

MachairWind Offshore Windfarm

Appendix 10.4 Interim Population Consequences of Disturbance (iPCoD) Modelling Technical Report



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Glossary of Acronyms

Term	Definition
CEA	Cumulative Effects Assessment
CGNS	Celtic Greater North Sea
CWSH	Coastal West Scotland and Hebrides
DRC	Dose Response Curve
EDR	Effective Deterrent Range
EIA	Environmental Impact Assessment
ETG	Expert Topic Group
FCS	Favorable Conservation Status
IAMMWG	Inter-Agency Marine Mammal Working Group
iPCoD	Interim Population Consequences of Disturbance
LSE	Likely Significant Effect
MPA	Marine Protected Area
MU	Management Unit
NCMPA	Nature Conservation Marine Protected Area
NRW	Natural Resource Wales
OW	Oceanic Waters
PTS	Permanent Threshold Shift
RIAA	Report to Inform Appropriate Assessment
SAC	Special Areas of Conservation
SCOS	Special Committee on Seals
$SEL_{cum} / LE_{p,t}$	Cumulative Sound exposure
SMRU	Sea Mammal Research Unit
$SPL_{peak} / L_{p, pk}$	Peak Sound Pressure Level
WDA	Windfarm Development Area
WS	West Scotland
WTG	Wind Turbine Generator



Glossary of Terms

Term	Definition
Development Area	Application boundary for consenting purposes which, for the Project, consists of a Windfarm Development Area, Offshore Export Cable Corridor, and Onshore Transmission Development Area. Separate consent and marine licence applications will be submitted for each Development Area where applicable.
Environmental Impact Assessment (EIA)	The process of evaluating the likely significant environmental effects of a proposed development over and above the existing circumstances (or 'baseline').
MachairWind Offshore Windfarm	An offshore windfarm capable of exporting around 2 GW of renewable energy to the National Electricity Transmission System. MachairWind Offshore Windfarm comprises three Development Areas: <ul style="list-style-type: none"> • The WDA – located on the west coast of Scotland to the northwest of Islay and west of Colonsay; • The Offshore Export Cable Corridor – a preliminary boundary extending from the WDA to mean high water springs at a landfall location near Girvan, South Ayrshire; and • The Onshore Transmission Development Area – a preliminary boundary which extends landward from mean low water springs and includes the land required for the landfall of the offshore export cable(s) and their route up to but not including the proposed high voltage direct current switching station which will be developed and constructed by Transmission Owner, ScottishPower Transmission. Separate consent and licence applications will be submitted for each Development Area.
Option Agreement Area (OAA)	The seabed area awarded to ScottishPower Renewables in January 2022 through the Scotwind leasing round.
OSPAR	OSPAR started in 1972 with the Oslo Convention against dumping and was broadened to cover land-based sources of marine pollution and the offshore industry by the Paris Convention of 1974. These two conventions were unified, updated and extended by the 1992 OSPAR Convention. OSPAR is so named because of the original Oslo and Paris Conventions ("OS" for Oslo and "PAR" for Paris).
The Applicant	The legal entity submitting consent applications for the MachairWind Offshore Windfarm, namely MachairWind Limited.
The Project	MachairWind Offshore Windfarm including all its Development Areas and associated infrastructure.
Windfarm Development Area (WDA)	The application boundary within the OAA where consent will be sought for the proposed WDA infrastructure. The WDA infrastructure is subject to Section 36 consent and marine licence applications (generation and transmission) which are being applied for separately from the Offshore ECC infrastructure and OnTDA infrastructure.
WDA restricted build area	Refers to the area within the WDA which is considered unsuitable for the installation of WTG and OSP foundations for engineering and environmental reasons.
WDA infrastructure	The offshore generation and transmission infrastructure located within the WDA including but not limited to: WTGs, WTG fixed foundations (and associated scour protection), OSP(s), OSP fixed foundations (and associated scour protection), IACs, OSP link and offshore export cable(s) and their associated external cable protection (insofar as these are located within the WDA) and fibre optic cables.
Wind Turbine Generator (WTG)	A wind turbine generator which converts wind energy into electrical energy. Each wind turbine generator is a complex system composed of a high number of components. Typically, the main components include the rotor assembly (composed of three blades and a hub); the nacelle (containing a generator, shaft and gearbox, power electronic converter and transformer); and the tower (containing lifting equipment and the switchgear).



1 APPENDIX 10.4 INTERIM POPULATION CONSEQUENCES OF DISTURBANCE (IPCoD) MODELLING TECHNICAL REPORT

1.1 INTRODUCTION

1. This appendix describes the method used for the Interim Population Consequences of Disturbance (iPCoD) modelling.
2. In **Chapter 10 Marine Mammals and Leatherback Turtle**, results for disturbance (Section 10.11.1.5) conclude that elevations in underwater noise due to piling could potentially lead to the behavioural disturbance of a significant number of individuals of the key species identified within the marine mammal Study Area, such as harbour porpoise (*Phocoena phocoena*), minke whale (*Balaenoptera acutorostrata*) and grey seal (*Halichoerus grypus*). Population modelling has therefore been conducted for these receptors, as well as bottlenose dolphin (*Tursiops truncatus*) and harbour seal (*Phoca vitulina*), for which demographic parameters are currently available.
3. 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 piling at the Windfarm Development Area (WDA).
4. 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 thousand 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. Auditory injury (Permanent Threshold Shift (PTS)) is also included within the modelling.
5. This appendix is structured as follows:
 - iPCoD modelling methodology including assumptions and limitations and Project specific detail (**Section 1.2**);
 - Approach to cumulative population modelling (**Section 1.2.3**);
 - Population modelling for the Report to Inform Marine Protected Area Assessment (**Section 1.2.4**);
 - Population modelling for the Report to Inform Appropriate Assessment (RIAA) (**Section 1.2.5**);
 - Population modelling results for the EIAR Chapter 10 Marine Mammals and Leatherback Turtle (**Section 1.3.1**); and
 - Population modelling results for Report to Inform Marine Protected Area Assessment (**Section 1.3.2**).

1.2 METHODOLOGY

1.2.1 Assumptions and Limitations

6. The first limitation is that the iPCoD model only contains parameters for five species (all listed in **Table 1.2**). As a result, the iPCoD model cannot be applied to other delphinid species or other mysticetes, meaning no population-level modelling can be undertaken for those taxa.
7. In addition, there is a lack of empirical data on how changes in behaviour and hearing sensitivity influence the ability of individual marine mammals to survive and reproduce. In the absence of such data, the iPCoD framework relies on an expert elicitation process described in Donovan et al. (2016) to estimate the effects of disturbance and permanent auditory injury (PTS) on survival and reproductive rates. This process generates statistical distributions representing expert opinion on these effects. Simulations are then run using values randomly selected from these distributions, effectively creating the responses of a “virtual” expert. This is repeated thousands of times to capture the uncertainty across expert judgements.



8. Overall, while the iPCoD model contains numerous assumptions and uncertainties regarding the links between impacts and vital rates, it currently represents the best available scientific and expert opinion.

1.2.1.1 *Duration of Disturbance*

9. The following section outlines why the current assumptions regarding the duration of disturbance for minke whales and bottlenose dolphins are considered no longer appropriate, based on updated scientific understanding and recent behavioural studies.
- The iPCoD model in the 2012 expert elicitation assumed that a disturbed animal would stop foraging for 24 hours after a disturbance event. Therefore, this incorporates a duration of disturbance for 24 hours (Harwood et al. 2014).
 - A more recent (2018) expert elicitation for harbour porpoises found the 24-hour assumption unrealistic and revised it to six hours of non-foraging time (Booth et al. 2019). However, minke whale and bottlenose dolphin were not re-evaluated in 2018, so the iPCoD model still uses the outdated 24-hour assumption for these species (the 2012 expert elicitation).
 - Current understanding of marine mammal responses to piling suggests a 24-hour feeding cessation is unrealistic.
 - A recent sonar disturbance study by Czapanskiy et al. (2021) defined:
 - One hour of feeding cessation = mild response
 - Two hours = strong response
 - Eight hours = extreme response
 - Therefore, assuming 24-hours of feeding cessation for minke whale and bottlenose dolphin exceeds what is typically considered an extreme reaction.
 - This outdated assumption therefore very likely overestimates disturbance impacts from piling at the WDA using the iPCoD assessment.
10. For all marine mammals, PTS numbers using cumulative sound exposure level ($SEL_{cum} / L_{E,p,t}$) have been presented in **Chapter 10 Marine Mammals and Leatherback Turtle**; with the exception of minke whale where only disturbance numbers have been incorporated into the modelling due to the lack of expert elicitation or empirical data regarding PTS.
11. Population modelling results for minke whale incorporating PTS numbers from $SEL_{cum} / L_{E,p,t}$ is presented in **Section 1.3** for information purposes as agreed with NatureScot, (see comment I.D. 71 in Table 10.2 in **Chapter 10 Marine Mammals and Leatherback Turtle**).
12. Population modelling has been carried out 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.

1.2.1.2 *Lack of Density Dependence*

13. Another limitation of the iPCoD model is the absence of density dependence, due to uncertainty about how it operates in marine mammal populations. Density dependence refers to changes in demographic rates as population density varies, with growth increasing at low density and decreasing at high density (Harwood et al. 2014).
14. In the bottlenose dolphin scenario, iPCoD assumes no density dependence because there are insufficient data to parameterise it. Consequently, the impacted population in the model cannot increase toward carrying capacity following disturbance.
15. However, expert elicitation for the Deepwater Horizon oil spill assessment (Schwacke et al. 2022) indicated that bottlenose dolphins likely exhibit concave density dependence in fertility. This would



mean that, in reality, an impacted population would be expected to recover to carrying capacity—assumed to equal the current un-impacted population size—rather than stabilising at a reduced level.

16. The limitations of assuming a simple linear relationship between maximum net productivity and carrying capacity have long been noted, as density dependence likely involves multiple biological parameters with inherent limits, such as fecundity and survival (Taylor & Master 1993). For UK harbour porpoise and other marine mammals, no published evidence of density dependence currently exists, so the iPCoD protocol does not incorporate such assumptions.

1.2.1.3 *Environmental and Demographic Stochasticity*

17. 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 because of changes in environmental conditions*' (Harwood et al. 2014). Demographic stochasticity is defined as '*variation among individuals in their realised vital rates because of random processes*' (Harwood et al. 2014).
18. 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 a Management Unit (MU) is less than 3,000 individuals. One consequence of demographic stochasticity is that two otherwise identical populations that experience 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).
19. 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 1.1**, 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.



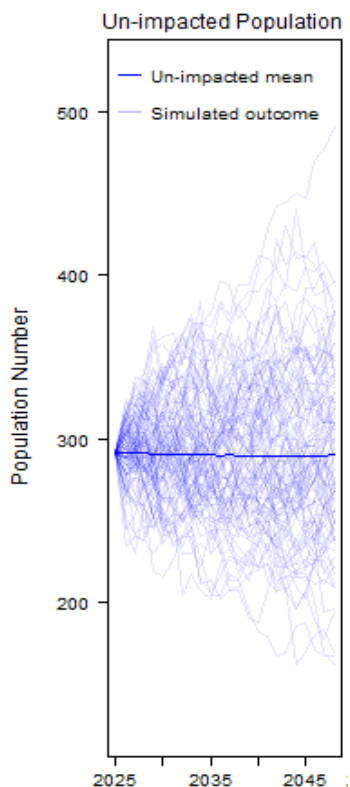


Plate 1.1 Simulated Un-impacted (baseline) Population Size over the 25 Years Modelled

20. 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 et al. (2019). 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.

1.2.1.4 Summary

40. All of the precaution built into the iPCoD model means 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 et al. (2019) and Sinclair et al. (2020). 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 there having been no update to the expert elicitation for this species.

1.2.2 Project Specific Detail

1.2.2.1 Piling Schedule

21. The piling schedule was developed from the Project’s design envelope (see **Chapter 3 Project Description**) which provided an estimate of the number of days piling for the wind turbine generator (WTG) foundations within a defined piling phase, which is scheduled to take place within an overall indicative schedule window assumed to be from Q3 2030 to Q4 2033.

1.2.2.2 Piling Parameters

22. The amount of piling required for the Project is dependent on the foundation types selected and the final piling schedule. The worst-case scenario for the WDA (maximum number of monopiles with the



highest strike rate) has been taken forward for modelling in iPCoD. The maximum number of WTGs to be installed is 144, with a single monopile installation per day, resulting in 144 piling days.

- 23. The number of marine mammals that are at potential risk of PTS is taken from a single pile event, using cumulative sound exposure level ($SEL_{cum} / LE_{p,t}$) for all marine mammals.
- 24. The worst-case piling parameters that have been used for the population modelling is presented in **Table 1.1**.

Table 1.1 Worst-case piling parameters

Parameters	Value
Number of monopiles	144
Number of piling days	144
Indicative piling schedule	Q3 2030 to Q4 2033

1.2.2.3 Model Inputs

- 25. The iPCoD model 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; and
 - Residual days of disturbance.
 - Number of animals predicted to experience PTS and disturbance during piling; and
 - Estimated piling schedule during the proposed construction programme.

1.2.2.3.1 Demographic Parameters

- 26. **Table 1.2** provides the reference populations in Management Units (MUs) that have been utilised in the iPCoD modelling, which are the same as the MUs referenced in **Chapter 10 Marine Mammals and Leatherback Turtle**. The UK portion has been used for the WDA alone assessment, and to assess for cumulative disturbance from other offshore windfarms piling at the same time as the Project.
- 27. **Table 1.2** presents the demographic parameters used to inform the iPCoD population models for each species and relevant MU. These parameters include age at independence and age at first breeding, which define the timing of recruitment into the breeding population, as well as calf/pup, juvenile and adult survival rates, which represent age-structured survivorship. Fertility reflects the average reproductive output of adult females, while the intrinsic population growth rate describes baseline population dynamics in the absence of disturbance. For harbour porpoise, bottlenose dolphin, minke whale and harbour seal, the growth rate is set to 1.00, representing a stable population with no net increase over time, consistent with precautionary assumptions where long-term population trends are uncertain or at equilibrium. In contrast, grey seal is assigned a growth rate of 1.01, reflecting evidence of a low-level background increase and slightly greater intrinsic recovery potential for this species.



Table 1.2 Demographic parameters recommended for each species for the relevant MU (Sinclair et al. 2019), MU for cetaceans (Inter-Agency Marine Mammal Working Group (IAMMWG), 2023), and pinnipeds (Special Committee on Seals (SCOS), 2024)

Species	Reference population / MU (UK portion)	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	24,305 (West Scotland (WS) MU)	1	5	0.6	0.85	0.925	0.48	1.000
Bottlenose dolphin	45 (Coastal West Scotland and the Hebrides (CWSH) MU) UK: 1,299 (Oceanic Waters (OW) MU)	2	9	0.86	0.94	0.94	0.25	1.000
Minke whale	UK: 10,288 (CGNS MU)	1	9	0.72	0.77	0.96	0.9	1.000
Grey seal	WS MU: 17,447 Wider population: 51,471	1	5	0.222	0.94	0.94	0.84	1.01
Harbour seal	WS MU: 19,707 Wider population: 31,627	1	4	0.55	0.61	0.95	0.88	1.000



1.2.2.3.2 Population Modelling for Disturbance from Piling at the WDA

28. Empirical evidence from monitoring undertaken during the construction of offshore windfarms (e.g. Graham et al. 2019; Brandt et al. 2011) indicates that detection rates of marine mammals return to baseline levels within hours following piling activity. Accordingly, for the purposes of this assessment, disturbance is assumed to be limited to the day (24 hour period) on which piling occurs (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 for the full day of piling and persists for a period of 24 hours after piling has ceased.

1.2.2.3.3 Number of Animals with PTS or Disturbed

29. The number of animals predicted to experience PTS and / or disturbance during piling was based on the density values derived as part of baseline characterisation in **Appendix 10.2 Marine Mammals and Leatherback Turtle Baseline**.

30. For all receptors, the estimated number of animals affected is based on the JNCC (2025) Effective Deterrent Ranges (EDRs) (**Table 1.3**) (see **Chapter 10 Marine Mammals and Leatherback Turtle**), which are considered to represent a realistic worst-case scenario. This approach is supported by Thompson et al. (2025), who demonstrated that dose–response curve assessments are likely to be overly precautionary, and that distance-based response functions provide a more realistic representation of disturbance. Such approaches are considered more representative of EDRs when estimating the number of animals likely to be affected.

31. **Table 1.3** presents the number of individuals that could potentially be disturbed due to piling at the WDA, which was used for the WDA alone assessments as well as the cumulative assessments.

Table 1.3 Estimated number of potential marine mammals to have PTS or to be disturbed during each piling event

Marine Mammal Receptor	PTS SEL _{cum} or L _{E,p,t}	Disturbance
Harbour porpoise	51	528
Bottlenose dolphin	0	54
Minke whale	231	264
Grey seal	0	1,106
Harbour seal	0	101

1.2.3 Cumulative Population Consequences of Disturbance from Piling at Other Projects

32. A review of the data available for screened in offshore windfarm projects has been undertaken, and project specific worst-case piling, PTS, and disturbance data have been incorporated into a cumulative iPCoD modelling run for each species considered in the WDA alone assessments.

33. The demographic parameters, marine mammal MUs and residual days of disturbance remained the same as for the WDA alone modelling. Piling days were distributed at random within the stated piling schedules for each project.

34. The piling parameters assessed for other projects in the iPCoD modelling are set out in **Table 1.4**.



Table 1.4 Worst-case piling parameters from other offshore windfarm projects for the cumulative assessment

Project	Number of Piling Days	Schedule
MachairWind WDA	144	Q3 2030 to Q4 2033
Awel y Mor	67	2029 to 2030
Dublin Array	50	2027 to 2030
Havbredey	No information, not included	
Malin Sea Wind	No information, not included	
Moor Vannin	No information, not included	
Northern Irish Sea Array	51	2027 to 2029
Spiorad na Mara	No information, not included	
Western Star	No information, not included	

35. 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 Project were assumed to also occur for projects where information was lacking.
36. For the Cumulative Effects Assessment (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 10.5 Cumulative Effects Assessment Screening**). Cumulative population modelling was undertaken only for minke whale, grey seal and harbour seal, as sufficient information was available from other offshore windfarm assessments to parameterise the iPCoD models for these species. In particular, detailed data on piling activities, construction schedules, and estimated disturbance metrics were available to support cumulative population modelling. In contrast, the offshore windfarms contributing to cumulative assessments for harbour porpoise WS MU and bottlenose dolphin CWSH and OW MUs were at an early scoping stage. As a result, detailed information on piling schedules, construction methodologies and timing was not available, and there was insufficient information to robustly parameterise population models for these species at this stage of the EIA.
37. **Table 1.5** presents the number of animals predicted to experience PTS and disturbance from piling at other offshore windfarm projects screened into the CEA. The numbers presented are based on the values the project has based their cumulative assessment on; taken from the relevant EIAs (**Table 1.5**). Where EIAs have screened out species from population modelling, these have not been included in the population modelling. However, a PrePARED case study demonstrated that CEA population-modelling 1,106 outcomes were consistent whether only EIA-stage projects were included or whether all projects were incorporated using EDR-based assumptions for those without EIAs (Sinclair & Klementisova, 2025).

Table 1.5 Estimated number of marine mammals to have PTS/Disturbance during each piling event

Offshore windfarm project	Number of animals affected					
	Minke whale		Grey seal		Harbour seal	
	PTS	Disturbance	PTS	Disturbance	PTS	Disturbance
MachairWind WDA	231	264	0	1,106	0	101
Awel y Mor	2	36	-	-	-	-



Offshore windfarm project	Number of animals affected					
	Minke whale		Grey seal		Harbour seal	
	PTS	Disturbance	PTS	Disturbance	PTS	Disturbance
Dublin Array	<1	57	-	-	-	-
Northern Irish Sea Array	6	222	0	790	0	200

1.2.4 Population Modelling for the Nature Conservation Marine Protected Area

- 38. Population modelling has been undertaken for the Sea of the Hebrides Nature Conservation Marine Protected Area (NCMPA) to assess for the WDA alone effect. There were no other offshore windfarm projects identified that could result in cumulative effects on the Sea of the Hebrides NCMPA and therefore population modelling was not carried out for cumulative effects.
- 39. See Section 6.1.2.4.1.1 of the **Report to Inform Marine Protected Area (MPA) Assessment** for the WDA alone population modelling results.

1.2.5 Population Modelling for the Report to Inform Appropriate Assessment

1.2.5.1 Population Modelling for the WDA Alone

- 40. Population modelling has been undertaken for the **Report to Inform Appropriate Assessment (RIAA)** to assess for the WDA alone only.
- 41. Population modelling for the WDA alone was carried out for:
 - Harbour porpoise – Inner Hebrides and Minches Special Areas of Conservation (SAC);
 - Harbour porpoise – Skerries and Causeway SAC;
 - Grey seal – Treshnish Isles SAC;
 - Harbour seal – South-East Islay Skerries SAC; and
 - Harbour seal – Eileanan agus Sgeiran Lois mor SAC.
- 42. While screened into the appropriate assessment, the Sound of Barra SAC and Ascrib, Isay and Dunvegan SACs designated for harbour seal were not subject to population modelling, as impacts from vessels is the only impact pathway with the potential for Likely Significant Effect (LSE).
- 43. For the harbour porpoise SACs, the number of individuals for each SAC is based on the WS MU (the same as presented in **Table 1.2**), and therefore the results of the assessment for each SAC are identical and as presented in **Chapter 10 Marine Mammals and Leatherback Turtle**.
- 44. For the seal SACs, the number of animals predicted to experience PTS and/or disturbance from piling at the WDA was based on the density and reference population for each relative SAC using Carter et al. (2022) (**Table 1.6**).

Table 1.6 Estimated number of potential individuals of seal SAC populations to have PTS or to be disturbed during each piling event

Marine Mammal Receptor and SAC	SAC Reference population	PTS (SEL _{cum})	Disturbance
Grey seal – Treshnish Isles SAC	636	1	29
Harbour seal – South-East Islay Skerries SAC	981	1	7



Marine Mammal Receptor and SAC	SAC Reference population	PTS (SEL _{cum})	Disturbance
Harbour seal – Eileanan agus Sgeiran Lois mor SAC	331	0	2

1.2.5.2 Population Modelling In-Combination with other Projects

45. Regarding in-combination population modelling, after the initial screening of UK and RoI offshore windfarms, further refinement was undertaken to identify projects whose construction schedules could realistically coincide with piling activities at the WDA. This review considered publicly available construction programmes and anticipated piling periods to develop a realistic, though still precautionary, list of projects that might overlap temporally with the Project, resulting in the potential for a LSE from piling on SACs (see **Appendix 10.5 Cumulative Effects Assessment Screening**).
46. Results of the CEA screening showed that only a single windfarm (Spiorad na Mara) is due to impact pile at the same time as the Project, while three other projects were identified to have the same construction window as piling at the WDA, (Malin Sea Wind, North Channel Wind 1 and 2).
47. The Inner Hebrides and Minches SAC was screened in for LSE by Spiorad na Mara, however, in-combination population modelling has not been undertaken as the Environmental Impact Assessment Report / RIAA for Spiorad na Mara was not available prior to the six month cut-off period agreed with NatureScot after which any new information was not included in the application. The Inner Hebrides and Minches and Skerries and Causeway SACs were considered by Malin Sea Wind and North Channel Wind 1 and 2, however, these windfarms have only submitted a scoping report (Malin Sea Wind Limited, 2023; North Channel Wind Limited, 2023), therefore there was insufficient information on the piling schedule and the number of piles. For these reasons, Malin Sea Wind and North Channel Wind has not considered further within the population modelling.
48. South-East Islay Skerries SAC was also considered by North Channel Wind 1 and 2, however, as above, this windfarm is not considered further in terms of a in-combination piling assessment.
49. For the Treshnish Isles SAC and Eileanan agus Sgeiran Lois mor SACs, population modelling was not undertaken to assess potential in-combination effects as there was no connectivity with other projects. They were therefore screened out of the in-combination assessment for piling (see the **RIAA** for further information).
50. In summary, no SAC has been taken forward for in-combination assessment of piling at the WDA with other projects, as all other piling projects have been screened out.

1.2.6 Presentation of Results

51. This section provides additional detail on how the results of the iPCoD modelling for piling-related disturbance in marine mammals are presented. In **Chapter 10 Marine Mammals and Leatherback Turtle**, the **Report to Inform MPA Assessment**, and the **RIAA**, the key metric used to determine effect significance is the median ratio of impacted to un-impacted population sizes for each relevant marine mammal population. The median is used because it is less influenced by extreme outliers than the mean, particularly when sample sizes are small (Sinclair et al., 2020). For completeness, mean values are also reported.
52. This ratio metric is also considered the least sensitive to errors in demographic parameter estimates, supporting more robust assessments of offshore renewable impacts (Jitlal et al., 2017; Sinclair et al., 2019). Sensitivity analyses have demonstrated that the counterfactual population size ratio; specifically the median ratio across all matched replicate pairs is a stable and reliable output for



population viability analyses in the context of offshore wind EIA (Jitlal et al., 2017; Sinclair et al., 2019).

53. Accordingly, the approach taken in **Chapter 10 Marine Mammals and Leatherback Turtle, the Report to Inform MPA Assessment** and the **RIAA** follows the recommendations provided by the iPCoD developers (Sinclair et al., 2019) and others (Jitlal et al., 2017), has been accepted in recent offshore wind EIAs, and represents current best practice.
54. 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).
55. 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, the ratio of the impacted to the unimpacted population size can be calculated and then the median of all these ratios determined. This result is expressed as a percentage in the iPCoD results tables in **Chapter 10 Marine Mammals and Leatherback Turtle, the Report to Inform MPA Assessment** and the **RIAA**.
56. 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 to calculate the median of the ratio of impacted:un-impacted population sizes, which is the primary metric for assessing effect significance.
57. 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 will not necessarily match the mean ratio of the impacted to un-impacted populations presented. Understanding these distinctions is key to accurately interpreting the results from the iPCoD model.
58. The results in **Chapter 10 Marine Mammals and Leatherback Turtle, the Report to Inform MPA Assessment** and the **RIAA** have therefore used the following timepoints:
- Time point 1 / 2030: first year of piling at the WDA;
 - Time point 2 / 2031: second year of piling;
 - Time point 3 / 2033: final year of piling;
 - Time point 5 / 2035: end of construction;
 - Time point 7 / 2039: six years after piling has finished;
 - Time point 13 / 2045: twelve years after piling has finished; and
 - Time point 26 / 2055: marks the end of 25 years of modelling, since piling first commenced.



59. In absence of guidance from NatureScot, under Natural Resource Wales (NRW) (2023) guidance,; where piling activities (WDA alone and cumulative) result in PTS and/or behavioural disturbance leading to a sustained population decline of greater than 1% per annum, relative to an unimpacted reference population, over a defined assessment period (e.g. the first six years, consistent with the former Favourable Conservation Status (FCS) reporting cycle), a significant effect cannot be ruled out. NRW's 2023 position statement indicates that this threshold may be applied to the interpretation of iPCoD outputs for behavioural disturbance, noting that the guidance is primarily focused on PTS and remains under development. In the absence of alternative regulatory direction, the application of the 1% threshold to the iPCoD results is considered a proportionate and defensible approach for interpreting the modelling outputs and informing the assessment. This approach has therefore been adopted.

1.3 MODELLING RESULTS

60. As described in **Section 1.2.1.1**, it has been agreed with NatureScot through email correspondence following the second Expert Topic Group (ETG) meeting on the 15 October 2025, that the population modelling for PTS $SEL_{cum} / L_{E,p,t}$ for minke whale is not presented as part of the main assessment due to the lack of expert elicitation for that species. It is therefore presented in this section for information purposes only. The assessment conclusions for minke whale are based on disturbance as presented in **Chapter 10 Marine Mammals and Leatherback Turtle** and on disturbance for minke whale in the Sea of Hebrides NCMPSA in the **Report to Inform MPA Assessment**.

61. In addition, the tables from population modelling undertaken in both **Chapter 10 Marine Mammals and Leatherback Turtle** and the **RIAA** are presented in this appendix.

1.3.1 Results Relevant to Chapter 10 Marine Mammals and Leatherback Turtle

1.3.1.1 Minke Whale WDA Alone Assessment

62. The PTS $SEL_{cum} / L_{E,p,t}$ population modelling for minke whale is based on:

- A worst-case of up to 264 minke whale being disturbed; (based on the results from the EDR assessment (Table 10.38 in **Chapter 10 Marine Mammals and Leatherback Turtle**);
- Up to 231 individuals could be at risk of permanent auditory injury based on PTS $SEL_{cum} / L_{E,p,t}$ (Table 10.26 in **Chapter 10 Marine Mammals and Leatherback Turtle**).

63. One year after the start of piling, the median ratio of impacted versus the unimpacted population size is 96.17%. At the final year of piling, the median ratio of impacted versus the unimpacted population size is 76.77%. This declining trajectory remains the same up until the end of the 25 years, with a 17.99% median ratio of the impacted versus the unimpacted population (**Table 1.7**).

64. There is a greater than 70% difference between the unimpacted and impacted population, in both the median and the mean during the 25 year period (**Table 1.7**; **Plate 1.2**).



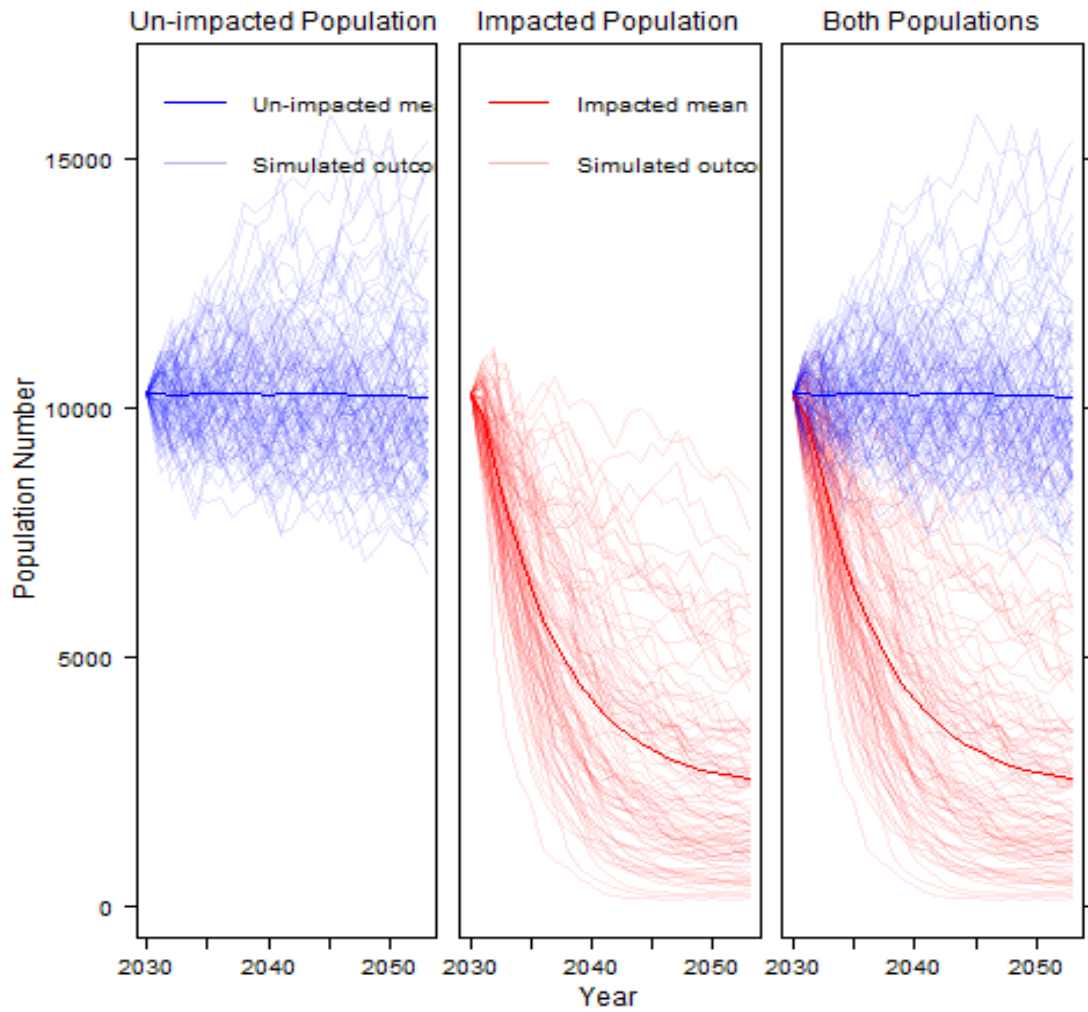


Plate 1.2 Simulated worst-case minke whale for CGNS MU (UK portion) both the unimpacted and the impacted populations using $SEL_{cum} / LE_{p,t}$ for WDA alone assessment



Table 1.7 Results of the iPCoD modelling for the Project, giving the mean population size of minke whale CGNS MU (UK) population ($SEL_{cum} / L_{E,p,t}$) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	10,286	10,286	100.00	10,286	10,286	100.00	10,286 – 102,86	10286 - 10286
2031	10,288	9,843	95.67	10,323	9,928	96.17	9,132 – 11,204	8,210 – 10,920
2033	10,294	7,903	76.77	10,264	8,256	80.44	8,720 – 11,848	3,750 – 10,566
2035	10,319	6,312	61.17	10,305	6,553	63.59	8,590 – 12,152	1,912 – 9,943
2039	10,266	4,070	39.65	10,151	3,795	37.39	8,389 – 12,670	406 – 8,942
2045	10,291	2,670	25.95	10,115	2,062	20.39	7,716 – 13,596	98 – 7,876
2055	10,298	2,485	24.13	10,114	1,820	17.99	7,486 – 13,795	92 -7,571



1.3.1.2 Minke Whale Cumulative Assessment

65. The PTS $SEL_{cum} / L_{E,p,t}$ population modelling for minke whale is based on:
- A worst-case of up to 264 minke whale being disturbed; (based on the results from the EDR assessment (Table 10.38 in **Chapter 10 Marine Mammals and Leatherback Turtle**); plus an additional 315 individuals that could be disturbed from other windfarms (**Table 1.5**)
 - Up to 231 individuals could be at risk of permanent auditory injury based on PTS $SEL_{cum} / L_{E,p,t}$ (Table 10.26 in **Chapter 10 Marine Mammals and Leatherback Turtle**); plus an additional 18 individuals being at risk of being exposed to PTS from other windfarms (**Table 1.5**)
66. One year after the start of piling, the median and mean ratio of impacted versus the unimpacted population size is 99.72%. At the final year of piling (2033), the median ratio of impacted versus the unimpacted population size is 87.56% and the mean ratio of impacted versus the unimpacted population size is 86.43%. This declining trajectory remains the same up until the end of the 25 years, with an 18.40% median ratio and a 23.99% mean ratio of the impacted versus the unimpacted population (**Table 1.8**).
67. There is a greater than 70% difference between the unimpacted and impacted population, in both the median and the mean during the 25 year period (**Table 1.8; Plate 1.3**).



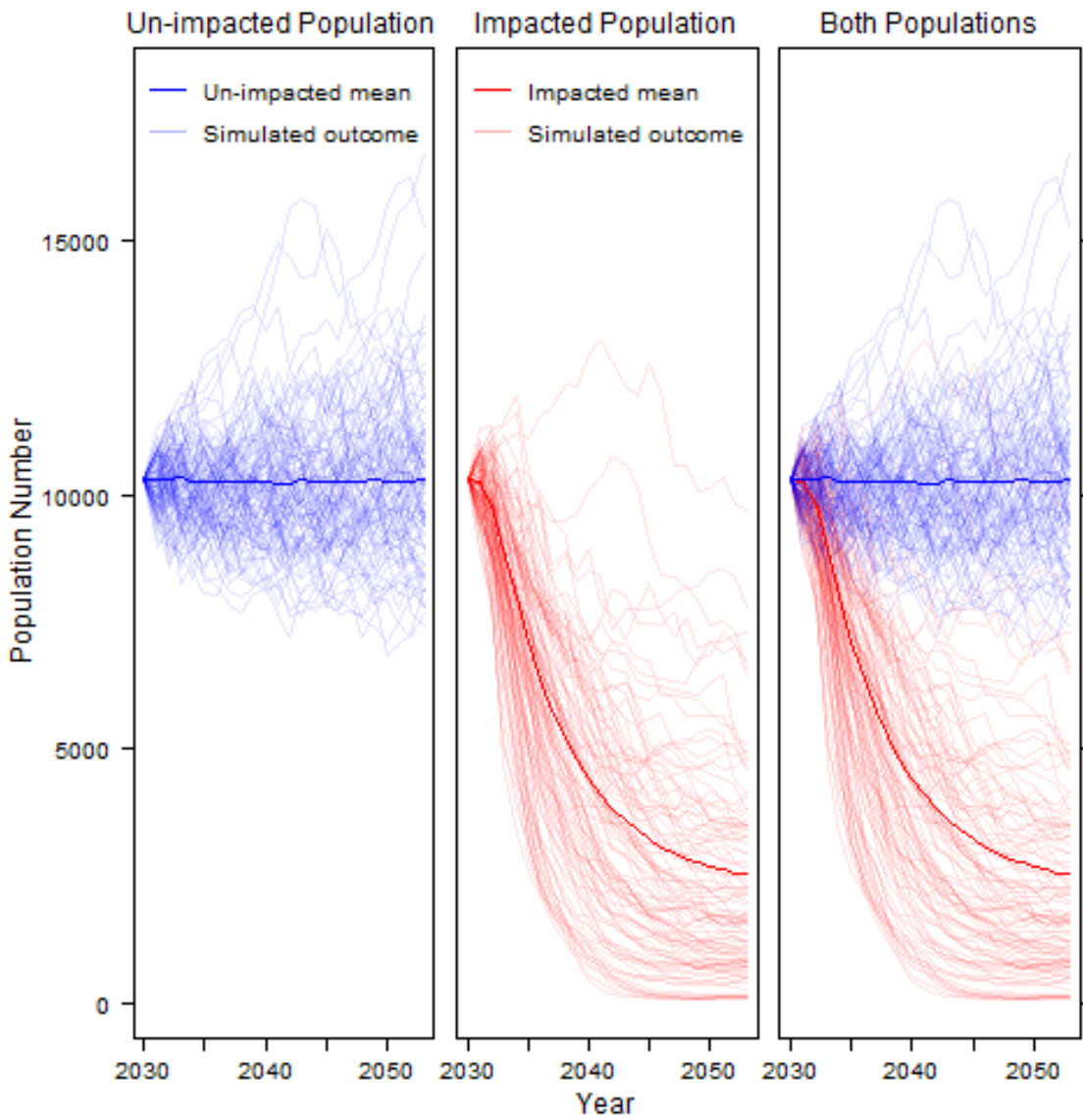


Plate 1.3 Simulated worst-case minke whale for CGNS MU (UK portion) both the unimpacted and the impacted populations using SELcum / LE,p,t .for cumulative PTS and disturbance



Table 1.8 Results of the cumulative iPCoD modelling for the Project, giving the mean population size of minke whale CGNS MU (UK) population ($SEL_{cum} / L_{E,p,t}$) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	10,288	10,288	100.00	10,286	10,286	100.00	10,288 – 10,288	10,288 – 10,288
2031	10,283	10,241	99.59	10,323	10,294	99.72	9,166 – 11,128	9,110 – 1,084
2033	10,329	8,927	86.43	10,317	9,034	87.56	8,856 – 11,822	5,913 – 11,058
2035	10,238	7,121	69.55	10,189	7,326	71.90	8,629 – 12,016	3,130 – 10,216
2039	10,242	4,411	43.07	10,141	4,250	41.91	8,210 – 12,509	674 – 9,041
2045	10,270	2,693	26.22	10,134	2,046	20.19	7,742 – 13,555	142 – 7,866
2055	10,326	2,477	23.99	10,099	1,858	18.40	7,484 – 14,084	126 -7,582



1.3.1.3 WDA Alone Assessment for Other Receptors

68. Population modelling for piling has been undertaken as described in **Section 1.2.2** for all species receptors where suitable parameters are available, namely harbour porpoise, bottlenose dolphin, minke whale, and grey and harbour seal at the MU scale. In accordance with NRW (2023), a sustained population decline of more than 1% per year relative to an unimpacted reference population, over a defined period (e.g. the first six years, reflecting the former FCS reporting cycle), indicates that a significant effect cannot be ruled out. Although the NRW guidance is primarily intended for assessing PTS and remains under development, it also states that this threshold may be applied to interpret iPCoD outputs for behavioural disturbance. In the absence of alternative guidance, application of the 1% threshold is considered appropriate and defensible and has therefore been adopted. Tabulated results are provided in this appendix, with figures and detailed discussion presented in **Chapter 10 Marine Mammals and Leatherback Turtle**.



Table 1.9 Results of the iPCoD modelling for MachairWind, giving the mean population size of harbour porpoise population (WS MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	24,304	24,304	100.00	24,304	24,304	100.00	24,304 – 24,304	24,304 – 24,304
2031	24,356	24,447	100.37	24,454	24,351	99.58	22,403– 25,932	22,395 – 25,924
2033	24,584	24,542	99.83	24,640	24,502	99.44	21,525 -27,199	21,463 – 27,116
2035	24,810	24,675	99.46	24,727	24,726	100.00	21,295 – 27,942	21,192 – 27,754
2039	25,188	24,805	98.48	24,874	25,103	100.92	20,124 – 29,588	20,109 – 29,440
2045	25,409	25,099	98.78	25,160	25,323	100.65	18,573 – 32,579	18,563 – 32,496
2055	24,304	24,304	100.00	24,304	24,304	100.00	18,062 – 33,416	17,985 – 33,300



Table 1.10 Results of the iPCoD modelling for MachairWind, giving the mean population size of bottlenose dolphin population (CWSH MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	44	44	100.00	44	44	100.00	44 – 44	44 – 44
2031	44	43	97.73	44	44	100.00	36 – 52	34 – 52
2033	44	40	90.91	44	40	90.91	32 – 56	28 – 54
2035	44	38	86.36	44	38	86.36	30 – 60	22 – 56
2039	44	39	88.64	44	38	86.36	24 – 66	20 – 64
2045	44	39	88.64	44	38	86.3	18 – 76	16 – 70
2055	45	40	88.89	44	38	86.36	16 – 82	12 – 76



Table 1.11 Results of the iPCoD modelling for MachairWind, giving the mean population size of bottlenose dolphin population (OW MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	1298	1298	100.00	1298	1298	100.00	1,298 – 1,298	1,298 – 1,298
2031	1,298	1,297	99.92	1,304	1,302	99.85	1,162 – 1,392	1,162 – 1,390
2033	1,298	1,288	99.23	1,305	1,298	99.46	1,096 – 1,452	1,072 – 1,446
2035	1,297	1,283	98.92	1,301	1,286	98.85	1,070 – 1,498	1,034 – 1,496
2039	1,293	1,282	99.10	1,290	1,278	99.07	1,018 – 1,600	992 – 1,598
2045	1,289	1,277	99.00	1,277	1,267	99.22	902 – 1,736	888 – 1,732
2055	1,294	1,282	99.07	1,282	1,272	99.22	876 – 1,782	770 – 1,774



Table 1.12 Results of the iPCoD modelling for MachairWind, giving the mean population size of minke whale population (disturbance only) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	10,288	10,288	100.00	10,288	10,288	100.00	10,288 – 10,288	10,288 – 10,288
2031	10,277	10,276	99.99	10,314	10,314	100.00	9,112 – 11,160	9,112 – 11,160
2033	10,286	10,280	99.94	10,289	10,279	99.90	8,832 – 11,854	8,832 – 11,854
2035	10302	10,294	99.92	10,262	10,256	99.94	8,670 – 12,142	86,70 – 12,142
2039	10263	10,261	99.98	101,82	10,179	99.97	8,351 – 12,750	83,51 – 12,750
2045	10,242	10,239	99.97	10,088	10,087	99.99	7,558 – 13,730	7,558 – 13,730
2055	10,258	10,255	99.97	10,071	10,071	100.00	7,444 – 13,982	7,444 – 13,982



Table 1.13 Results of the iPCoD modelling for MachairWind, giving the mean population size of grey seal population (West MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	17,450	17,450	100.00	17,450	17,450	100.00	17,450 – 17,450	17,450 – 17,450
2031	17,600	17,600	100.00	17,651	17,651	100.00	16,236 – 18,774	16,236 – 18,774
2033	18,000	17,989	99.94	18,096	18,075	99.88	15,758 – 197,70	15,758 – 19,756
2035	18,337	18,321	99.91	18,391	18,377	99.92	15,770 - 20626	15,770 – 20,626
2039	19,380	19,360	99.90	19,323	19,308	99.92	15,682 - 23143	15,682 – 23,105
2045	21,360	21,337	99.89	21,113	21,105	99.96	15,874 - 27611	15,874 – 27,590
2055	22,454	22430	99.89	22,251	22,236	99.93	16,371 - 29859	16,371 – 29,832



Table 1.14 Results of the iPCoD modelling for MachairWind, giving the mean population size of grey seal population (wider MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	50,198	50,198	100.00	50,198	50,198	100.00	50,198 – 50,198	50,198 – 50,198
2031	50,695	50,695	100.00	50,813	50,813	100.00	47,018 – 53,776	47,018 – 53,776
2033	51,688	51,688	100.00	51,787	51,787	100.00	45,972 – 56,743	45,972 – 56,743
2035	52,578	52,578	100.00	52,565	52,565	100.00	45,392 – 59,186	45,392 – 59,186
2039	55,418	55,417	100.00	55,226	55,226	100.00	44,977 – 66,081	44,977 – 66,081
2045	61,476	61,476	100.00	61,146	61,146	100.00	46,079 – 79,484	46,079 – 79,484
2055	64,449	64,449	100.00	63,664	63,664	100.00	47,057 – 86,325	47,057 – 86,325



Table 1.15 Results of the iPCoD modelling for MachairWind, giving the mean population size of harbour seal population (West MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	19,708	19,708	100.00	19,708	19,708	100.00	19,708 – 19,708	19,708 – 19,708
2031	19,711	19,711	100.00	19,760	19,760	100.00	18,110 – 21,044	18,110 – 21,044
2033	19,665	19,665	100.00	19,670	19,670	100.00	17,600 – 21,726	17,600 – 21,726
2035	19,662	19,662	100.00	19,591	19,591	100.00	17,391 – 22,502	17,391 – 22,502
2039	19,685	19,685	100.00	19,549	19,549	100.00	16,618 – 23,555	16,618 – 23,555
2045	19,773	19,773	100.00	19,625	19,625	100.00	15,689 – 24,661	15,689 – 24,661
2055	19,831	19,831	100.00	19,623	19,623	100.00	15,612 – 25,549	15,612 – 25,549



Table 1.16 Results of the iPCoD modelling for MachairWind, giving the mean population size of harbour seal population (wider MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	33,014	33,014	100.00	33,014	33,014	100.00	33,014 – 33,014	33,014 – 33,014
2031	33,018	33,018	100.00	33,067	33,067	100.00	30,234 – 35,524	30,234 – 35,524
2033	33,020	33,020	100.00	32,999	32,999	100.00	29,595 – 36,685	29,595 – 36,685
2035	33,040	33,040	100.00	32,993	32,993	100.00	29,026 – 37,164	29,026 – 37,164
2039	32,974	32,974	100.00	32,949	32,949	100.00	27,774 – 38,830	27,774 – 38,830
2045	32,836	32,836	100.00	32,704	32,704	100.00	26,096 – 41,015	26,096 – 41,015
2055	32,799	32,799	100.00	32,543	32,543	100.00	25,249 – 41,923	25,249 – 41,923



1.3.1.4 Cumulative Assessment for Minke Whale, Grey Seal and Harbour Seal

69. Cumulative population modelling has been undertaken to assess the potential cumulative effects of piling-related disturbance and injury on relevant marine mammal populations, taking account of multiple pathways of impact and temporal overlap across projects. The modelling provides a framework for evaluating whether repeated or concurrent exposures could result in population-level consequences, beyond those predicted for the WDA alone. In particular, the approach enables assessment of the magnitude, direction and persistence of potential cumulative effects relative to an unimpacted reference population, thereby informing the determination of significance in accordance with current regulatory guidance.
70. The Population modelling has been undertaken as described in **Section 1.2.3** for minke whale, grey seal and harbour seal. Tabulated results are provided in this appendix, with figures and detailed discussion presented in **Chapter 10 Marine Mammals and Leatherback Turtle**.



Table 1.17 Results of the iPCoD modelling for MachairWind, giving the mean population size of minke whale population (disturbance only) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	10,288	10,288	100.00	10,288	10,288	100.00	10,288 – 10,288	10,288 – 10,288
2031	10,278	10,277	99.99	10,336	10,335	99.9	9,116 – 11,138	9,116 – 11,160
2033	10,281	10,279	99.98	10,301	10,300	99.99	8,826 – 11,772	8,826 – 11,772
2035	10,278	10,275	99.97	10,266	10,266	100.00	8,715 – 12,066	8,715 – 12,066
2039	10,259	10,258	99.99	10,198	10,198	100.00	8,250– 12,750	8,250– 12,750
2045	10,256	10,256	100.00	10,101	10,101	100.00	7,782 – 13,775	7,782 – 13,775
2055	10,238	10,238	100.00	9,989	9,989	100.00	7,460 – 14,539	7,460 – 14,539



Table 1.18 Results of the iPCoD modelling for MachairWind, giving the mean population size of grey seal population (wider MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	51,471	51,471	100.00	51,471	51,471	100.00	51,471 – 51,471	51,471 – 51,471
2031	51,489	51,489	100.00	51,601	51,601	100.00	46,035 – 55,907	46,035 – 55,907
2033	52,028	52,028	100.00	52,069	52,069	100.00	45,836 – 56,743	45,836 – 57,325
2035	53,165	53,165	100.00	53,314	53,314	100.00	45,415 – 59,186	45,415 – 60,275
2039	55,999	55,999	100.00	55,981	55,981	100.00	44,853 – 66,081	44,853 – 67,873
2045	61,647	61,647	100.00	61,178	61,178	100.00	45,642 – 79,484	45,642 – 80,659
2055	64,854	64,854	100.00	64,096	64,096	100.00	45,577 – 86,325	45,577 – 87,702



Table 1.19 Results of the iPCoD modelling for MachairWind, giving the mean population size of harbour seal population (wider MU) for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			95 % Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	31,627	31,627	100.00	31,627	31,627	100.00	31,627– 31,627	31,627– 31,627
2031	31,629	31,629	100.00	31,623	31,623	100.00	31,623 – 31,623	28,974 – 33,943
2033	31,713	31,713	100.00	31,674	31,674	100.00	31,674 – 31,674	28,470 – 35,095
2035	31,622	31,622	100.00	31,516	31,516	100.00	31,516 – 31,516	27,613 – 35,712
2039	31,617	31,617	100.00	31,413	31,413	100.00	31,413– 31,413	26,843 – 37,084
2045	31,765	31,765	100.00	31,525	31,525	100.00	31,525 – 31,525	25,126 – 39,344
2055	31,867	31,867	100.00	31,443	31,443	100.00	31,443 – 31,443	24,611 – 40,637



1.3.2 Results Relevant to the Report to Inform MPA Assessment

71. The PTS $SEL_{cum} / LE_{p,t}$ population modelling for minke whale in the NCMPA Sea of the Hebrides is based on the following:
- A worst-case of up to 45 minke whale being disturbed; (based on the results of the EDR assessment (Table 6.7 in the **Report to Inform MPA Assessment**).
 - Up to 39 individuals could be at risk of permanent auditory injury based on PTS $SEL_{cum} / LE_{p,t}$ (Table 6.4 in the **Report to Inform MPA Assessment**).
72. One year after the start of piling the median ratio of impacted versus the unimpacted population size is 88.53%. One year after piling finishes, the median ratio of impacted versus the unimpacted population size is 52.27%. This declining trajectory remains the same up until the end of the 25 years, with a 17.20% median ratio of the impacted versus the unimpacted population (**Table 1.20**).
73. The model predicts an over 80% difference between the unimpacted and impacted population over the 25 year period (**Table 1.20**; **Plate 1.4**).

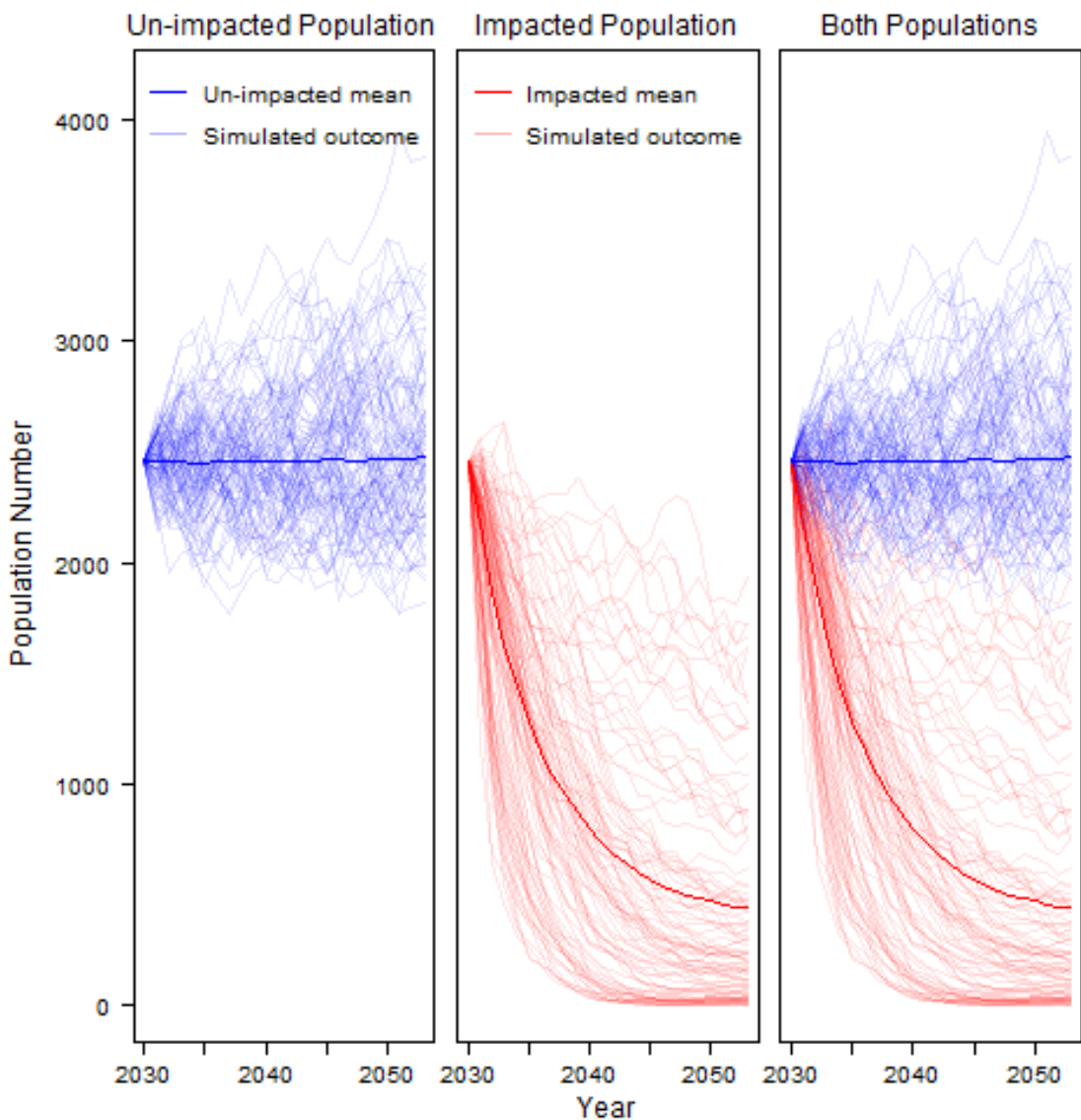


Plate 1.4 Simulated worst-case minke whale WS population sizes for both the unimpacted and the impacted populations using $SEL_{cum} / LE_{p,t}$.



Table 1.20 Results of the iPCoD modelling using the number disturbance and $PTS_{SEL_{cum}} / L_{E,p,t}$ for piling at MachairWind WDA, giving the mean population size of minke whale WS population for years up to 2055 for both impacted and unimpacted populations as well as the mean and median ratio

Time period	Mean			Median			Lower 2.5% and upper 97% Confidence Intervals	
	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop	Impacted as % of unimpacted	Un-impacted pop	Impacted pop
Start	2,458	2,458	100.00	2,458	2,458	100.00	2,458 - 2,458	2,458 - 2,458
2031	2,459	2,177	88.53	2,470	2,244	90.8	2,190 - 2,666	1502 - 2,544
2033	2,457	1,634	66.50	2,450	1,724	70.37	2,094 - 2,838	658 - 2,412
2035	2,447	1,279	52.27	2,428	1,318	54.28	2,068 - 2,918	322 - 2,328
2039	2,454	800	32.60	2,438	706	28.96	1,992 - 3,028	44 - 2,112
2045	2,474	471	19.04	2,438	264	10.83	1,834 - 3,270	4 - 1,849
2055	2,465	424	17.20	2,431	236	9.71	1,768 - 3,404	6 - 1,728



REFERENCES

- Booth, C. G., F. Heinis, and Harwood, J. (2019). Updating the Interim PCoD Model: Workshop Report - New transfer functions for the effects of disturbance on vital rates in marine mammal species. Report Code SMRUC-BEI-2018-011, submitted to the Department for Business, Energy and Industrial Strategy (BEIS), February 2019 (unpublished).
- Brandt, M. J., Diederichs, A., Betke, K. and Nehls, G. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. *Marine Ecology Progress Series*, 421, 205-216.
- Buchan Offshore Wind Limited (2025). *Pre-Application Consultation (PAC) Report*. July 2025. Available at: https://buchan-eia.com/wp-content/uploads/BUCH3500_Buchan_PAC_report_d4.pdf [Accessed 8 May 2026].
- Carter, C., Clark, C., Comay, L., Keating-Bitonti, C., Marshak, A., Sheikh, P., & Ward, E. (2022). *Offshore Wind Development and Marine Mammals*. Marine Mammal Commission, Washington, DC. May 2022.
- Genos Offshore Windfarm Limited (2024). *Environmental Impact Assessment (EIA) Scoping Report and supporting application documents*.
- Czapanskiy, M. F., M. S. Savoca, W. T. Gough, P. S. Segre, D. M. Wisniewska, D. E. Cade, and J. A. Goldbogen (2021). Modelling short-term energetic costs of sonar disturbance to cetaceans using high-resolution foraging data. *Journal of Applied Ecology*.
- Donovan, C., J. Harwood, S. King, C. Booth, B. Caneco, and C. Walker (2016). Expert elicitation methods in quantifying the consequences of acoustic disturbance from offshore renewable energy developments. Pages 231-237. *The Effects of Noise on Aquatic Life II*. Springer. *Scottish Marine And Freshwater Science*, 5(2).
- Equinor (2022). *Equinor Annual Report 2022 – Sustainability and Energy Transition*. Published March 2023. Available at: <https://www.equinor.com/investors/2022-annual-report> [Accessed 8 May 2026].
- Graham, I. M., Merchant, N. D., Farcas, A., Barton, T. R., Cheney, B., Bono, S., & Thompson, P. M. (2019). Harbour porpoise responses to pile-driving diminish over time. *Royal Society Open Science*, 6(6), 190335. <https://doi.org/10.1098/rsos.190335> [Accessed 8 May 2026].
- Graham, I. M., Pirotta, E., Merchant, N. D., Farcas, A., Barton, T. R., Cheney, B., Hastie, G. D., & Thompson, P. M. (2017). Responses of bottlenose dolphins and harbor porpoises to impact and vibration piling noise during harbor construction. *Ecosphere*, 8(5), e01793. <https://doi.org/10.1002/ecs2.1793> [Accessed 8 May 2026].
- Harwood, J., S. King, R. Schick, C. Donovan, and C. Booth. (2014). A Protocol For Implementing The Interim Population Consequences Of Disturbance (PCoD) Approach: Quantifying And Assessing The Effects Of UK Offshore Renewable Energy Developments On Marine Mammal Populations. Report Number SMRUL-TCE-2013- 014.
- Jital, M., Burthe, S., Freeman, S., and Daunt, F. (2017). Testing and Validating Metrics of Change Produced by Population Viability Analysis (PVA). *Scottish Marine and Freshwater Science*: 8(23).
- King, S. L., R. S. Schick, C. Donovan, C. G. Booth, M. Burgman, L. Thomas, and J. Harwood. (2015). An interim framework for assessing the population consequences of disturbance. *Methods in Ecology and Evolution* 6:1150-1158.
- Malin Sea Wind Limited (2023). *Malin Sea Wind Offshore Wind Farm Environmental Scoping Report*. Malin Sea Wind Limited.
- North Channel Wind Limited (2023). *Environmental Scoping Report*. North Channel Wind.
- Schwacke, L.H., Marques, T.A., Thomas, L., Booth, C.G., Balmer, B.C., Barratclough, A., Colegrove, K., De Guise, S., Garrison, L.P., Gomez, F.M. and Morey, J.S., (2022). Modeling population effects of the Deepwater Horizon oil spill on a long-lived species. *Conservation Biology*, 36(4), p.e13878.
- SCOS (2021). *Scientific Advice on Matters Related to the Management of Seal Populations: 2021*



SCOS (2023). Scientific Advice on Matters Related to the Management of Seal Populations: 2023

Sinclair, R. R., Sparling, C. E., and Harwood, J. (2020). Review Of Demographic Parameters and Sensitivity Analysis to Inform Inputs and Outputs of Population Consequences of Disturbance Assessments for Marine Mammals. *Scottish Marine and Freshwater Science*, 11(14), 74. <https://doi.org/10.7489/12331-1> [Accessed 8 May 2026]

Sinclair, R., Booth, C., Harwood, J. & Sparling, C. (2019). Helpfile for the interim PCoD v5 model. March 2019.

Sinclair, RR & Klementisová, K (2025). Offshore Wind Farm Cumulative Effects Assessments – Case Study 1: Including projects without an EIA. PrePARED Report, No. 9. October 2025

SSE Renewables & Equinor (2025). *Dogger Bank D Offshore Wind Project – Seabed Lease Finalisation and Project Progression*.

SSE Renewables & RWE (2024). *North Falls Offshore Wind Farm Extension – Development Consent Order Application*.

SSE Renewables, Marubeni Corporation & Copenhagen Infrastructure Partners (2024). *Ossian Floating Offshore Wind Farm – Array Consent Application and EIA*.

Taylor, B. L., and Master, D. P. (1993). Implications of Non-Linear Density Dependence. *Marine Mammal Science*, 9(4), 360-371.

