwake: spring – 7.2%, breeding – 26.1%, autumn – 5.4%; and,
- Lesser black-backed gull: spring – 3.3%, breeding – 17%, autumn – 3.3%, winter – 5%.

Table 3. Comparison of annual mortality estimates apportioned to SPA populations between those presented at Deadline 6 (ExA; AS; 10.D6.15) and the revised Project Design Envelope.

Species	Breeding season	Deadline 6 Estimate	Revised Project Design Envelope (current assessment)	Percentage reduction for revised Project Design Envelope
		Worst case annual mortality apportioned to SPA	Worst case annual mortality apportioned to SPA	
Gannet	Full	36.2	32.8	10
	Migration free	35.2	24.8	29.5
Kittiwake	Full	14.8	9.1	38.5
	Migration free	11.0	6.7	39.1
Lesser black-backed gull	Full	5.3	4.0	24.5
	Migration free	3.5	2.4	31.4

17. Since the apportioned mortality estimates (Table 3) are significantly lower than those presented at Deadline 6, reduced by between 10% and 39% (varying for each species and depending on the length of breeding season applied), the conclusions of no Adverse Effects on the Integrity of both the Flamborough and Filey Coast SPA and Alde-Ore Estuary SPA due to collisions at the Norfolk Vanguard Wind farm remain.

18. Tables of monthly and seasonal collisions are provided in Table 4 (monthly), Table 5 (seasonal; migration free months) and Table 6 (seasonal; full breeding months). For instances when months overlap both the breeding season and migration or nonbreeding seasons, the breeding period has been prioritised and the nonbreeding period reduced in duration (e.g. if March is identified as both a spring migration and breeding month it has been included in only the breeding season). If a particular season is not defined for a species (e.g. midwinter/nonbreeding for gannet) the corresponding cell in the table has been left blank.

Table 4. Norfolk Vanguard monthly collision risk mortalities for scenario a (two-thirds of the turbines in Norfolk Vanguard West and one-third in Norfolk Vanguard East) and scenario b (half of the turbines in each site). The worst case (highest) collision estimates are high-lighted grey.

Species	Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Red-throated diver	a	2.08 (0-5.03)	0.41 (0-1.19)	0.2 (0-0.59)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.54 (0.14-1.22)	0.43 (0-1.25)	3.65 (0.14-9.28)
	b	1.55 (0-3.76)	0.31 (0-0.89)	0.3 (0-0.89)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.82 (0.21-1.85)	0.32 (0-0.93)	3.29 (0.21-8.31)
Fulmar	a	0.48 (0.11-1.05)	0.29 (0.02-0.68)	0.34 (0.03-0.8)	0.32 (0.05-0.74)	0.75 (0.3-1.37)	0.46 (0.09-0.9)	0.27 (0.06-0.57)	0.95 (0.37-1.65)	0.35 (0.06-0.8)	1.33 (0.76-1.97)	0.45 (0.08-0.95)	0.31 (0.07-0.64)	6.29 (1.99-12.13)
	b	0.52 (0.13-1.1)	0.29 (0.02-0.67)	0.38 (0.04-0.88)	0.36 (0.08-0.79)	1.04 (0.46-1.81)	0.56 (0.14-1.07)	0.24 (0.04-0.51)	1.05 (0.38-1.84)	0.45 (0.09-0.98)	1.06 (0.56-1.62)	0.54 (0.12-1.12)	0.43 (0.11-0.85)	6.92 (2.18-13.24)
Gannet	a	0.78 (0-2.26)	1.35 (0-3.78)	1.85 (0-4.52)	0.52 (0-1.38)	1.53 (0-3.86)	5.72 (1.45-11.92)	3.69 (0.59-8.43)	6.69 (1.38-13.09)	5.41 (1.67-10.61)	13.75 (7.52-21.24)	43.02 (30.86-56.69)	10.56 (7.38-14.09)	94.87 (50.83-151.88)
	b	0.89 (0-2.52)	1.46 (0-3.93)	1.66 (0-4.25)	0.78 (0-2.09)	1.85 (0-4.52)	7.77 (2.19-15.36)	2.94 (0.44-6.82)	6.84 (1.24-13.65)	6.76 (2.52-12.5)	12.07 (6.15-19.27)	52.65 (38.93-67.91)	16 (11.18-21.36)	111.66 (62.66-174.18)
Arctic skua	a	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.05 (0-0.17)	0.12 (0-0.27)	0 (0-0)	0 (0-0)	0 (0-0)	0.17 (0-0.43)
	b	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.08 (0-0.25)	0.18 (0-0.41)	0 (0-0)	0 (0-0)	0 (0-0)	0.26 (0-0.66)
Great skua	a	0 (0-0)	0 (0-0)	0.08 (0-0.25)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.88 (0.08-2.56)	0.14 (0-0.39)	0 (0-0)	0 (0-0)	1.1 (0.08-3.2)
	b	0 (0-0)	0 (0-0)	0.13 (0-0.38)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.95 (0.12-2.55)	0.21 (0-0.6)	0 (0-0)	0 (0-0)	1.29 (0.12-3.52)

Species	Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Kittiwake	a	30.27 (21.57-40.61)	13.65 (7.58-21.25)	21.51 (12.84-31.51)	9.87 (5.63-15.74)	9.73 (2.37-19.12)	11.63 (4.03-20.62)	4.76 (1.17-9.61)	4.03 (0.48-9.02)	2.67 (0.44-5.63)	5.35 (1.5-10.69)	26.19 (15.95-37.7)	10.53 (6.07-15.96)	150.2 (79.64-237.45)
	b	43.35 (32.33-56.15)	18.99 (11.49-28.12)	27.79 (18.25-38.94)	13.28 (8.1-20.06)	12.53 (3.6-23.22)	9.66 (3.01-17.97)	4.07 (0.87-8.71)	3.32 (0.36-7.67)	2.33 (0.33-5.11)	5 (1.49-9.99)	30.17 (18.86-42.74)	15.6 (9.2-23.12)	186.09 (107.89-281.79)
Black-headed gull	a	0.24 (0-0.61)	0.83 (0-1.95)	0.62 (0-1.85)	0.67 (0-1.67)	0.19 (0-0.58)	0 (0-0)	0.57 (0-1.58)	0 (0-0)	0 (0-0)	1.06 (0-2.85)	0.17 (0-0.5)	0 (0-0)	4.35 (0-11.58)
	b	0.37 (0-0.92)	0.62 (0-1.45)	0.68 (0-2.04)	0.5 (0-1.25)	0.29 (0-0.87)	0 (0-0)	0.65 (0-1.73)	0 (0-0)	0 (0-0)	0.87 (0-2.36)	0.25 (0-0.76)	0 (0-0)	4.23 (0-11.39)
Little gull	a	0 (0-0)	0.08 (0-0.25)	0 (0-0)	0 (0-0)	2.09 (0.7-3.82)	0 (0-0)	0 (0-0)	2.12 (1.14-3.26)	0.61 (0-1.83)	0 (0-0)	1.26 (0-3.09)	0 (0-0)	6.16 (1.84-12.25)
	b	0 (0-0)	0.13 (0-0.38)	0 (0-0)	0 (0-0)	3.16 (1.05-5.79)	0 (0-0)	0 (0-0)	3.21 (1.73-4.94)	0.52 (0-1.55)	0 (0-0)	1.25 (0-3.02)	0 (0-0)	8.26 (2.78-15.68)
Common gull	a	0.78 (0-1.95)	1.04 (0-2.6)	1.83 (0-4.48)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.52 (0-1.57)	1.95 (0.19-5.69)	5.6 (1.62-10.95)	0.18 (0-0.53)	11.9 (1.81-27.75)
	b	1.19 (0-2.95)	0.77 (0-1.94)	1.83 (0-4.42)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0.39 (0-1.17)	2.05 (0.29-5.42)	4.45 (1.21-8.97)	0.27 (0-0.8)	10.94 (1.5-25.67)
Lesser black-backed gull	a	1.13 (0-2.61)	0.3 (0-0.76)	0.77 (0-3.06)	0.92 (0-2.96)	0 (0-0)	4.17 (0.6-8.93)	5.8 (2.36-11.03)	10.52 (3.88-18.95)	3.44 (1.07-6.42)	3.78 (1.04-8.23)	0.46 (0-1.22)	0.4 (0-0.99)	31.7 (8.95-65.16)
	b	1.72 (0-3.95)	0.46 (0-1.16)	0.75 (0-2.98)	0.97 (0-3.21)	0 (0-0)	3.11 (0.44-6.67)	4.69 (1.76-9.14)	9.98 (3.57-18.27)	2.57 (0.8-4.79)	2.93 (0.78-6.44)	0.69 (0-1.85)	0.6 (0-1.5)	28.47 (7.36-59.96)

Species	Scenario	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
Herring gull	a	9.09 (6.19-12.43)	0.53 (0-1.58)	0.26 (0-1.04)	0.41 (0-1.42)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.74 (0.18-4.51)	0.6 (0-1.4)	12.62 (6.37-22.38)
	b	13.77 (9.38-18.83)	0.39 (0-1.18)	0.39 (0-1.57)	0.61 (0-2.16)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	0 (0-0)	1.85 (0.27-4.47)	0.91 (0-2.12)	17.93 (9.65-30.33)
Great Black-backed Gull	a	22.49 (15.25-31.64)	4.49 (0.59-9.75)	0.92 (0-2.75)	0.49 (0-1.22)	0.77 (0-2.3)	0 (0-0)	1.55 (0-3.88)	5.99 (1.5-10.88)	6.37 (1.86-11.67)	1.34 (0-3.34)	4.76 (1.41-9.46)	2.81 (0.73-5.57)	51.97 (21.34-92.46)
	b	32.65 (23.11-44.15)	3.65 (0.44-8.03)	0.86 (0-2.58)	0.74 (0-1.85)	0.57 (0-1.72)	0 (0-0)	1.16 (0-2.9)	7.36 (2.28-13.03)	4.75 (1.39-8.71)	1 (0-2.49)	4.93 (1.66-9.36)	4.26 (1.11-8.44)	61.94 (29.99-103.25)

Table 5. Norfolk Vanguard seasonal collisions using the migration-free breeding season for scenario a (two-thirds of the turbines in Norfolk Vanguard West and one-third in Norfolk Vanguard East) and scenario b (half of the turbines in each site).The worst case (highest) collision estimates are high-lighted grey.

Species	Scenario	Spring	Breeding	Autumn	Midwinter/non-breeding	Annual
Red-throated diver	a	0.61 (0-1.78)	0 (0-0)	0.54 (0.14-1.22)	2.5 (0-6.28)	3.65 (0.14-9.28)
	b	0.6 (0-1.78)	0 (0-0)	0.82 (0.21-1.85)	1.87 (0-4.68)	3.29 (0.21-8.31)
Fulmar	a	1.41 (0.22-3.17)	2.75 (0.87-5.23)	1.68 (0.81-2.77)	0.45 (0.08-0.95)	6.29 (1.98-12.12)
	b	1.62 (0.3-3.5)	3.25 (1.11-6.02)	1.51 (0.65-2.6)	0.54 (0.12-1.12)	6.92 (2.18-13.24)
Gannet	a	14.54 (7.38-24.66)	18.15 (3.42-38.68)	62.18 (40.04-88.55)	0 (7.38-0)	94.87 (58.22-151.89)
	b	20 (11.18-32.06)	20.18 (3.87-42.44)	71.48 (47.6-99.68)	0 (11.18-0)	111.66 (73.83-174.18)
Arctic skua	a	0 (0-0)	0 (0-0)	0.17 (0-0.43)	0 (0-0)	0.17 (0-0.43)
	b	0 (0-0)	0 (0-0)	0.26 (0-0.66)	0 (0-0)	0.26 (0-0.66)
Great skua	a	0.08 (0-0.25)	0 (0-0)	1.02 (0.08-2.95)	0 (0-0)	1.1 (0.08-3.2)
	b	0.13 (0-0.38)	0 (0-0)	1.16 (0.12-3.14)	0 (0-0)	1.29 (0.12-3.52)
Kittiwake	a	75.31 (47.62-109.1)	26.13 (7.57-49.35)	48.76 (24.45-79)	0 (0-0)	150.2 (79.64-237.45)
	b	103.42 (70.17-143.28)	26.26 (7.48-49.89)	56.41 (30.24-88.62)	0 (0-0)	186.09 (107.89-281.79)
Black-headed gull	a	0 (0-0)	1.43 (0-3.83)	0 (0-0)	2.91 (0-7.75)	4.34 (0-11.58)
	b	0 (0-0)	1.44 (0-3.85)	0 (0-0)	2.79 (0-7.54)	4.23 (0-11.39)
Little gull	a	0 (0-0)	2.09 (0.7-3.82)	0 (0-0)	4.07 (1.14-8.43)	6.16 (1.84-12.25)
	b	0 (0-0)	3.16 (1.05-5.79)	0 (0-0)	5.1 (1.73-9.89)	8.26 (2.78-15.68)
Common gull	a	0 (0-0)	0 (0-0)	0 (0-0)	11.9 (1.81-27.75)	11.9 (1.81-27.75)
	b	0 (0-0)	0 (0-0)	0 (0-0)	10.94 (1.5-25.67)	10.94 (1.5-25.67)
Lesser black-backed gull	a	1.69 (0-6.02)	9.97 (2.96-19.96)	17.74 (5.99-33.59)	2.29 (0-5.58)	31.69 (8.95-65.15)
	b	1.72 (0-6.19)	7.8 (2.21-15.81)	15.47 (5.15-29.5)	3.48 (0-8.46)	28.47 (7.36-59.96)
Herring gull	a	0 (0-0)	0 (0-0)	0 (0-0)	12.62 (6.37-22.38)	12.62 (6.37-22.38)
	b	0 (0-0)	0 (0-0)	0 (0-0)	17.93 (9.65-30.33)	17.93 (9.65-30.33)
Great Black-backed Gull	a	0 (0-0)	2.32 (0-6.18)	0 (0-0)	49.66 (21.34-86.28)	51.98 (21.34-92.46)
	b	0 (0-0)	1.73 (0-4.61)	0 (0-0)	60.21 (29.99-98.63)	61.94 (29.99-103.24)

Table 6. Norfolk Vanguard seasonal collisions using the full breeding season for scenario a (two-thirds of the turbines in Norfolk Vanguard West and one-third in Norfolk Vanguard East) and scenario b (half of the turbines in each site).. The worst case (highest) collision estimates are high-lighted grey out.

Species	Scenario	Spring	Breeding	Autumn	Midwinter/non-breeding	Annual
Red-throated diver	a	0.41 (0-1.19)	0.2 (0-0.59)	0.54 (0.14-1.22)	2.5 (0-6.28)	3.65 (0.14-9.28)
	b	0.31 (0-0.89)	0.3 (0-0.89)	0.82 (0.21-1.85)	1.87 (0-4.68)	3.3 (0.21-8.31)
Fulmar	a	0.31 (0.07-0.64)	3.85 (1.03-7.77)	1.68 (0.81-2.77)	0.45 (0.08-0.95)	6.29 (1.99-12.13)
	b	0.43 (0.11-0.85)	4.44 (1.3-8.67)	1.51 (0.65-2.6)	0.54 (0.12-1.12)	6.92 (2.18-13.24)
Gannet	a	12.69 (7.38-20.14)	25.41 (5.08-53.81)	56.76 (38.37-77.94)	0 (0-0)	94.86 (50.83-151.89)
	b	18.34 (11.18-27.81)	28.59 (6.4-59.19)	64.72 (45.08-87.18)	0 (0-0)	111.65 (62.66-174.18)
Arctic skua	a	0 (0-0)	0 (0-0)	0.17 (0-0.43)	0 (0-0)	0.17 (0-0.43)
	b	0 (0-0)	0 (0-0)	0.26 (0-0.66)	0 (0-0)	0.26 (0-0.66)
Great skua	a	0.08 (0-0.25)	0 (0-0)	1.02 (0.08-2.95)	0 (0-0)	1.1 (0.08-3.2)
	b	0.13 (0-0.38)	0 (0-0)	1.16 (0.12-3.14)	0 (0-0)	1.29 (0.12-3.52)
Kittiwake	a	43.92 (29.15-61.86)	61.54 (26.52-105.62)	44.74 (23.97-69.98)	0 (0-0)	150.2 (79.64-237.46)
	b	62.34 (43.82-84.28)	70.65 (34.2-116.56)	53.09 (29.88-80.95)	0 (0-0)	186.08 (107.9-281.79)
Black-headed gull	a	0 (0-0)	1.43 (0-3.83)	0 (0-0)	2.91 (0-7.75)	4.34 (0-11.58)
	b	0 (0-0)	1.44 (0-3.85)	0 (0-0)	2.79 (0-7.54)	4.23 (0-11.39)
Little gull	a	0 (0-0)	2.09 (0.7-3.82)	0 (0-0)	4.07 (1.14-8.43)	6.16 (1.84-12.25)
	b	0 (0-0)	3.16 (1.05-5.79)	0 (0-0)	5.1 (1.73-9.89)	8.26 (2.78-15.68)
Common gull	a	0 (0-0)	0 (0-0)	0 (0-0)	11.9 (1.81-27.75)	11.9 (1.81-27.75)
	b	0 (0-0)	0 (0-0)	0 (0-0)	10.94 (1.5-25.67)	10.94 (1.5-25.67)
Lesser black-backed gull	a	0.77 (0-3.06)	21.41 (6.84-41.87)	7.23 (2.11-14.65)	2.29 (0-5.58)	31.7 (8.95-65.16)
	b	0.75 (0-2.98)	18.76 (5.78-37.29)	5.49 (1.58-11.24)	3.48 (0-8.46)	28.48 (7.36-59.97)
Herring gull	a	0 (0-0)	0.66 (0-2.46)	0 (0-0)	11.96 (6.37-19.92)	12.62 (6.37-22.38)
	b	0 (0-0)	1.01 (0-3.73)	0 (0-0)	16.93 (9.65-26.6)	17.94 (9.65-30.33)
Great Black-backed Gull	a	0 (0-0)	9.72 (1.5-21.03)	0 (0-0)	42.26 (19.84-71.44)	51.98 (21.34-92.47)
	b	0 (0-0)	10.69 (2.28-22.07)	0 (0-0)	51.25 (27.71-81.18)	61.94 (29.99-103.25)

3 CONCLUSIONS AND NEXT STEPS

19. Following a review of the project design in order to mitigate the potential risks of seabird impacts from the Project (and in order to address requests by the Examining Authority, Natural England and the Royal Society for the Protection of Birds to explore options for project mitigation), revised turbine layouts have been developed which reduce the maximum proportion of turbines which will be installed in Norfolk Vanguard East and Norfolk Vanguard West. That is, no more than two-thirds of the turbines will be installed in NV West (and no more than one-third will be installed in Norfolk Vanguard East), or no more than half of the turbines will be installed in NV East (and no more than half of the turbines will be installed in Norfolk Vanguard West). These replace the previous worst case layouts (as presented in the ES) which assumed that all turbines would be installed in either NV East or NV West.

20. Updated collision risk modelling has been undertaken for these two layout revisions. Both options result in large decreases in the predicted maximum collision mortality for the project. For each species the worst case scenario (i.e. the layout with the higher mortality) is highlighted in grey and has been used for assessment. The revised worst case predictions result in an average reduction in total annual mortality of 34% compared with the predictions based on 100% of the turbines in either NV East or NV West. For the key collision risk species, the reductions calculated are:

- Gannet by 37%,
- Kittiwake by 41%,
- Lesser black-backed gull by 20%,
- Herring gull by 52%, and
- Great black-backed gull by 38%.

21. For species with potential connectivity to SPA populations, similar reductions in mortality were calculated:

- Gannet (Flamborough and Filey Coast SPA) mortality reduced by between 10% and 29% for the full and migration-free breeding seasons respectively;
- Kittiwake (Flamborough and Filey Coast SPA) mortality reduced by between 38% and 39% for the full and migration-free breeding seasons respectively; and,
- Lesser black-backed gull (Alde-Ore Estuary SPA) mortality reduced by between 24% and 31% for the full and migration-free breeding seasons respectively.

22. This note presents detailed outputs for the Norfolk Vanguard Wind Farm at both EIA (Environmental Impact Assessment) and HRA (Habitats Regulations Assessment) level.

23. Revised cumulative (EIA) and in-combination (HRA) collision assessments will be provided at Deadline 7, following further engagement with Natural England and RSPB.

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Appendix 1. Input parameters

Table 7. Species specific input parameters. Note for all species flapping flight was assumed and an equal percentage of flights are assumed to be upwind and downwind (i.e. 50% each).

Species	Biometrics			Nocturnal activity factor (%; gannet evidence based rates from Furness et al. 2018)	Avoidance rate (%; SD if applicable)
	Body length (m)	Wingspan (m)	Flight speed (ms^{-1})		
Red-throated diver	0.73	1.3	17	50	98
Fulmar	0.48	1.07	13	75	98
Gannet	0.94	1.72	14.9	25	98.9 (0.2)
Arctic skua	0.44	1.18	13.3	0	98
Great skua	0.56	1.36	14.9	0	98
Kittiwake	0.39	1.08	13.1	50	98.9 (0.2)
Black-headed gull	0.37	1.1	11.9	50	99.2 (0.1)
Little gull	0.26	0.78	12.2	25	99.2 (0.1)
Common gull	0.42	1.3	13.4	50	99.2 (0.1)
Lesser black-backed gull	0.58	1.42	13.1	50	99.5 (0.1)
Herring gull	0.6	1.44	12.8	50	99.5 (0.1)
Great black-backed gull	0.71	1.58	13.7	50	99.5 (0.1)

Table 8. Wind farm and turbine input parameters.

Model (MW)	Number	Rotor radius (m)	Hub height (m)	RPM	Max. blade width (m)	Blade pitch (°)	Tidal offset (m; difference between MSL and HAT)	Operational period (%)	Latitude (°)		Windfarm width (km)	
									East	West	East	West
10	180	95	117	8.3	7.5	15	0.8	90	52.2	52.9	22.3	17.7