Bellrock Offshore Wind Farm

Wind Farm Development Area

Environmental Impact Assessment Report - Volume IV

Appendix 9.5: Marine Mammals Information and Modelling Methods for Disturbance

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Glossary of Terminology

Term	Definition
Applicant	Bellrock Offshore Wind Farm Limited, the legal entity submitting Section 36 Consent and Marine Licence applications for the Bellrock Wind Farm Development Area.
Bellrock Offshore Wind Farm (or the Bellrock Project)	An offshore wind farm capable of exporting up to 1.8 GW of renewable energy to the National Electricity Transmission System. The Wind Farm Development Area is located 120 km east of Stonehaven, and will connect to the National Electricity Transmission System at the proposed SSEN Transmission Hurlie substation, west of Stonehaven in Aberdeenshire. The Bellrock Offshore Wind Farm comprises of the following Development Areas: ▪ Wind Farm Development Area; ▪ Offshore Transmission Development Area; and ▪ Onshore Transmission Development Area.
Development Area	For consenting purposes, the area for which separate consents and/or Marine Licences will be sought by the Applicant, comprising: ▪ Wind Farm Development Area; ▪ Offshore Transmission Development Area; and ▪ Onshore Transmission Development Area.
Dynamic inter-array cable	The section of inter-array cable between the floating substructure and the seabed, which is designed to accommodate the dynamic movement of the floating substructure.
Floating offshore unit	The combined wind turbine generator and floating substructure.
Floating substructure	A floating structure which provides buoyancy and, in conjunction with the station keeping system, supports a superstructure (e.g. wind turbine generator or offshore substation), and maintaining its position within the structure's excursion limit.
Inter-array cable	Armoured cable containing electrical and fibre optic cores, which link the wind turbine generators to each other and to the subsea cable hubs and/or the offshore substations and include dynamic inter-array cable and static inter-array cable sections.
Site preparation works	Preparatory activities undertaken within the Wind Farm Development Area prior to the commencement of construction of the Wind Farm Infrastructure, which may comprise (and which may require separate consents): ▪ Geophysical surveys, geotechnical surveys, and non-archaeological/archaeological diver/ remotely operated vehicle surveys; ▪ Seabed preparation including sand wave levelling, slope levelling for gravity based anchors (if selected), boulder clearance, and pre-lay grapnel runs; ▪ Unexploded ordnance survey and/or clearance; ▪ Debris clearance; and ▪ Out of service cable/pipeline removal.
SSEN Transmission Hurlie substation	The onshore substation to be developed by SSEN Transmission, which will receive renewable electricity from the Bellrock Project onshore substation and allow supply of renewable electricity from the wind farm to the National Electricity Transmission System.
Station keeping system	The system (including mooring lines and anchors) used to hold a floating offshore unit within its excursion limit and maintain the intended orientation of the floating offshore unit.

Term	Definition
Wind Farm Development Area	The boundary within which the Wind Farm Infrastructure will be constructed, operated and maintained, and decommissioned.
Wind Farm Infrastructure	Infrastructure located within the Wind Farm Development Area including wind turbine generators; floating substructures, station keeping systems and associated scour protection; inter-array cables and associated cable protection; subsea cable hubs; and ancillary infrastructure including buoys (including activities associated with the Wind Farm Infrastructure construction, operation and maintenance, and decommissioning).
Wind turbine generator	A wind turbine generator converts wind energy into electrical energy. The main components include rotor assembly (composed of three blades and a hub); nacelle (containing the generator, shaft and gearbox, power electronic converter and transformer); and a tower (containing lifting equipment and switchgear).

Glossary of Abbreviations

Term	Definition
CEA	Cumulative effects assessment
DRC	Dose-response curve
EIA	Environmental impact assessment
FOU	Floating offshore unit
FSS	Floating substructure
Hz	hertz
IAMMWG	Inter-Agency Marine Mammal Working Group
iPCoD	interim Population Consequences of Disturbance
MU	Management unit
OWF	Offshore wind farm
PrePARED	Predators and Prey Around Renewable Energy Development
PTS	Permanent threshold shift
rms	Root mean square
SAC	Special Area of Conservation
SCANS	Small Cetaceans in the European Atlantic and North Sea
SCOS	Special Committee on Seals
SD	Standard deviation
SEL	Sound exposure level
SEL_{cum}	Cumulative sound exposure level
SEL_{ss}	Single-pulse sound exposure level
SKS	Station keeping system
SPL	Sound pressure level
UK	United Kingdom
WFDA	Wind Farm Development Area
WTG	Wind turbine generator

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1 Introduction

1. This Marine Mammals Information and Modelling Methods for Disturbance report is an Appendix to **Chapter 9: Marine Mammals (Volume II)** of the Bellrock Wind Farm Development Area (WFDA) Environmental Impact Assessment (EIA) Report.

2. The disturbance effects of the Bellrock Wind Farm Infrastructure have been addressed in **Chapter 9: Marine Mammals (Volume II)** and the purpose of this Appendix is to provide further information on the modelling approaches used to assess disturbance caused by underwater noise.

3. The infrastructure in the Bellrock WFDA will include:

- Up to 132 wind turbine generators (WTGs) with floating substructures (FSSs) (together termed ‘floating offshore unit’ (FOU));
- Station keeping systems (SKSs) for each FSS, including mooring lines and anchoring systems and ancillary elements;
- Up to 18 subsea cable hubs;
- A network of static inter-array cables (on the seabed) and dynamic inter-array cables (in the water column) linking the individual FOUs to subsea cable hub(s) or offshore substations; and
- Associated scour and cable protection, as required.

4. A full description of the Bellrock WFDA is provided in **Chapter 4: Project Description** (**Volume II**).

5. **Section 2** and **Section 3** set out the methodologies used for the interim Population Consequences of Disturbance (iPCoD) and the dose-response curve (DRC) approach. Section 9.8.1.3.2 of **Chapter 9: Marine Mammals (Volume II)** details the findings for the disturbance assessment.

6. **Section 4** details how disturbance through underwater noise from vessel activities may affect marine mammals. Assessment of this potential and the increased risk of vessel collision is set out in Sections 9.8.1.6 of **Chapter 9: Marine Mammals (Volume II)**.

2 Population Modelling

7. This section supports **Chapter 9: Marine Mammals (Volume II)**, Section 9.8.1.3.2.3.1 that presents the Project-alone iPCoD results, and Section 9.9.3.2.3 in which long-term modelling results for the cumulative disturbance of the Bellrock WFDA with other plans and projects were presented.

2.1 Introduction

8. In Section 9.8.1.3.2 of **Chapter 9: Marine Mammals (Volume II)**, the results for disturbance from piling conclude that elevations in subsea noise from noisy activities arising from the Bellrock WFDA could potentially lead to the behavioural disturbance of a large number of individuals of the key species identified within the marine mammal study area (Section 9.6 in **Chapter 9: Marine Mammals (Volume III)**).

9. The iPCoD framework (Harwood et al. 2014, King et al. 2015, Harwood and King 2017) has been used to predict the potential medium- and long-term population consequences from the estimated disturbance resulting from the piling at the Bellrock WFDA.

10. 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.

11. Population modelling has been conducted for the following species:

- Harbour porpoise *Phocoena phocoena*;
- Bottlenose dolphin *Tursiops truncates*;
- Minke whale *Balaenoptera acutorostrata*;
- Grey seal *Halichoerus grypus;* and
- Harbour seal *Phoca vitulina.*

12. As there are no parameters within the iPCoD model for common dolphin, white-beaked dolphin, killer whale, fin whale or humpback dolphin, it is not possible to undertake iPCoD modelling for these species. Instead, other methods of assessment have been used to assess disturbance (dose-response curves and qualitative assessments) and are detailed in Section 9.8.1.3.2 in **Chapter 9: Marine Mammals (Volume II).**

2.2 Methodology

2.2.1 Piling Parameters

13. The amount of piling required is dependent on the number of structures and design of the SKS. The worst-case scenario for the Bellrock WFDA (e.g. the maximum number of piles with the highest strike rate) has been taken forward for modelling in iPCoD.

14. The number of marine mammals that are potentially disturbed are based on the DRC assessment (see **Section 3**) from installing a single pile at the Bellrock WFDA.

15. At this early stage of development, uncertainty exists around the exact piling schedule that would be used for installation of the SKSs at the Bellrock WFDA. The exact piling schedule will only be known post-consent award, once more detailed geotechnical surveys and detailed design have been undertaken. The offshore construction phase is currently set to be a maximum of seven years from 2031 - 2037, with approximately one year of site preparation works from 2030; the period during which piling is likely to occur would be shorter (estimated at eight months per year due to weather restrictions) and occurring in first six years of the seven year construction phase. Therefore, the required number of piling days have been distributed randomly within the eight month period per year (**Table 2.1**).

Table 2.1: Piling Parameters used as Inputs to the Interim Population Consequences of Disturbance (iPCoD) Model

Parameters	Value
Number of piles	1,188 (9 piles per FOU and 132 FOUs)
Number of piling days	396 (assuming 3 piles per day)
Piling schedule	Six years with piling expected between March - October

2.2.1.1 Piling Schedule

16. The piling schedule was developed assuming the worst-case of 1,188 piles to be installed individually (up to 9 piles for each FOU). The schedule assumes that these days would take place on randomly allocated days within the piling windows over the first six years of the 7 year construction phase.

2.2.1.2 Residual Days Disturbance

17. Empirical evidence from constructed wind farms (e.g. Graham et al. 2019; Brandt et al. 2011) suggests that animals return to baseline levels in the hours following a disturbance from piling. 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.

2.2.2 Model Inputs

18. The iPCoD model was set up using the program R v4.3.1 (R Core Team 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 disturbance during piling; and
- Estimated piling schedule during the proposed construction programme.

2.2.2.1 Demographic Parameters

19. Demographic parameters for the key species assessed in the population model are presented in **Table 2.2**.

20. There are significant differences in harbour seal population dynamics between regions in the UK. Harbour seal counts in all surveyed areas (Northern Ireland, East Scotland, Moray Firth, and Southeast England MUs) in 2021 were substantially lower compared to the previous survey round conducted between 2016-2019 (Special Committee on Seals (SCOS), 2022). There have been general declines in counts around Scotland, but the declines are not universal with some populations either stable or increasing. For instance, the Orkney & North Coast Management Unit (MU) and in East Scotland (i.e. the Firth of Tay and Eden Estuary SAC are continuing to decline, and in Shetland and the Moray Firth, the current population size is at least 40% below the pre-2002 level with no indication of recovery (SCOS, 2022).

Table 2.2: Demographic Parameters Recommended for Each Species for the Relevant Management Unit (MU)

Species	Age Calves/ Pup Becomes Independent	Age of First Birth	Calf/ Pup Survival	Juvenile Survival	Adult Survival	Fertility	Growth Rate
	Age 1	Age 2	Surv [1]	Surv [7]	Surv [13]		
Harbour porpoise	1	5	0.6	0.85	0.925[1]	0.479[1]	1.00
Bottlenose dolphin[2]	2	9	0.9	0.94	0.9497	0.3	1.0180
Minke whale	1	9	0.72	0.77	0.96	0.90	1.00
Grey seal	1	5	0.222	0.94	0.94	0.84	1.01
Harbour seal (stable population)[3]	1	4	0.55	0.61	0.9451	0.88	1.00
Harbour seal (declining population)[4]	1	4	0.5	0.5	0.7701	0.88	0.82

Notes:

Table parameters and terms used are extracted from Table 3 in Sinclair et al. 2020.

[1] Assuming high adult survival in the North Sea

[2] Based on Coastal East Scotland MU

[3] Based on the parameters on the Moray Firth MU

[4] Based on the parameters for East Scotland MU modified using survival

2.2.2.2 Reference Population

21. **Table 2.3** provides the reference populations used in the iPCoD modelling.

Table 2.3: Reference Populations Used in the Interim Population Consequences of Disturbance (iPCoD) Modelling

Species	MU(s) Relevant for the Bellrock WFDA	Population	Source
Harbour porpoise	North Sea MU	346,601	Inter-Agency Marine Mammal Working Group (IAMMWG), 2023
Bottlenose dolphin	Greater North Sea (GNS) MU	2,022	
Minke whale	Celtic and Greater North Sea (CGNS) MU	20,118	
Grey seal	Moray Firth, East Scotland and Northeast England MUs	33,336	SCOS, 2024
Harbour seal	East Scotland MU	383	

2.2.2.3 Vulnerable Sub-populations

22. For the purposes of the modelling, it was assumed that the entire population of interest was potentially vulnerable to pile driving disturbance.

2.2.2.4 Number of Animals Predicted to Experience Disturbance

23. The number of animals predicted to experience disturbance during piling was based on the density values provided as part of the baseline assessment in **Chapter 9: Marine Mammals (Volume II)**. In the case of disturbance, the estimated numbers of all marine mammal receptors were derived though the DRC assessment (see **Section 3**). The worst-case numbers that have been identified through the assessment for disturbance due to unmitigated piling at the Bellrock WFDA (as presented in **Table 2.4**) are directly applied into the model.

Table 2.4: Estimated Number of Marine Mammals to Experience Disturbance During Each Piling Event

Species	Number of Animals Affected During Each Piling Event
Harbour porpoise	8,554
Bottlenose dolphin	32
Minke whale	504
Grey seal	200
Harbour seal	0.002

24. For cumulative effects assessments (CEA), the number of animals predicted to experience disturbance during piling was based on the density values that were published in the respective EIA chapters for the projects screened into the CEA (see **Appendix 9.4: Mammals Cumulative Effects Assessment Screening (Volume IV)** for details). **Table 2.5** presents the number of individuals that could potentially experience disturbance from piling at the offshore wind farm (OWF) projects screened into the CEA. The number of animals predicted to experience disturbance during piling was based on the values the project has based their cumulative assessment on; taken from the relevant EIAs. Where EIAs have screened out species from population modelling, these have not been included in the population modelling, see **Table 2.5**. However, a PrePARED case study has indicated CEA population modelling results were the same between methods of including EIA projects only and all projects (using the effective deterrent range approach for projects without EIAs) (Sinclair and Klementisova, 2025).

Table 2.5: Estimated Number of Marine Mammals to be Disturbed During Each Piling Event for Cumulative Effect Assessment

Project	Harbour Porpoise	Bottlenose Dolphin	Minke Whale	Grey Seal	Harbour Seal
Buchan	11,527	87	376	N/A	N/A
Cenos	8,863	N/A[1]	358	127	N/A
Dogger Bank D	5,015	67	44	N/A	N/A
Dogger Bank South (West)	5,098	0.1	57	N/A	N/A
Muir Mhor	14,630	74	735	1156	1
North Falls	6,832	N/A	37	N/A	N/A
Ossian (wind turbine)	3,857	2	169	131	N/A
Ossian (OSP)	7,310	4	319	344	N/A
Sheringham Shoal Extension	1,338	0.009	8	N/A	N/A
West of Orkney	1,349	N/A	90	N/A	N/A

Notes:

Cells marked N/A indicate where projects have been screened out for certain species.

[1] Bottlenose dolphin not included in Cenos iPCoD modelling, as agreed with NatureScot (Cenos Offshore Wind Limited, 2024).

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2.2.3 Assumptions and Limitations

25. The iPCoD framework (version 5.2) (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 Bellrock WFDA.

26. Insufficient empirical evidence regarding how alterations 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 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 hundreds 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 the time of assessment.

27. In the latest update of the iPCoD model there was no elicitation for minke whale (PTS or disturbance) or bottlenose dolphins (disturbance) and the results presented in **Chapter 9: Marine Mammals (Volume II)** were highly conservative and represent an overestimation of any potential population level effects. There were several precautions built into the iPCoD model that mean the results are highly precautionary and overestimate the true population level effects. These include, but are not limited to, the following three factors:

- The fact that the model assumed a minke whale and bottlenose dolphin would not forage for 24 hours after being disturbed;
- The lack of density dependence in the model (meaning the population would not respond to any reduction in population size); and
- The level of environmental and demographic stochasticity in the model.

28. The following sections explore the background to each of these factors to illustrate the level of conservatism in this modelling and provide critical context for the evaluation of these results.

2.2.3.1 Duration of Disturbance

29. 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 exercise 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).

30. The expert elicitation for disturbance in 2018 did not include minke whales and bottlenose dolphins and, thus, the iPCoD model still assumes 24 hours of non-foraging time for these species. 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). Hence, it is regarded as unrealistic and likely to inflate the actual disturbance levels anticipated from the Bellrock WFDA. For this reason, the current version of iPCoD is considered overly precautionary for minke whale and bottlenose dolphin.

2.2.3.2 Lack of Density Dependence

31. 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).

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

33. 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. 2022), experts agreed that there would likely be a concave density dependence on fertility. This means 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.

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

2.2.3.3 Environmental and Demographic Stochasticity

35. 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 populations. 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*’. Demographic stochasticity is defined as ‘*variation among individuals in their realised vital rates as a result of random processes*’ (Harwood et al. 2014).

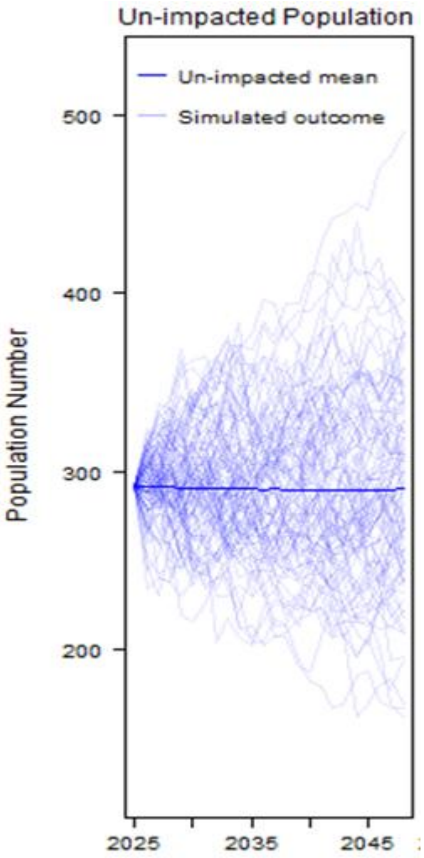
36. The iPCoD protocol describes this in further detail: ‘Demographic stochasticity is caused by the fact that, even if survival and fertility rates are constant, the number of animals in a population that die and give birth will vary from year to year because of chance events’.

37. Demographic stochasticity has its greatest effect on the dynamics of relatively small populations, and has been incorporated into the model for all situations where the estimated population within an MU is less than 3,000 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).

38. 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 of environmental and demographic stochasticity. In the example provided in **Plate 2.1** 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 2.1: Simulated Un-impacted (Baseline) Population Size Over the 25 Years Modelled (Example Output)



39. Despite these limitations and uncertainties, the assessment in **Chapter 9: Marine Mammals (Volume II)** has been carried out using the iPCoD model, according to best practice, using the best available scientific information, and the latest expert elicitation results from Booth and Heinis (2018). The information provided is considered to be sufficient to carry out an adequate assessment for harbour porpoise, bottlenose dolphin, minke whale, grey and harbour seal.

2.2.4 Summary

40. All of the precautions built into the iPCoD model mean that the results are considered to be highly precautionary. Despite the discussed 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 and Heinis (2018). The information provided is therefore considered to be sufficient to carry out an adequate assessment for bottlenose dolphin, harbour porpoise, harbour seal and grey seal. Results have also been presented for minke whale, noting the caveat above regarding no update to the expert elicitation for minke whale.

2.3 Presentation of Results

41. The iPCoD modelling results presented in Sections 9.8.1.3.2.3.1 and 9.9.3.2.3 in **Chapter 9: Marine Mammals (Volume II)** consider the median of the ratio of impacted:un-impacted population sizes for the relevant marine mammal populations as the key metric to determine effect significance using the iPCoD method. This is due to the fact that the median of the ratio of impacted:un-impacted population sizes is considered more statistically robust to the effects of extreme outliers than the mean value, particularly with lower sample sizes (Sinclair et al. 2020). The mean has also been presented for completeness.

42. In addition, this metric is considered least sensitive to misspecification of demographic parameters, therefore enabling more robust assessment of offshore renewable effects. Evaluations of the sensitivity of outputs to misspecification of demographic parameters have demonstrated that the ratio output metric that is counterfactual of population size (the median of the ratio of the impacted to un-impacted population size across all simulated matched replicate pairs) is a robust metric. Therefore, it is recommended for population viability type analyses that compare modelled populations with counterfactual populations in the context of offshore wind EIAs (Jital et al. 2017; Sinclair et al. 2020). The approach taken in the Bellrock WFDA EIA Report is therefore in line with the guidance set out by the iPCoD developers (Sinclair et al. 2020) and others (Jitlal et al. 2017).

43. This rationale, developed by the authors of the iPCoD code, has resulted in the median of the ratio of impacted:un-impacted population sizes being used and accepted for other recent OWF EIAs. The following projects presented the median of the ratio of impacted to un-impacted population size:

- Buchan (Buchan Offshore Wind, 2025);
- Cenos (Cenos Offshore Windfarm Limited, 2024);
- Dogger Bank D (SSE Renewables & Equinor, 2025);
- Ossian (SSE, Marubeni & CIP, 2024);
- Sheringham Shoal Extension (Equinor, 2022);
- North Falls (SSE & RWE, 2024); and
- West of Orkney (Offshore Wind Power Limited, 2024).

44. The iPCoD model runs 1,000 simulations to project population growth for both impacted and unimpacted populations over a set period, typically 25 years. This results in 1,000 pairs of population metrics for each time point, comparing those that have been affected by disturbance with those that have not. From these pairs, calculating the ratio of the impacted to the unimpacted population size, and then determine the median of all these ratios. This result is expressed as a percentage in the iPCoD results tables: **Table 9.32** to **Table 9.36** for Bellrock WFDA-alone assessment and **Table 9.72** to **Table 9.76** for cumulative disturbance of **Chapter 9: Marine Mammals (Volume II)**.

45. It is crucial to understand that this method is different from simply calculating the median population sizes of impacted and unimpacted groups separately. The first method, as described above, takes the ratio for each of the 1,000 pairs of impacted and unimpacted populations and then finds the median of these ratios. This provides a comprehensive view of how the populations interact across all simulations. The second method finds the median size of the impacted populations and the unimpacted populations independently and then compares these two median values. This means that the two methods can yield different results: one captures the overall population differences as influenced by variations across all simulations, while the other focuses only on the central tendency of each group's medians. Therefore, it is not possible to use the average (mean or median) population values presented within the iPCoD tables to calculate the median of the ratio of impacted:un-impacted population sizes, which is also presented in the same tables and is the primary metric for assessing effect significance.

46. It is also important to note that calculating the percentage difference between the mean sizes of the impacted and un-impacted population sizes at a given timepoint (presented in the result tables) will not necessarily match the mean ratio of the impacted to un-impacted populations presented in the same tables. Understanding these distinctions is key to accurately interpreting the results from the iPCoD model.

47. The results in **Chapter 9: Marine Mammals (Volume II)** will therefore be presented using the following timepoints:

- Time point 1/2031: first year of piling at the Bellrock WFDA;
- Time point 2/2032: second year of piling;
- Time point 3/2033: third year of piling;
- Time point 7/2036: marks the end of the six-year window over which piling could occur;
- Time point 13/2043: six years after piling has finished;
- Time point 19/2049: twelve years after piling has finished; and
- Time point 26/2056: marks the end of 25 years of modelling, since piling first commenced.

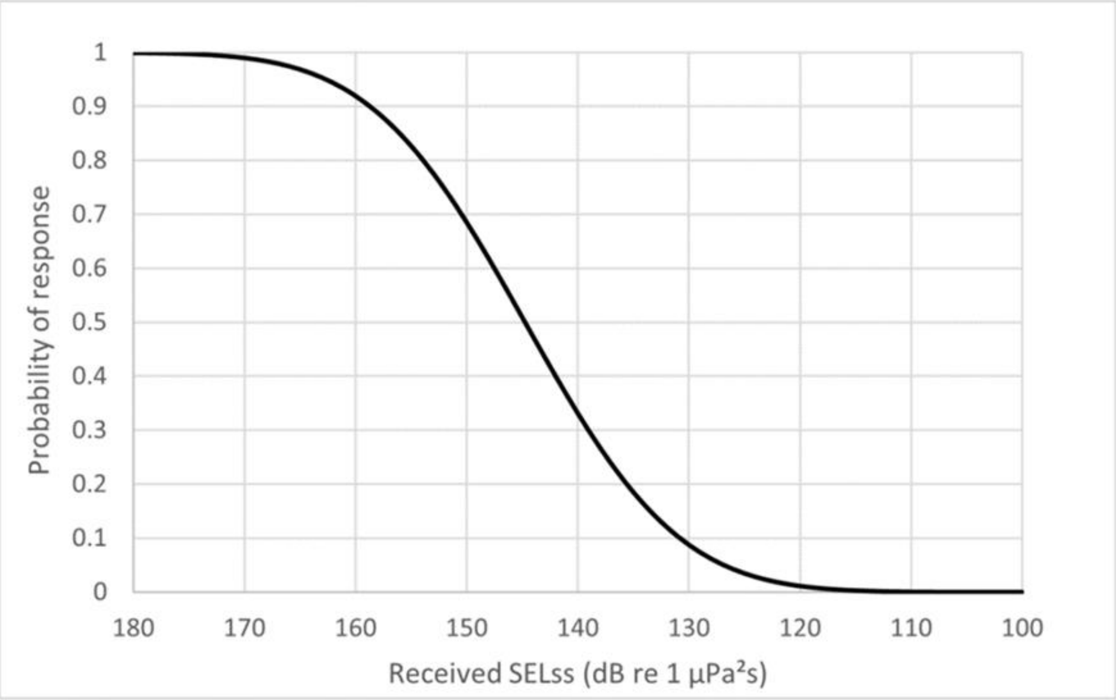
3 Dose-response Curves

48. This section in the Appendix supports Section 9.8.1.3.2.2.1 of **Chapter 9: Marine Mammals (Volume II)**, which presents the number of individuals that could be affected from piling disturbance.

49. The dose-response methodology has been adopted in this assessment for species with appropriate dose-response experiments published in scientific literature, specifically for harbour porpoise, harbour seal and grey seal (per current best practice guidance in Southall et al. 2021).

50. The dose-response relationship for harbour porpoise was developed by Graham et al. (2017b) using data collected during Phase 1 of piling at the Beatrice OWF. This relationship is displayed in **Plate 3.1**. Subsequent studies revealed that the responses of harbour porpoises to piling noise diminished over the construction period (Graham et al. 2019). Therefore, applying the dose-response relationship from an initial piling event to all piling events in the marine mammal assessment is considered conservative.

Plate 3.1: Dose-response Relationship Developed by Graham et al. Used for Harbour Porpoise in the Assessment

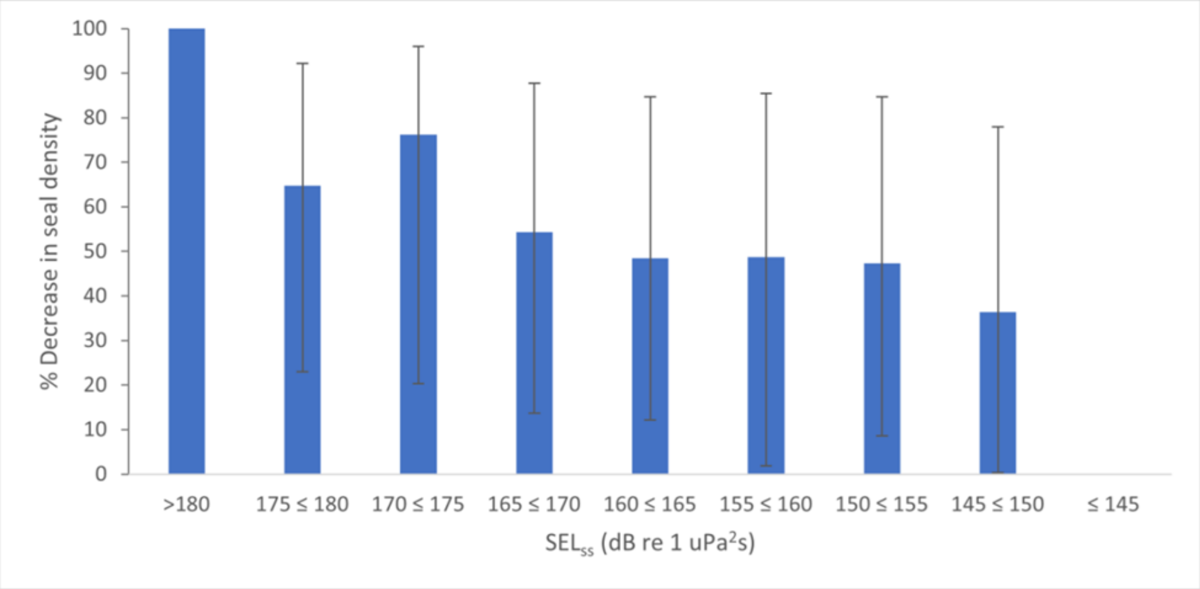


51. For both harbour seal and grey seal, a dose-response relationship, derived from harbour seal telemetry data collected during several months of piling at the Lincs OWF, has been used (Whyte et al. 2020). Whyte et al. (2020) tested the effects of pile driving noise (characterised as SEL_{ss} (dB re 1 µPa^2s)) on harbour seal disturbance in 5 dB increments between 115 to 180 dB SEL_{ss} (dB re

1 μPa²s). From this data, a dose-response curve was derived and applied to SEL contours from 120 to 200 dB SEL re 1 μPa²s.

52. As shown in **Plate 3.2**, the highest SEL from single strike (SEL_{ss}) considered in the Whyte et al. (2020) study was 180 dB re 1μPa²s. The marine mammal assessment has therefore conservatively assumed that at SEL_{ss} > 180 dB re 1μPa²s, all seals would be disturbed. The dose-response curve for harbour seal has been used for grey seals, as both species have similar hearing audiograms.

Plate 3.2: Dose-response Behavioural Disturbance Data for Harbour Seal Derived from The Data Collected and Analysed by Whyte et al.



53. In the absence of other accepted disturbance methods, the dose-response approach has been implemented for assessing disturbance impacts on dolphins, minke whale, and fin whale. However, it is important to emphasise that due to the distinct differences in audiograms and behaviours of harbour porpoises, this approach may be excessively precautionary and therefore not suitable for this species.

3.1 Methodology

54. To estimate the number of animals disturbed by piling, SEL_{ss} contours at 5 dB increments (see **Figure 9.5.1** presented in **Annex 1**) were overlain on the relevant species density surfaces, to quantify the number of animals receiving each SEL_{ss}, and, subsequently, the number of animals likely to be disturbed, based on the corresponding DRC. The modelling methodology for how contours are produced are further described in Section 3 in **Appendix 9.2: Underwater Noise Modelling Report (Volume IV)**.

55. The following underlying densities were used for the DRC for each species:

- **Harbour porpoise and minke whale:** Small Cetaceans in the European Atlantic and North Sea (SCANS) IV surrounding the Bellrock WFDA (NS-C, NS-D, NS-E, NS-F, NS-G, CS-K);
- **Bottlenose dolphin and common dolphin**: due to a lack of densities in the majority of the North Sea SCANS-IV and III blocks, the Waggitt et al. (2019) was applied, covering a sufficiently large area to apply this data (see **Appendix 9.1: Marine Mammals Technical Report (Volume IV)**) for more information on caveats for using this data on a small spatial scale);
- **White-beaked dolphin**: Small Cetaceans in the European Atlantic and North Sea (SCANS) III surrounding the Bellrock WFDA (O,R,S,T blocks);
- **Grey seal**: absolute densities provided by Carter et al. (2025); and
- **Harbour seal**: relative densities provided by Carter et al. (2022), with species-specific correction factors applied (see **Appendix 9.1: Marine Mammals Technical Report (Volume IV)** and SCOS-BP 21/02 in SCOS, 2021).

3.2 Assumptions and Limitations

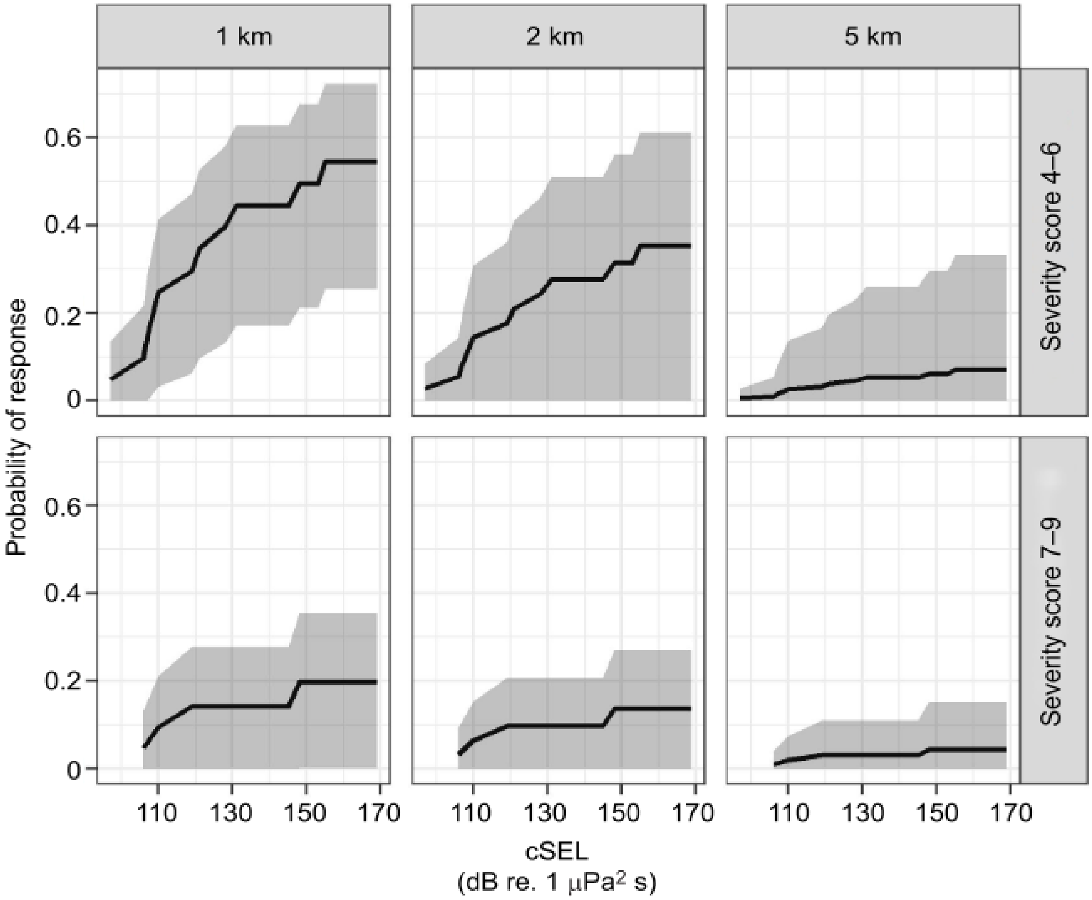
56. There is a lack of empirical data on dolphin species, minke whale or grey seal responses to pile driving to derive species-specific DRCs for these species. For grey seal, the harbour seal DRC has been used as a reasonable proxy since both species were of the same hearing group. For the remaining species, all dolphins and minke whale, the harbour porpoise dose-response curve was used although there were uncertainties regarding the use of this proxy since the species have all been classified as being in different hearing groups. Therefore, in reality their response to the same sound source is unlikely to be similar.

57. The use of the dose-response relationship for harbour seal from Whyte et al. (2020) and for harbour porpoise Graham et al. (2017b) in conjunction with the modelling results presented here was conservative (see **Section 3.3** for further information). The exact drivers behind the dose-response relationship were unknown and likely to be influenced by a combination of distance from the sound source and the received level. Yet the DRC presented in Whyte et al. (2020) and Graham et al. (2017b) are based upon received level only. Responses of animals were not only elicited by the received level but also by other factors, such as signal shape. The shape of a signal with the same SEL from the same sound source differs depending on distance.

58. Piling noise has been noted to lose its impulsive character with distance (Southall et al. 2007; Hastie et al. 2019; Southall et al. 2019.). Therefore, animals were expected to react less strongly to piling noise with the same received levels when exposed at larger distances, although these may also be due to other factors such as frequency weightings. Such an effect has been quantified for blue whales with regard to military sonar.

59. Where a received level of 170 dB SEL from cumulative exposure (SEL_{cum}) at 1 km resulted in a probability response of >0.5 at severity score 4 to 6 whereas the same received level of 170 dB SEL_{cum} at 5 km resulted in a probability of response of <0.1 at severity score 4 to 6 **Plate 3.3** (Southall et al. 2019). This is important to note, since the original dataset in Whyte et al. (2020) showed that "*predicted seal density significantly decreased within 25 km or above* SEL_{SS} *145 dB re 1μPa²s*".

Plate 3.3: Behavioural Response Probability for Blue Whales Exposed to Military Sonar as a Function of Received Level and Distance from the Sound Source. Severity Score 4-6 Denotes 'Moderate Severity' and 7-9 Denotes 'High Severity'



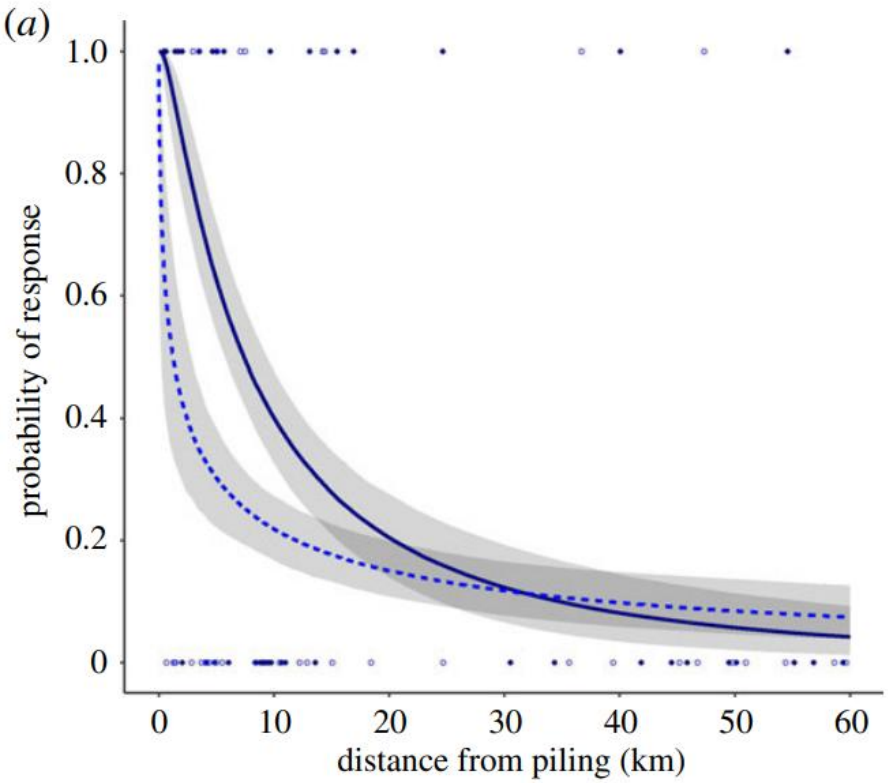
60. In addition to these issues, it should be recognised that estimates of received noise levels were likely to be extremely conservative given they have been based on the maximum hammer energy. In practice, pile driving at other UK OWFs has often been completed using much lower than the predicted hammer energies as shown for other OWFs (Dudgeon OWF Limited, 2016).

3.3 Deterrence Function

61. Recent findings have indicated predictions of dose response are overly precautious, leading assessments to be unrealistic. The PrePARED project compared responses of harbour porpoises to pile driving noise at the Moray West wind farm with predictions made during earlier regulatory assessments (Thompson et al. 2025). The comparisons indicated the Graham et al. (2017) dose-response function resulted in highly conservative predictions of disturbance. In the Moray West regulatory assessments, over 4,500 harbour porpoises were predicted to be disturbed by a single piling event (Moray West, 2023). However, during construction monitoring at Moray West it was indicated disturbance of harbour porpoise was more likely to have impacted less than 100 individuals (Thompson et al. 2025). Observations made at Moray West across the 35 km range of overlap also highlighted that observations were better predicted by the Graham et al. (2017b) deterrence function than the recommended dose-response function.

62. Therefore, this new evidence indicates assessments are likely to be more realistic if based on the deterrence function, derived from the Beatrice Offshore Wind Farm monitoring data in Graham et al. (2019) instead of the dose response function presented in Graham et al. (2017b). Due to this, the deterrence function was used to calculate disturbance for harbour porpoise to provide a comparison against the predictions using the dose-response model. **Plate 3.4** shows the probability of response based on the deterrence function, predictions were based on the more conservative harbour porpoise responses to the first location piled.

Plate 3.4 : **Graham et al. Deterrence Function Based Upon Analysis of the Full Beatric Construction Monitoring Data (solid navy line = first location piled; dotted line = final location piled)**



63. **Table 3.1** shows the results of both the dose-response model and the deterrence function used to estimate the disturbance predictions for harbour porpoise. Both approaches used SCANS IV density estimates (Gilles et al. 2023), and the worst-case piling location. Results indicate a significantly lower amount of harbour porpoise were predicted to be disturbed using the distance-based deterrence function when compared to the results of the dose response curve assessment used in **Chapter 9: Marine Mammals (Volume II)**. The approach taken in the EIA to assess potential disturbance from piling is shown to be precautionary for harbour porpoise. The DRC has also been applied to all other quantitative cetacean assessments meaning the potential number of animals disturbed by piling in **Section 9.8.1.3.2** of **Chapter 9: Marine Mammals (Volume II)** and in the iPCoD modelling is probably overstated.

Table 3.1: Comparison of Disturbance Assessment Methods

Disturbance Approach	Predicted Number of Harbour Porpoise Disturbed	Percentage (%) of Reference Population
Deterrence function	733	0.2%
Dose-response function	8,554	2.47%

4 Review of Potential Disturbance from Vessel Activity

64. This part of the Appendix supports Sections 9.8.1.6 and 9.9.3.3 of **Chapter 9: Marine Mammals (Volume II)** which provides an assessment of the potential for disturbance from construction and the elevated risk of vessel collision with marine mammals.

65. Vessel noise has been shown to affect the behaviour of marine mammals, where changes in vocalisation and behavioural state have been observed, in addition to displacement of animals from areas where ships were present. It is challenging to predict the distance at which animals may react to vessels, behavioural responses can depend on species, location, vessel type and size, speed, noise levels and frequency, ambient noise levels and environmental conditions.

66. Benhemma-Le Gall et al. (2023) found that vessel type mattered. Beatrice OWF (anchored vessel) saw a 32.8% decrease, and Moray East (jack-up vessel) saw a 13.2% decrease in porpoise detections before piling mitigation. Additional research in UK waters has shown that porpoises alter surfacing rates and movement patterns in response to different vessel types, indicating sensitivity to disturbance (Grundy, 2021).

67. A recent study combined aerial surveys conducted between 2015 and 2022 with automatic identification system vessel traffic data and environmental covariates to evaluate the influence of maritime activity on harbour porpoise distribution in the North Sea (Pigeault et al. 2024). Key findings indicated harbour porpoise on occasion avoided areas with numerous vessels or frequent vessel movements within a radius of up to 9 km. However, Pigeault et al. (2024) didn’t assess marine mammal responses to vessels at different distance ranges, instead they reported within a 9 km radius, the average presence of 5 to 7 ships/min decreased the expected number of porpoise sightings by a quarter. Therefore, not all animals within the 9 km radius will be disturbed, therefore this disturbance range can be considered overly precautionary.

68. Displacement was seen with harbour porpoise detections around a pile driving site, where detections declined several hours prior to the start of pile driving. The decline was assumed to be due to the increase in other construction related activities and vessel presence in advance of the actual pile driving (Brandt et al. 2018; Benhemma-Le Gall et al. 2021). At the Beatrice and Moray East offshore wind farms, Benhemma-Le Gall et al. (2021) observed reduced harbour porpoise activity during construction. Porpoise detections decreased by 35.2% at 2 km from construction, 24% at 3 km, and increased by 7.2% at 4 km, suggesting a behavioural response within a 4 km radius. Although the study indicates a higher proportion were disturbed at 2 km, a precautionary approach of using a 4 km disturbance range has been applied in Section 9.8.1.6 of **Chapter 9: Marine Mammals (Volume II)**.

69. Brandt et al. (2018) also found a decline in harbour porpoise within 2 km of German OWFs before piling due to vessel activity. Further research by Frankish et al. (2023) indicated most observations of harbour porpoise deterrence were at close distances to vessel (less than 30 m). The study also

found 5 to 9% of harbour porpoise where deterred when vessels were 2 km away. This provides further evidence that applying a 4 km disturbance range for vessel disturbance is precautionary.

70. Tagging studies in harbour seals revealed individual variability, with some seals avoiding noisy areas while others showed signs of habituation (Nachsteim et al. 2023). A UK telemetry study showed there was no evidence of reduced seal presence as a result of vessel traffic. This was despite distributional overlaps (overlaps were most frequently found within 50 km of the coast) between seal and vessel presence and high cumulative sound levels (Jones et al. 2017).

71. A study of grey seal pup tracks in the Celtic Sea and adult grey seals in the English Channel found that no animals were exposed to cumulative shipping noise that exceeded thresholds for temporary threshold shifts (using the Southall et al. 2019 thresholds) (Trigg et al. 2020). A study of grey seal pupping beaches around Ramsey Island in Pembrokeshire found that disturbance occurred when vessels were closer than 150 m to seal locations (Strong and Morris, 2010). Reduced presence of common dolphins was seen with the construction of a pipeline in NW Ireland due to vessel presence, however patterns suggested disturbance impacts were only short term (Culloch et al. 2016).

72. Studies for bottlenose dolphin have indicated that vessel presence has the potential to increase swimming speeds and reduce the time spent for foraging, resting and socialising (Marley et al. 2017b; Piwetz, 2019). Behavioural changes associated with disturbance have also been seen in common dolphins, due to the presence of vessels. Foraging and resting activity was significantly disrupted by vessel activity and returns to foraging activity took significantly longer than returns to other states (Stockin et al. 2008; Meissner et al. 2015). Vessel noise has also been linked to reduced whistle rates, elevated stress hormones, and disruption of cooperative foraging (Erbe et al. 2019). Chronic exposure may reduce foraging efficiency and increase energy expenditure, with potential consequences for health and reproductive success (Tougaard, 2025; Wisniewska et al. 2018). Behavioural changes have also been seen in minke whale with vessel interactions including a decrease in foraging activity, increase in swim speeds and energy expenditure (Christiansen et al. 2014).

73. Evidence suggests marine mammal species respond to vessel presence in a variety of ways, but all have the potential to be disturbed either through displacement, behavioural changes or both. Responses depended on a range of environmental factors but also the type and size of vessels. Some of the studies mentioned above based findings on fast moving vessels and vessels seeking close proximity to species, such as fast ferries and whale watching vessels (Wisniewska et al. 2018; Christiansen et al. 2014). Therefore, less of a disturbance effect is likely for the proposed construction vessels which would be slow moving or stationary. As a precautionary approach, for the marine mammal assessments, the sensitivity for the disturbance from vessels is the same as for any other underwater noise, meaning it is medium for harbour porpoise and whales, and low for dolphins and seals.

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Annex 1: Figures

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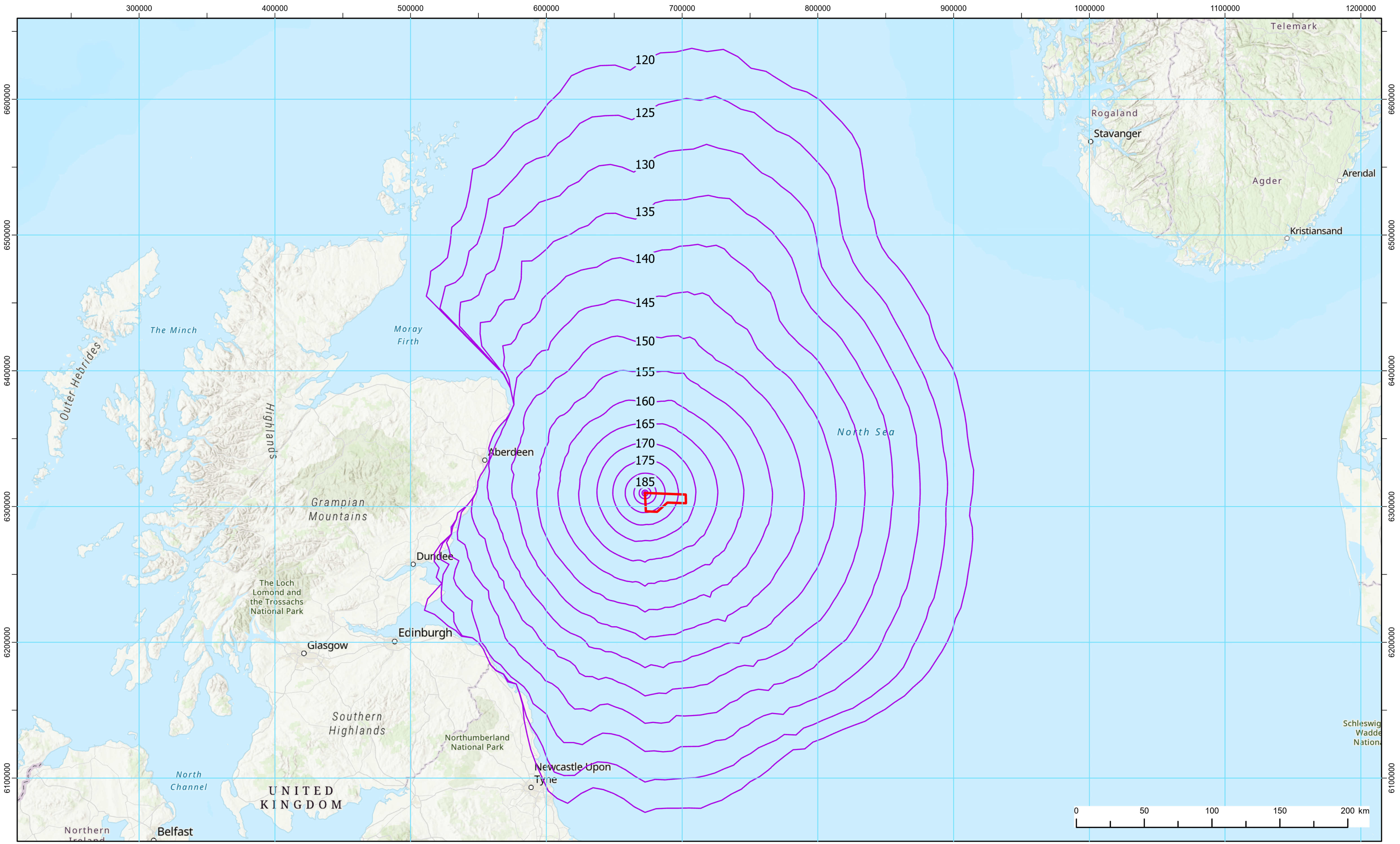

Haskoning
Enhancing Society Together

Bellrock

Legend:

🟥 Bellrock Wind Farm Development Area

— Driven Pille NW SPLpeak (5 dB)

REV	DATE	STATUS	DRW	CHK	APR
1	31/03/2026	Final	DL	SA	BMcG

Coordinate System: WGS 1984 UTM Zone 30N

Source:

Sources: Esri, TomTom, Garmin, FAO, NOAA, USGS, © OpenStreetMap contributors, and the GIS User Community, Esri, USGS, © 2026 Subacoustech. © Haskoning UK Ltd, 2026.

Scale @ A3
1:2,500,000

Figure Title:

Modelled Underwater Noise Contours for Sound Exposure Level (SEL) of a Single Strike at 5 db Contours at the NW Corner of the Bellrock Wind Farm Development Area

Project:
Bellrock Wind Farm
Development Area (WFDA)

Report:
EIA Report
Appendix 9.5: Information and Modelling Methods for Disturbance to Marine Mammals

Drawing No.: RHDV_BEL_CST_REP_0003_036

Figure 9.5.1

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