RWE Renewables UK Dogger Bank South (West) Limited

RWE Renewables UK Dogger Bank South (East) Limited

Dogger Bank South Offshore Wind Farms

Environmental Statement

Volume 7

Appendix 11-4 iPCoD Modelling

May 2024

Application Reference: 7.11.11.4

APFP Regulation: 5(2)(a)

Revision: 01

Company:	**RWE Renewables UK Dogger Bank South (West) Limited and RWE Renewables UK Dogger Bank South (East) Limited**	Asset:	**Development**
Project:	**Dogger Bank South Offshore Wind Farms**	Sub Project/Package:	**Consents**
Document Title or Description:	Appendix 11-4 - Population Modelling Methodology		
Document Number:	004300152-01	Contractor Reference Number:	PC2340-RHD-OF-ZZ-AX-Z-0083

Rev No.	Date	Status/Reason for Issue	Author	Checked by	Approved by
01	May 2024	Final for DCO Application	RHDHV	RWE	RWE

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Term	Definition
Concurrent Scenario	A potential construction scenario for the Projects where DBS East and DBS West are both constructed at the same time.
Dogger Bank South (DBS) Offshore Wind Farms	The collective name for the two Projects, DBS East and DBS West.
Electrical Switching Platform (ESP)	The Electrical Switching Platform (ESP), if required would be located either within one of the Array Areas (alongside an Offshore Converter Platform (OCP)) or the Export Cable Platform Search Area.
In Isolation Scenario	A potential construction scenario for one Project which includes either DBS East or DBS West array, associated offshore and onshore cabling and only the eastern Onshore Converter Station within the Onshore Substation Zone and only the northern route of the onward cable route to the proposed Birkhill Wood National Grid Substation.
Offshore Export Cable Corridor	This is the area which will contain the Offshore Export Cables (and potentially the ESP) between the Offshore Converter Platforms and Transition Joint Bays at the landfall.
Sequential Scenario	A potential construction scenario for the Projects where DBS East and DBS West are constructed with a lag between the commencement of construction activities. Either Project could be built first.
The Applicants	The Applicants for the Projects are RWE Renewables UK Dogger Bank South (East) Limited and RWE Renewables UK Dogger Bank South (West) Limited. The Applicants are themselves jointly owned by the RWE Group of companies (51% stake) and Masdar (49% stake).
The Projects	DBS East and DBS West (collectively referred to as the Dogger Bank South Offshore Wind Farms).

Acronyms

Term	Definition
DBS	Dogger Bank South
ES	Environment Statement
GNS	Greater North Sea
iPCoD	Interim Population Consequence of Disturbance
MU	Management Unit
OECC	Offshore Export Cable corridor
OWF	Offshore Windfarm
PTS	Permanent Threshold Shift
SCOS	Special Committee on Seals
SE	South East

11.4 Population modelling for disturbance.

11.4.1 Introduction

1. This appendix provides the method used for the interim Population Consequences of Disturbance (iPCoD) model. In **Volume 7**, **Chapter 11 Marine Mammals (application ref: 7.11)**, results for disturbance (section 11.6.1.2), conclude that elevations in subsea noise due to piling could potentially lead to the behavioural disturbance of a large number of individuals of the key species identified within the marine mammal study area.

2. Population modelling has therefore been conducted for harbour porpoise, bottlenose dolphin, minke whale, grey seal and harbour seal. The iPCoD framework (Harwood *et al*. 2014; King *et al*. 2015) has been used to predict the potential medium- and long-term population consequences of the predicted amount of disturbance resulting from the piling at the Projects.

3. iPCoD uses a stage-structured model of population dynamics with nine age classes and one stage class (adults 10 years and older). The model is used to run a number of simulations of future population trajectory with and without the predicted level of impact to allow an understanding of the potential future population-level consequences of predicted behavioural responses and auditory injury.

11.4.2 Assumptions and limitations

4. The iPCoD framework (Harwood *et al*. 2014; King *et al*. 2015) has been used to predict the potential medium- and long-term population consequences of the predicted amount of disturbance resulting from the piling at the Projects[1].

[1] iPCoD version 5.2

5. There is a lack of empirical data on the way in which changes in behaviour and hearing sensitivity may affect the ability of individual marine mammals to survive and reproduce. Therefore, in the absence of empirical data, the iPCoD framework uses the results of an expert elicitation process described in Donovan *et al*. (2016) to predict the effects of disturbance and PTS on survival and reproductive rates. The process generates a set of statistical distributions for these effects and then simulations are conducted using values randomly selected from these distributions that represent the opinions of a "virtual" expert. This process is repeated many 100s of times to capture the uncertainty among experts. While the iPCoD model is subject to many assumptions and uncertainties relating to the link between impacts and vital rates, the model presents the best available scientific expert opinion at this time.

11.4.2.1 Duration of disturbance

6. The iPCoD model for minke whale and bottlenose dolphin disturbance was last updated following the expert elicitation in 2013 (Harwood *et al*. 2014). When this expert elicitation was conducted, the experts provided responses on the assumption that a disturbed individual would not forage for 24 hours. However, the most recent expert elicitation in 2018 highlighted that this was an unrealistic assumption for harbour porpoises (generally considered to be more responsive than minke whales and bottlenose dolphin), and was amended to assume that disturbance resulted in 6 hours of non-foraging time (Booth *et al*. 2019).

7. Minke whales and bottlenose dolphins were not included in the updated expert elicitation for disturbance, and, thus, the iPCoD model still assumes 24 hours of non-foraging time for minke whales and bottlenose dolphin. Given the current understanding of marine mammal reactions to pile driving, this scenario appears unrealistic. A recent study estimated energetic costs associated with disturbance from sonar, where it was assumed that one hour of feeding cessation was classified as a mild response, two hours of feeding cessation was classified as a strong response and eight hours of feeding cessation was classified as an extreme response (Czapanskiy *et al*. 2021).

8. The presumption of a 24-hour feeding cessation for minke whale and bottlenose dolphin surpasses what is typically deemed an extreme response. Hence, it is regarded as unrealistic and likely to inflate the actual disturbance levels anticipated from the Projects. For this reason, the current version of iPCoD is not deemed appropriate for minke whale and bottlenose dolphin.

9. Despite these limitations and uncertainties, this assessment has been carried out according to best practice, using the best available scientific information, and the latest expert elicitation results from Sinclair *et al.* (2020). The information provided is therefore considered to be sufficient to carry out an adequate assessment for harbour porpoise, bottlenose dolphin, minke whale, grey seal, and harbour seal.

11.4.2.2 Lack of density dependence

10. Another potential limitation of the iPCoD model is that no form of density dependence has been incorporated due to the uncertainties as to how this may occur. Density dependence is described as 'the process whereby demographic rates change in response to changes in population density, resulting in an increase in the population growth rate when density decreases, and a decrease in that growth rate when density increases' (Harwood *et al.* 2014).

11. The iPCoD scenario run for bottlenose dolphin assumes no density dependence since there is insufficient data to parameterise this relationship. Essentially, this means that there is no ability for the modelled impacted population to increase in size and return to carrying capacity following disturbance.

12. At a recent expert elicitation on bottlenose dolphins, conducted for the purpose of modelling population impacts of the Deepwater Horizon oil spill (Schwacke *et al.* 2021), experts agreed that there would likely be a concave density dependence on fertility, which means that, in reality, it would be expected that the impacted population would recover to carrying capacity (which is assumed to be equal to the size of un-impacted population – i.e. it is assumed the un-impacted population is at carrying capacity) rather than continuing at a stable trajectory that is smaller than that of the un-impacted population.

13. The limitations for assuming a simple linear ratio between the maximum net productivity level and carrying capacity have been highlighted by Taylor & Master (1993) as simple models demonstrate that density dependence is likely to involve several biological parameters which themselves have biological limits (e.g. fecundity and survival). For UK populations of harbour porpoise (and other marine mammal species) however, there is no published evidence for density dependence and therefore, density dependence assumptions are not currently included within the iPCoD protocol.

11.4.2.3 Environmental and demographic stochasticity

14. The iPCoD model attempts to model some of the sources of uncertainty inherent in the calculation of the potential effects of disturbance on marine mammal population. This includes demographic stochasticity and environmental variation. Environmental variation is defined as *'the variation in demographic rates among years as a result of changes in environmental conditions'* (Harwood *et al.* 2014). Demographic stochasticity is defined as *'variation among individuals in their realised vital rates as a result of random processes'* (Harwood *et al.* 2014).

15. The iPCoD protocol describes this in further detail: 'Demographic stochasticity is caused by the fact that, even if survival and fertility rates are constant, the number of animals in a population that die and give birth will vary from year to year because of chance events'. Demographic stochasticity has its greatest effect on the dynamics of relatively small populations, and we have incorporated it in models for all situations where the estimated population within an Management Unit (MU) is less than 3000 individuals. One consequence of demographic stochasticity is that two otherwise identical populations that experience exactly the same sequence of environmental conditions will follow slightly different trajectories over time. As a result, it is possible for a "lucky" population that experiences disturbance effects to increase, whereas an identical undisturbed but "unlucky" population may decrease' (Harwood et al. 2014).

16. This is clearly evidenced in the outputs of iPCoD where the un-impacted (baseline) population size varies greatly between iterations, not as a result of disturbance but simply as a result on environmental and demographic stochasticity. In the example provided in **Plate 11-4-1**, after 25 years of simulation, the un-impacted population size varies between 176 (lower 2.5%) and 418 (upper 97.5%). Thus, the change in population size resulting from the impact of disturbance is significantly smaller than that driven by the environmental and demographic stochasticity in the model.

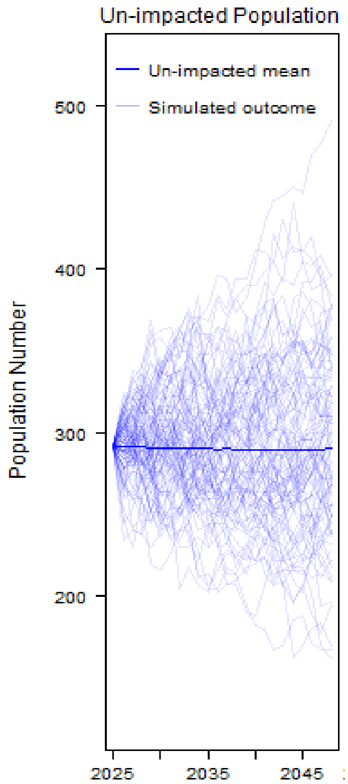

Plate 11-4-1 Simulated Un-impacted (baseline) Population Size over the 25 Years Modelled

17. Despite these limitations and uncertainties, this assessment has been carried out according to best practice, using the best available scientific information, and the latest expert elicitation results from Booth & Heinis (2018). The information provided is therefore considered to be sufficient to carry out an adequate assessment for harbour porpoise, bottlenose dolphin, minke whale, grey and harbour seal.

11.4.3 Methodology

11.4.3.1 Piling Parameters

18. The amount of piling required for the Projects is dependent on the construction scenario taken forwards and the final design of the Project(s): DBS East or DBS West In Isolation, or DBS East and DBS West (Sequentially or Concurrently). The construction scenario of constructing the Projects sequentially has been taken forward for modelling in iPCoD as it was considered the worst case, resulting in the largest number of disturbed animals over time, and if results had shown there was a consequence of disturbance, other project scenarios would have been modelled.

19. The amount of piling required is also dependent on the foundations selected and the final piling schedule. The worst case scenario for the Projects (maximum number of monopiles with the highest strike rate) has been taken forward for modelling in iPCoD.

20. The number of marine mammals that are at potential risk of PTS is taken from a single pile event, using cumulative sound exposure level (SEL_{cum}) for the worse location at DBS East, DBS West and the Offshore Export Cable Corridor.

21. Whilst there is potential that piling for DBS East and DBS West could occur concurrently, thereby reducing the number of days in which disturbance can occur, as a worst case it has been assumed that the Projects along with the potential monopile in the Offshore Export Cable Corridor would be constructed sequentially, therefore there would be approximately 202 days of disturbance within the four-year construction period that has been modelled.

22. Therefore, the actual piling days for each construction scenario have been distributed randomly within the summer period where piling is most likely to occur (**Table 11-4-1**). Piling for monopiles (over jacket pin-piles) has been modelled as it is the worst case.

Table 11-4-1 Piling Parameters Used as Inputs to the iPCoD Model

Parameters	Location	Value
Number of monopiles	DBS East	104
	DBS West	104
	OECC	1[2]
Number of piling days	DBS East	104
	DBS West	104
	OECC	1[2]
Piling Schedule	DBS East	Q2 2027 to Q3 2029 - days selected randomly
	DBS West	Q2 2030 to Q3 2032 - days selected randomly
	OECC	Q2 2027 to Q3 2032 --days selected randomly

[2] The Electrical Switching Platform (ESP) could be located in either the Array Areas or Offshore Export Cable Corridor, but not both. The total number of platforms for either Project is four, but the ESP has been assessed in both locations as a precautionary worst case.

11.4.3.2 Model inputs

23. The iPCoD model[3] was set up using the program R v4.2.3 (2023) with RStudio as the user interface. To enable the iPCoD model to be run, the following data were provided:

- Demographic parameters for each key species.
- User specified input parameters.
  - Vulnerable subpopulations.
  - Residual days of disturbance.
- Number of animals predicted to experience PTS and/or disturbance during piling; and
- Estimated piling schedule during the proposed construction programme.

11.4.3.3 Demographic Parameters

24. Demographic parameters for the key species assessed in the population model are presented in

[3] https://www.smruconsulting.com/population-consequences-of-disturbance-pcod

25. **Table** 11-4-2. In the case of harbour seal, evidence for demographic parameters for the English populations is lacking (Sinclair *et al.*, 2020). The combined counts for harbour seal in the south east (SE) England MU in 2019 (3,081) was 27.6% lower than the 2012 to 2018 mean count. Additional surveys in 2020 and 2021 confirmed the decrease (SCOS, 2021). Given that the SE England MU appears to be decreasing in recent years, the worst case demographic parameters for the similarly decreasing population on the Scottish East coast have been utilised in the modelling as well as the numbers for the SE England harbour sela population.

26. There are no parameters within the iPCoD model for common dolphin or white-beaked dolphin so these were the only two species that population modelling could not be carried out.

Table 11-4-2 Demographic parameters recommended for each species for the relevant Management Unit (MU) (Sinclair et al. 2019)

Species	MU	Age calf/pup becomes independent	Age of first birth	Calf / Pup Survival	Juvenile Survival	Adult Survival	Fertility	Growth Rate
		age1	age2	Surv [1]	Surv [7]	Surv [13]		
Harbour porpoise	346,601	1	5	0.8455	0.85	0.925	0.34	1.000
Bottlenose dolphin	2,022	2	9	0.8	0.94	0.94	0.25	1.000
Minke whale	20,118	1	9	0.70	0.77	0.96	0.91	1.000
Grey seal	30,592 (56,505)	1	6	0.222	0.94	0.94	0.84	1.01
Harbour seal (stable population)	4,868	1	4	0.354	0.86	0.95	0.91	1.000
Harbour seal (declining population)	4,868	1	4	0.24	0.86	0.80	0.90	0.8956

11.4.3.4 Reference Populations

27. Table 11-4-3 provides the reference populations used in the iPCoD modelling, which are the same as what has been referenced in **Volume 7, Chapter 11 Marine Mammals (application ref: 7.11)** and **Volume 7, Appendix 11-2 Marine Mammal Information (application ref: 7.11.11.2)**.

Table 11-4-3 Reference Population Uses in the iPCoD Modelling.

Marine mammal species	Area	Population
Harbour porpoise	North Sea (NS)	346,601
Bottlenose dolphin	Greater North Sea (GNS)	2,022
Minke whale	Celtic Greater North Sea (CGNS)	20,118
Grey seal	SE England	30,592
	SE and northeast (NE) England	56,505
Harbour seal	SE England	4,868

11.4.3.5 Residual Days Disturbance

11.4.3.5.1 Population modelling for disturbance from DBS Projects

28. Empirical evidence from constructed wind farms (e.g. Graham *et al*, 2019; Brandt *et al*. 2011) suggests that the detection of animals returns to baseline levels in the hours following a disturbance from piling and therefore, for the most part, it can be assumed that the disturbance occurs only on the day (24 hours) that piling takes place (at least in the case of harbour porpoise which was the focus of these studies). However, the number of residual days of disturbance has, conservatively, been selected as one, meaning that the model assumes that disturbance occurs on the day of piling and persists for a period of 24 hours after piling has ceased.

11.4.3.6 Cumulative population consequences of disturbance from pile driving at other projects

29. A review of the data available for screened in offshore wind farms has been undertaken, and project specific worst case pile driving, PTS, and disturbance data have been incorporated into a cumulative iPCoD modelling run for each species considered, namely harbour porpoise, bottlenose dolphin, minke whale, grey and harbour seal.

30. The demographic parameters, reference populations, and residual days of disturbance remained the same as for project alone modelling. Piling days were distributed at random within the stated piling schedules for each project.

31. The piling parameters assessed for other projects in the iPCoD modelling are set out in **Table 11-4-4**.

32. A number of projects did not report PTS or disturbance numbers for some, or all, species considered within this assessment. In these cases, the worst case PTS or disturbance numbers from the Projects were assumed to also occur for projects where information was lacking.

Table 11-4-4 Piling Parameters for Other Projects Screened into the Cumulative iPCoD Modelling

Parameters	Project	Value
Number of piling days	DBS East	104
	DBS West	104
	OECC	1
	Berwick Bank	307
	Dudgeon Extension	34
	East Anglia Hub	88
	Five Estuaries	79
	Hornsea Project Three	319
	Hornsea Project Four	180
	North Falls	140
	Outer Dowsing	93
	Rampion 2	325
	Seagreen 1A	36
	Sheringham Shoal Extension	27
	West of Orkney	125
Piling Schedule	DBS East	Q2 2027 to Q3 2030
	DBS West	Q2 2030 to Q3 2032

Parameters	Project	Value
	OECC	Q2 2027 to Q3 2032
	Berwick Bank	2024-2027
	Dudgeon Extension	2026-2027
	East Anglia Hub	2024/2025 to 2027
	Five Estuaries	2028-2030
	Hornsea Project Three	2023 to 2027
	Hornsea Project Four	2027-2028
	North Falls	2027-2030
	Outer Dowsing	2028-2030
	Rampion 2	2025-2029
	Seagreen 1A	2026-2027
	Sheringham Shoal Extension	2027-2028
	West of Orkney	2028-2031

11.4.3.7 Number of animals with PTS or Disturbed

11.4.3.7.1 Population modelling for disturbance from the DBS Projects

33. The number of animals predicted to experience permanent threshold shift (PTS) and/or disturbance during piling was based on the density values provided as part of the baseline assessment of the Environment Statement (ES) (**Volume 7, Chapter 11 (application ref: 7.11.0)**) for harbour porpoise. In the case of disturbance, the estimated number of animals affected are based on effective deterrent ranges. Whilst this report provides alternative estimates of the number of animals disturbed, based on a dose-response analysis (which can be considered more realistic), the estimates resulting from Effective Deterrent Ranges (EDRs) are greater, and therefore have been used in the iPCoD model as a conservative worst case.

34. **Table 11-4-5** presents the number of individuals that could potentially be disturbed due to piling at DBS East, DBS West and the Offshore Export Cable Corridor.

Table 11-4-5 Estimated Number of Potential Marine Mammals to have PTS or to be Disturbed During Each Piling Event (percentage of reference population in brackets)

Marine mammal species	DBS East		DBS West		OECC	
	PTS	Disturbance	PTS	Disturbance	PTS	Disturbance
Harbour porpoise	144 (0.415%)	4,295.5 (1.24%)	132 (0.038%)	5,097.7 (1.47%)	325.5 (0.117%)	7,940.5 (2.29%)
Bottle-nose dolphin	0.004 (0.00002 %)	0.1 (0.006%)	0.004 (0.00002 %	0.1 (0.006%)	0.001 (0.0006 %	0.5 (0.022%
Minke whale	5.6 (0.027%)	28.3 (0.14%)	3.1 (0.155%	56.5 (0.281%)	42.5 (0.211%	56.5 (0.281%)
Grey seal	1.1 (0.003% & 0.001%)	3,124.2 (10.21% & 5.53%)	1.1 (0.003% & 0.001%)	2,378.7 (7.78% & 4.21%)	12.2 (0.039% & 0.015%)	9,102.6 (24.0% & 13.0%)
Harbour seal	0.01 (0.002%)	8.1 (0.17%)	0.004 (0.00008 %)	7.0 (0.14%)	0.04 (0.0008 %)	23.1 (0.47%)

11.4.3.7.2 Population Modelling of Cumulative Impacts for all OWF

35. The number of animals predicted to experience PTS and/or disturbance during piling was based on the density values that were published in the projects Preliminary Environmental Impact report (PEIR) or ES chapters for the respective projects (**Table 11-4-6** and **Table 11-4-7**).

Table 11-4-6 Estimated Number of Marine Mammals to have PTS During Each Piling Event

OWF Project	Number of animals affected				
	Harbour porpoise	Bottlenose dolphin	Minke whale	Grey seal	Harbour seal
Berwick Bank	-	-	1	-	-
Dudgeon Extension	100	0.003	1.5	0.13	0.3
East Anglia Hub	573	*0.004*	*42.5*	0.1	0.05
Five Estuaries	237	*0.004*	*42.5*	0.9	0.9
GreenVolt	0.013	0.00003	0.14	0.0004	0.00000002
Hornsea Project Three	-	-	-	-	-
Hornsea Project Four	-	-	-	-	-
North Falls	62.1	*-0.004*	1.9	0.02	0.0003
Outer Dowsing	64	0	1	0	0
Rampion 2	26	-	1	-	-
Seagreen 1A	-	-	-	-	-
Sheringham Shoal Extension	0.13	0.003	0.92	0.39	0.2
West of Orkney	93	-	22	-	-

Table 11-4-7 Estimated Number of Marine Mammals to have Disturbance During Each Piling Event

OWF Project	**Number of animals affected**				
	Harbour porpoise	**Bottlenose dolphin**	**Minke whale**	**Grey seal**	**Harbour seal**
Berwick Bank	1754	64	82	705	2
Dudgeon Extension	804	0.011	11	347	43
East Anglia Hub	1289	*0.5*	*56.5*	2	1
Five Estuaries	7031	*0.5*	*56.5*	112	3
GreenVolt	29.1	1.14	1.5	13.9	0.00008
Hornsea Project Three	2507	*0.5*	38	48.2	*3.3*
Hornsea Project Four	6417	14	*56.5*	1489	5
North Falls	1289.1	*-0.5*	*56.5*	217.9	2.7
Outer Dowsing	5229	4	22	615	35
Rampion 2	752	-	8	-	-
Seagreen 1A	1403	4.1	91	51	0.28
Sheringham Shoal Extension	582	0.01	7.2	338	84
West of Orkney	1,349	-	90	-	-

11.4.3.8 Piling schedule

36. The piling schedule was developed from the project design envelope which provided an estimate of the number of days piling for the wind turbine within a defined piling phase, which is scheduled to take place within an overall offshore piling construction window, as described in **Volume 7, Chapter 5 Project Description (application ref: 7.5)**.

11.4.4 Results from Population modelling

37. The results from the iPCoD modelling for the Projects is presented in section 11.6 of **Volume 7**, **Chapter 11 Marine Mammals (application ref: 7.11)**.

38. Additional modelling has been undertaken to determine the potential for population level effects due to cumulative disturbance with other offshore wind farm piling activities (see section 11.7 of **Volume 7**, **Chapter 11 Marine Mammals (application ref: 7.11)**).

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