Bowdun Offshore Wind Farm, Offshore EIA Report

Volume 3, Technical Appendix 10.3: Marine Mammal Interim Population Consequences of Disturbance Model Modelling Report

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Glossary

Defined term	Definition
Array Area	The Array Area is the area in which the Offshore Generation Assets will be located.
Cumulative Effects	The effects of the Proposed Development assessed together with effects from the Onshore Infrastructure forming the Project as well as one or more different projects on the same receptor/resource.
Digital Aerial Surveys (DAS)	A method for undertaking baseline ornithological and marine mammal data collection surveys. Usually undertaken over a period of 24 months.
Effect	Term used to express the consequence of an impact (i.e. the result of change or changes) on specific environmental resources or receptors. The significance of an effect is determined by correlating the magnitude of the impact with the importance, or sensitivity of the receptor or resource in accordance with defined significance criteria.
Environmental Impact Assessment (EIA)	Process for the assessment of likely significant environmental effects of a project on the physical, biological, and human environment during construction, Operation and Maintenance (O&M) and decommissioning.
Maximum Design Scenario (MDS)	The scenario within the design envelope likely to result in the greatest impact on a particular topic receptor, and therefore the one that should be assessed for that topic receptor.
Offshore Export Cables	Subsea cables used to transmit electricity generated offshore by the Wind Turbines from the OSPs to shore. The Transition Joint Bay (TJB) is the location where the Offshore Export Cables terminate, and the onshore cabling begins.
Offshore Substation Platform(s) (OSPs)	OSPs comprise the support structure, topside and electrical components used for collecting and/or converting electricity generated by the Wind Turbines for transmission by the Offshore Export Cables.
Piling	The action of installing piles: installation can use various methodologies, the most common of which are impact piling (in which the piles are struck by a “hammer”) and drilling (during which a hole is drilled into the seafloor, the drilling tool is removed, and the pile is slotted into that hole).
Project (the)	An overarching term for the Bowdun Offshore Wind Farm (Bowdun OWF) comprising the offshore and onshore infrastructure required to generate and transmit electricity from the Array Area to the onshore Grid Connection Point. The Project includes both the Offshore Generation Assets, the Offshore Transmission Assets and the Onshore Transmission Assets.
Proposed Development	Term used to define the Offshore Infrastructure associated with the Project seaward of Mean High Water Springs (MHWS) for which consent is being sought. Further details of the parameters are included in Volume 1, Chapter 3: Project Description.
Study Area	For each environmental topic, the baseline environment will be characterised, and the potential environmental impacts will be described within a topic-specific study area. Specific study areas are defined for each topic and are based on the maximum spatial extent across which potential impacts of the Project may be experienced by the relevant receptors (i.e. Zone of Influence).
Thistle Wind Partners (TWP)	Company established for the development of the Project.

Acronyms

Acronym	Definition
BOWFL	Bowdun Offshore Wind Farm Limited
CEA	Cumulative Effects Assessment
CGNS	Celtic and Greater North Seas
DAS	Digital Aerial Surveys
EIA	Environmental Impact Assessment
GNS	Greater North Sea
HVAC	High Voltage Alternating Current
IAC	Inter-Array Cable
IAMMWG	Inter-Agency Marine Mammal Working Group
iPCoD	Interim Population Consequences of Disturbance Model
MDS	Maximum Design Scenario
MU	Management Unit
OEP	Offshore Electrical Platform
OLA	Option to Lease Area
OSP	Offshore Substation Platform
OWF	Offshore Wind Farm
POA	Plan Option Area
SAC	Special Area of Conservation
SCOS	Special Committee on Seals
SEL	Sound Exposure Level
SMP	Sectoral Marine Plan
SMRU	Sea Mammal Research Unit
SMU	Seal Management Unit
TWP	Thistle Wind Partners Limited

Table of Units

Units	Definition
dB	Decibel
kJ	Kilojoule
MW	MegaWatt
SELss	Single Strike Sound Exposure Level
%	Percent

1 Introduction

1.1 Overview

1.1.1 This Interim Population Consequences of Disturbance (iPCoD) Technical Report provides a description of the methods used for the assessment of marine mammal population trajectories in relation to construction piling for the offshore elements of the Bowdun Offshore Wind Farm (OWF) Project (hereafter referred to as the Proposed Development). An interpretation of the results for the Proposed Development alone, and cumulatively with all other relevant projects is provided.

1.1.2 The Proposed Development covers the Option Lease Area (OLA) and comprises of the Array Area, which is located in the E3 Plan Option Area (POA) detailed in the Scottish Sectoral Marine Plan (SMP) (Scottish Government, 2020), and the Export Cable Corridor. The Array Area is located 38 km from the Aberdeenshire coast at its closest point, covering an area of 187 km^2. The Proposed Development will comprise of Wind Turbines (fixed foundations), Inter-Array Cables (IACs), Offshore Substation Platforms (OSPs), Interconnector Cables, Offshore Export Cables and any necessary scour/cable protection. The Export Cable Corridor will include a maximum of three High Voltage Alternating Current (HVAC) Offshore Export Cables, each with a length of up to 70 km and will make Landfall at Benholm, Aberdeenshire.

1.1.3 An Environmental Impact Assessment (EIA) has been carried out to determine the potential effects of the Proposed Development on marine mammals from a range of impacts (Volume 2, Chapter 10: Marine Mammals). This iPCoD report provides the information to support the EIA assessment for marine mammals.

1.1.4 Subsea noise modelling was undertaken (Volume 3, Technical Appendix 10.4: Subsea Noise Technical Report) to predict the potential spatial scale of the impact of piling associated with the installation of Wind Turbine and OSP foundations.

1.1.5 Two piling scenarios were modelled: a temporal scenario representing sequential piling of the foundations, and a spatial scenario representing concurrent piling where two piles are installed at the same time. The temporal scale reflects the largest number of days where piling may occur, and the spatial scale represents the potential for a greater number of animals disturbed but over a shorter timeframe. The piling scenarios are hereafter referred to as the 'maximum temporal scenario' and the 'maximum spatial scenario', respectively.

1.1.6 Population modelling was carried out to determine the potential for a short to medium term exposure to piling to result in long term population-level effects on any marine mammal species. Piling could occur intermittently within an 18-month piling period for Wind Turbines and within a three-month piling period for OSPs, during the five-year offshore construction timeframe (expected to occur between 2031 and 2035, inclusive). In this context short term refers to the duration of individual piling operations (i.e. days), medium term refers to the duration of the piling phase (i.e. up to three calendar years) and long term

refers to the period of time over which iPCoD models are able to predict population trajectories (i.e. up to 25 years).

1.1.7 The iPCoD model was developed by the Sea Mammal Research Unit (SMRU) with a team of researchers at the University of St Andrews (SMRU Consulting, 2025).

1.2 Background

1.2.1 The iPCoD model simulates the potential changes in a population of marine mammals over time, for both an "impacted" and an "un-impacted population". This provides a counterfactual comparison of the modelled population trajectories and includes consideration of population changes as a result of natural environmental variation, demographic stochasticity (i.e. variability in population growth rates) and anthropogenic disturbance (Harwood *et al.*, 2014; King *et al.*, 2015). This approach has been widely used in previous offshore wind applications, and consented projects in the UK (e.g. Berwick Bank Offshore Wind Farm (SSE Renewables, 2022), Awel y Môr Offshore Wind Farm (RWE Renewables UK, 2021), Hornsea Four Offshore Wind Project (Ørsted, 2021) and Hornsea Project Three Offshore Wind Farm (Ørsted, 2018)).

1.2.2 The iPCoD model is a framework whereby the user enters key information, such as basic demographic rates, with an estimate of population size, and the number of individuals at risk of injury and/or disturbance, together with a day-by-day piling schedule.

1.2.3 The model calculates the total number of disturbance days experienced by each individual animal and then assigns the level of disturbance into categories; the model then modifies the survival and fertility rates in response to the disturbance category to simulate population effects. The levels of disturbance and the degree of modification of vital rates used within the model were informed by an expert elicitation process for five key UK marine mammal species (harbour porpoise *Phocoena phocoena*, bottlenose dolphin *Tursiops truncatus*, minke whale *Balaenoptera acutorostrata*, harbour seal *Phoca vitulina*, and grey seal *Halichoerus grypus*) initially in 2013 to 2014 (Harwood *et al.*, 2014).

1.2.4 The relationship between disturbance and survival/reproduction assumes that individual animals would have a limited ability to alter their activity budget to compensate for a reduction in time spent feeding (Houston *et al.*, 2012; King *et al.*, 2015). The individual's ability to provision/care for young, evade predation or resist disease could be affected, and it is expected that effects would be reflected in changes to vital rates. Note, however, that this relationship is highly simplified (Harwood *et al.*, 2014), and an individual's response to disturbance will depend on factors including the context of the disturbance, the individual's existing condition and its exposure history (Ellison *et al.*, 2012). The iPCoD framework applies simulated changes in vital rates to infer the number of animals that may be affected by disturbance to iteratively project the size of the population.

1.2.5 Following the initial development of the iPCoD model, a study was undertaken to update the transfer functions on the effects of auditory injury and disturbance on the probability of survival and giving birth to viable young for harbour porpoise, harbour seal and grey seal (again via expert elicitation) (Booth and Heinis, 2018; Booth *et al.*, 2019). The iPCoD model code has been updated in light of additional work undertaken since it was originally launched in February 2014 (version 1) and iPCoD version 5.2 was used in the modelling for this report (Harwood *et al.*, 2014; Sinclair *et al.*, 2019).

Limitations

1.2.6 There are several precautions built into the iPCoD model which means the results are considered to be highly precautionary, and likely to overestimate the true population effects.

1.2.7 No form of density dependence has been incorporated into the model due to the uncertainties as to how to estimate carrying capacity or how to model the mechanism of density dependence. As discussed in Harwood *et al.* (2014), the concept of density dependence is fundamental to understanding how animal populations respond to a reduction in population size. Density-dependent factors, such as resource availability or competition for space, can limit population growth. If the population declines, these factors no longer become limiting and therefore, for the remaining individuals in a population, there is likely to be an increase in survival rate and reproduction. This then allows the population to expand back to previous levels at which density-dependent factors become limiting again (i.e. population remains at carrying capacity).

1.2.8 The latest expert elicitation process (Booth and Heinis, 2018; Booth *et al.*, 2019) did not update minke whale parameters, such that the model assumes that minke whales will not forage for 24 hours after being disturbed, which is now considered to be precautionary.

1.2.9 The estimates of the number of animals disturbed is taken from noise impact assessments with many layers of precaution (see Volume 3, Technical Appendix 10.4: Subsea Noise Technical Report for more details).

2 Methodology

2.1 Introduction

2.1.1 The iPCoD model v5.2 (Harwood *et al.*, 2014) was set up using the program R v4.5.0 (R Core Team, 2023) with RStudio v 2024.12.1+563 (Posit team, 2023) as the user interface. To enable the iPCoD model to be run, the following input data is required:

- reference population size (Section 2.4) and demographic parameters (Section 2.5) for the key species;
- residual days of disturbance (Section 2.6);
- number of animals predicted to experience disturbance during piling (Section 2.7); and
- estimated piling schedule during the proposed construction programme (Section 2.8).

2.2 Maximum Design Scenario

2.2.1 The Maximum Design Scenario (MDS) for piling at the Proposed Development has been developed on the basis that pile driving operations would be required for the installation of Wind Turbine and OSP foundations. The piling parameters associated with these differed between the maximum temporal scenario and maximum spatial scenario, and are discussed in the following paragraphs, respectively.

2.2.2 Full details of the MDS are presented in Volume 2, Chapter 10: Marine Mammals.

Maximum Temporal Scenario

2.2.3 The maximum temporal scenario is represented by piling occurring over the greatest number of days, resulting from piling at only one location at a time. Sound introduced into the marine environment over a longer period of time may prolong the risk for disturbance to marine mammals, with potential effects during multiple stages of a species' annual cycle.

2.2.4 The maximum temporal scenario was assessed on the number of piles that could be installed within one 24-hour period. The maximum temporal scenario (i.e. the longest duration of piling) would therefore be represented by up to one pile being installed around a single Wind Turbine location or at a single OSP location, in a single day (24 hours), equating to 268 days for Wind Turbines and 36 days for OSPs. The maximum duration of piling for the temporal spatial scenario would be 304 days.

2.2.5 A summary of the maximum temporal scenario used for iPCoD modelling is presented in Table 2.1.

Maximum Spatial Scenario

2.2.6 For the maximum spatial scenario, the largest hammer energy and maximum spacing between concurrent piling events would reduce the time required for piling operations overall but would lead to the largest spatial area of ensonification at any one time. Minimum spacing between concurrent piling locations represents the highest risk of injury to marine mammals as sound from adjacent foundations could combine to produce a greater radius of effect compared to a single piling event.

2.2.7 Within the overall piling period, concurrent piling for Wind Turbine foundations (i.e. at two Wind Turbines within the same 24-hour period) would occur over 20 days. Concurrent piling of OSP foundations would occur over nine days of the overall piling period. The maximum duration of piling for the maximum spatial scenario would be 29 days.

2.2.8 A summary of the maximum spatial scenario used for iPCoD modelling is presented in Table 2.2.

Table 2.1: Summary of the Maximum Temporal Scenario used in iPCoD for Piling of Offshore Foundations at the Proposed Development

Piling Operation	Foundation	Number of Piled Locations	Number of Piles	Maximum Hammer Energy (kJ)	Number of Vessels	Maximum Number of Piles Installed per Day	Maximum Piling Days (24 Hours)
Wind Turbine (single piling)	15 MW four-legged jacket	67	268	4,500	1	1	268
OSP (single piling)	Jacket	2	36	4,500	1	1	36
	Total	69	304	-	-	-	**304**

Table 2.2: Summary of the Maximum Spatial Scenario used in iPCoD for Piling of Offshore Foundations at the Proposed Development

Piling Operation	Foundation	Number of Piled Locations	Number of Piles	Maximum Hammer Energy (kJ)	Number of Vessels	Maximum Number of Piles Installed per Day[1]	Maximum Piling Days (24 Hours)
Wind Turbine (concurrent)	25 MW monopile	40	40	6,250	2	2	20
OSP (concurrent)	Jacket	2	36	4,500	2	4	9
	Total	42	76	-	-	-	**29**

[1] Based on concurrent piling at two vessels.

2.2.9 It is estimated that piling activity at the Proposed Development will take place within a three-year timeframe (2031 to 2033) (Volume 1, Chapter 3: Project Description). Piling of Wind Turbine foundations is currently estimated to take place between Q4 2031 and Q1 2033 (inclusive), while piling of OSP foundations is estimated at within Q4 2033. Based on this, a piling schedule was created to be used within the iPCoD model for both the maximum temporal scenario and maximum spatial scenario.

2.3 Key Species

2.3.1 Marine mammal species considered were those that were determined to be important marine mammal features within both the Local Marine Mammal Study Area and the Regional Marine Mammal Study Area (Volume 2, Chapter 10: Marine Mammals), following a review of the Proposed Development's Digital Aerial Survey (DAS) data, and available published data sets (see Volume 3, Technical Appendix 10.2: Marine Mammal Digital Aerial Survey Report), and for which a population model in iPCoD was available.

2.3.2 The baseline characterisation for the Proposed Development identified the following marine mammal species within the Local and Regional Marine Mammal Study Areas (Volume 3, Technical Appendix 10.1: Marine Mammal Technical Report):

- harbour porpoise;
- bottlenose dolphin;
- Risso's dolphin *Grampus griseus*;
- white-beaked dolphin *Lagenorhynchus albirostris*;
- minke whale;
- humpback whale *Megaptera novaeangliae*;
- fin whale *Balaenoptera physalus*;
- grey seal; and
- harbour seal.

2.3.3 Currently, no parameters are available to construct a suitable population model for white-beaked dolphin, Risso's dolphin, humpback whale and fin whale in the iPCoD framework, so population modelling for these species has not been undertaken.

2.3.4 Therefore, the species included for iPCoD modelling were:

- harbour porpoise;
- bottlenose dolphin;
- minke whale;
- grey seal; and
- harbour seal.

2.3.5 The piling parameters defined in the MDS (see Section 2.2) were subsequently incorporated into an acoustic sound propagation model to predict the potential range of effect (injury and disturbance) for each key species.

2.3.6 The assessment presented a range of densities for each key species (as listed in Paragraph 2.3.2), however, for the purpose of undertaking the population modelling the most precautionary densities and relevant reference populations were taken forward. The total number of animals potentially disturbed for each species was quantified by applying the highest density estimate to the dose-response curve derived by Graham *et al.* (2019). This approach considers a proportional response within consecutive mapped contours denoting incremental 5 dB decreases in received single strike Sound Exposure Level (SEL_{ss}) predicted using the underwater noise model. To this end a 100% disturbance was predicted in all species at received levels >180 dB SEL_{ss}. The predicted rate of disturbance then decreases proportionally in response to received level, reducing at greater distances from the piling source. The dose-response relationship based on published empirical evidence and further detail is provided in Volume 2, Chapter 10: Marine Mammals.

2.4 Reference Populations

2.4.1 Key species population estimates based upon Management Units (MUs) were specified in the iPCoD models as the reference populations against which any effects (i.e. number of animals experiencing disturbance) were assessed. Relevant MUs were determined by their coincidence with the location of the Proposed Development. This section details these reference populations.

2.4.2 For harbour porpoise and minke whale, only one MU for each species occurs in the vicinity of the Proposed Development (Inter-Agency Marine Mammal Working Group ((IAMMWG, 2022), and the respective population estimates for these MUs have been used for iPCoD modelling: the North Sea MU for harbour porpoise (Figure 2.1) and the Celtic and Greater North Seas (CGNS) MU for minke whale (Figure 2.3).

2.4.3 For bottlenose dolphin, the Coastal East Scotland MU and the Greater North Sea (GNS) MU (Figure 2.2) were used as the relevant reference population, given that the location of the Proposed Development overlaps with both. Therefore, for bottlenose dolphin the reference population comprises the sum of the population estimates for the Coastal East Scotland MU and GNS MU.

2.4.4 The Proposed Development is located within the East Scotland Seal MU (SMU) (Figure 2.4), and telemetry data suggest connectivity between the East Scotland SMU, the Moray Firth SMU and the North Coast and Orkney SMU. Therefore, the grey seal reference population comprises the sum of the population estimates for these three SMUs (Special Committee on Seals (SCOS, 2022).

2.4.5 For harbour seal, telemetry data suggest connectivity between the East Scotland SMU and the Moray Firth SMU. Therefore, the harbour seal reference population comprises the sum of the population estimates for these two SMUs (SCOS, 2022).

2.4.6 The population estimates used to parameterise iPCoD models were taken from IAMMWG (2022) for cetacean species and from telemetry maps and haul-out counts relevant to the Proposed Development (Marwood and Stevens, 2024) and SCOS (2022) for the pinniped species. The population estimates are summarised in Table 2.3.

Table 2.3: Reference Populations Used in the iPCoD Modelling

Species	Management Unit/ Seal Management Unit	Population Estimate UK portion (Number of Animals)	Population Estimate in Whole MU (Number of Animals)	Reference
Harbour porpoise	North Sea MU	159,632	346,601	IAMMWG (2022)
Bottlenose dolphin	Coastal East Scotland MU	226	Located entirely in UK waters	Cheney *et al.* (2024)
	GNS MU	1,885	2,022	IAMMWG (2022)
	Coastal East Scotland MU and GNS MU	226 + 1,885 = 2,111	226 + 2,022 = 2,248	Cheney *et al.* (2024); IAMMWG (2022)
Minke whale	CGNS MU	10,288	20,118	IAMMWG (2022)
Grey seal	North Coast and Orkney SMU, Moray Firth SMU, and East Scotland SMU	34,191 + 7,380 + 10,784 = 52,355	SMUs in UK waters only	SCOS (2022); Marwood and Stevens (2024)
Harbour seal	Moray Firth and East Scotland SMU	958 + 364 = 1,322		

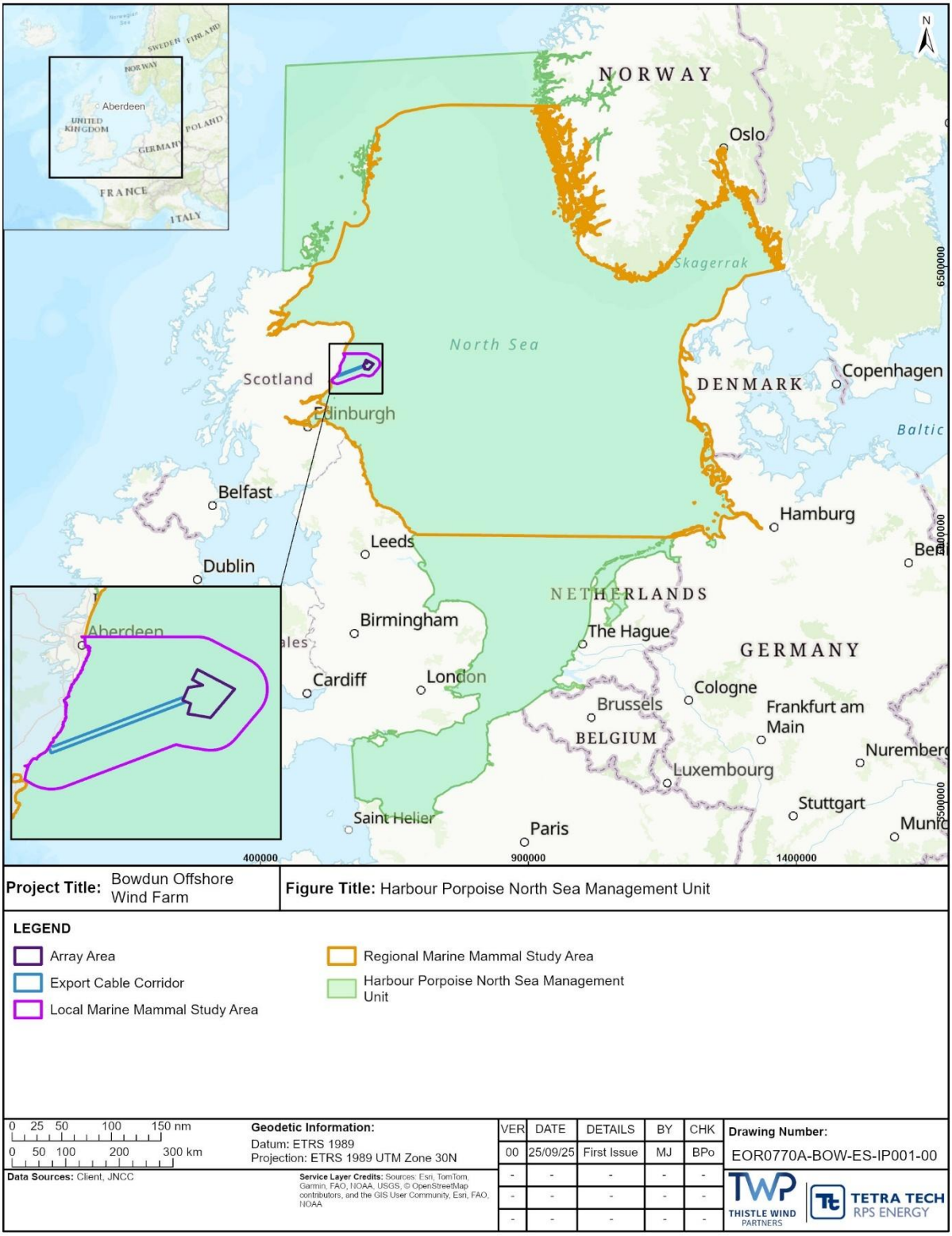

Figure 2.1: Harbour Porpoise North Sea Management Unit (IAMMWG, 2022)

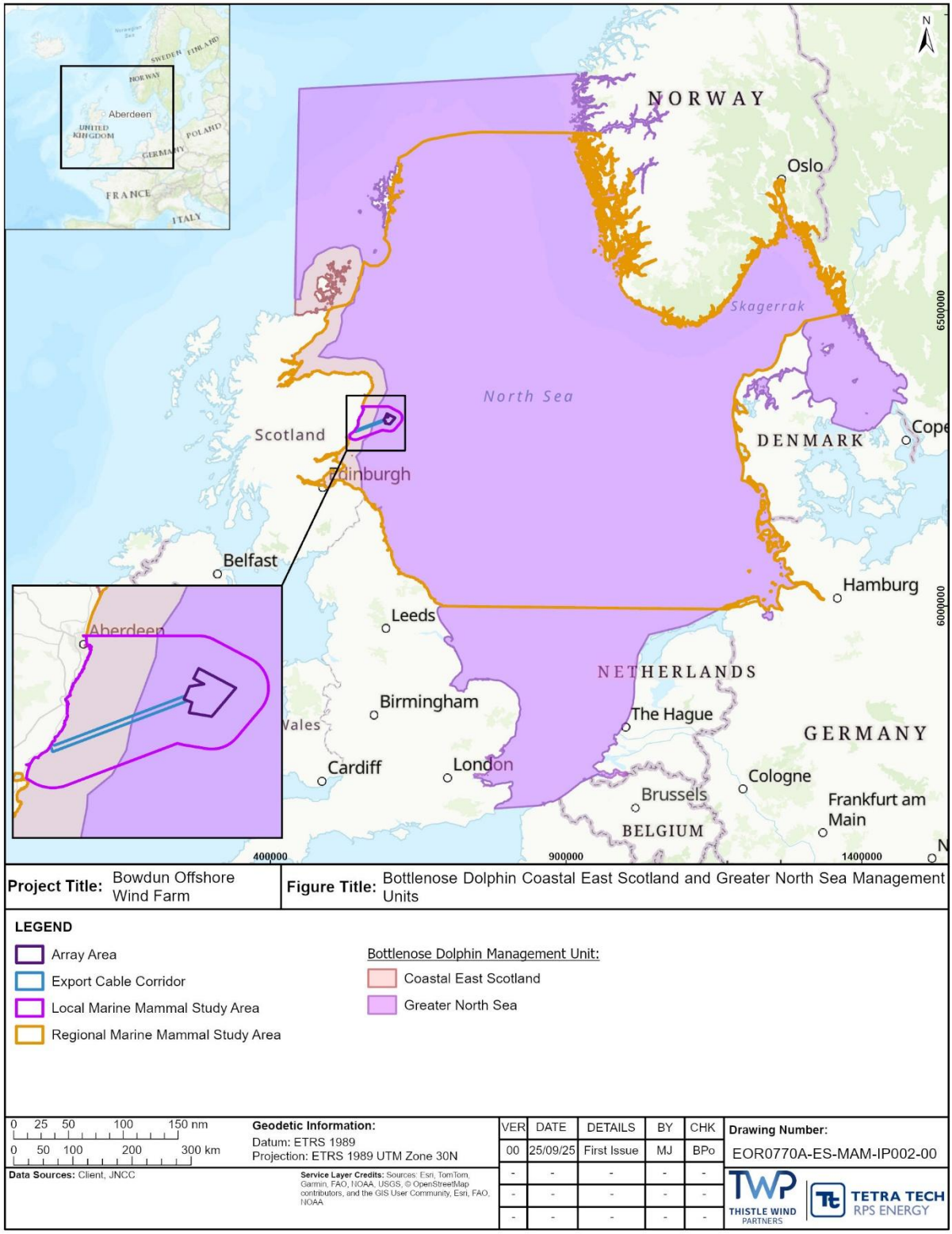

Figure 2.2: Bottlenose Dolphin Coastal East Scotland and Greater North Sea Management Unit (IAMMWG, 2022)

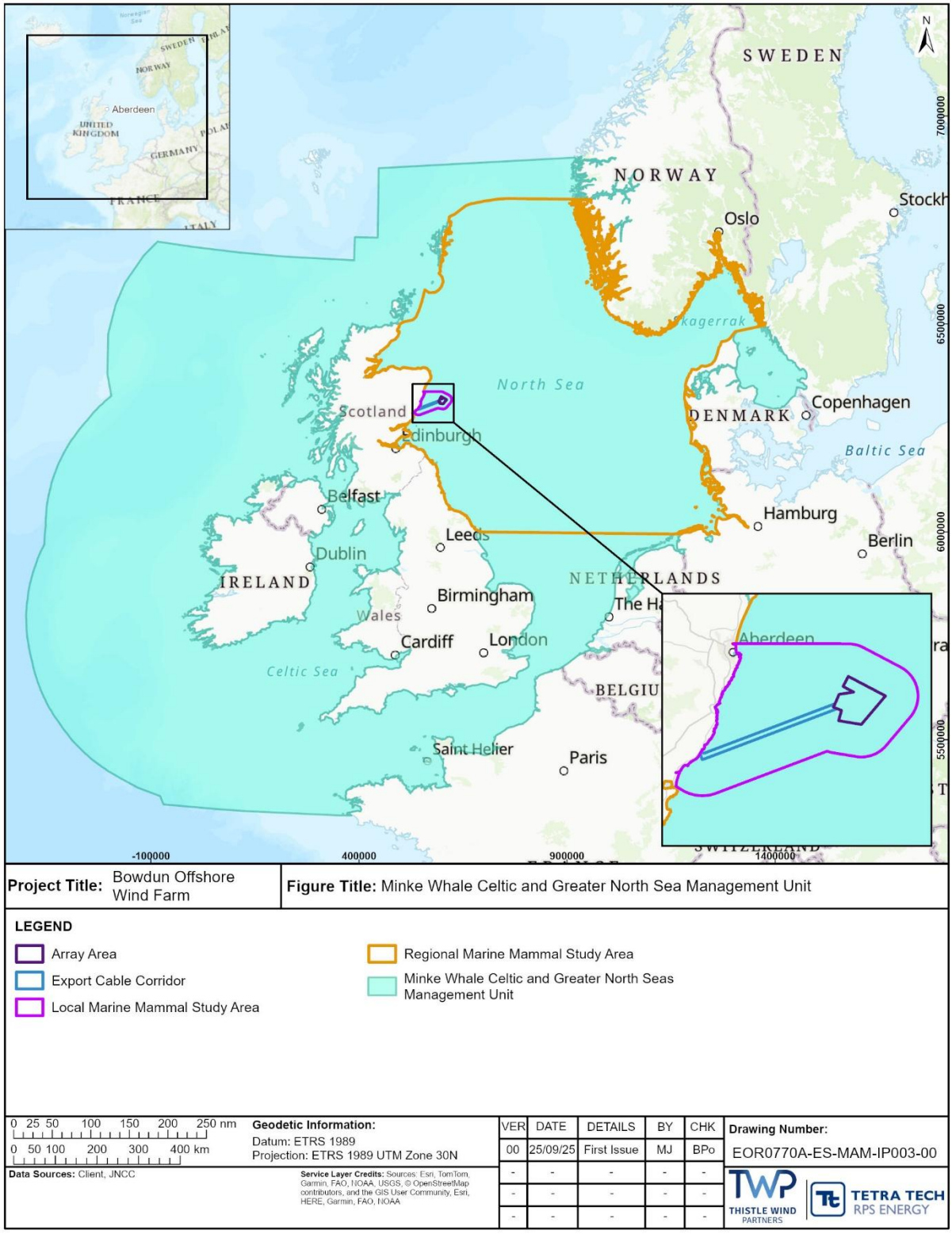

Figure 2.3: Minke Whale CGNS MU (IAMMWG, 2022)

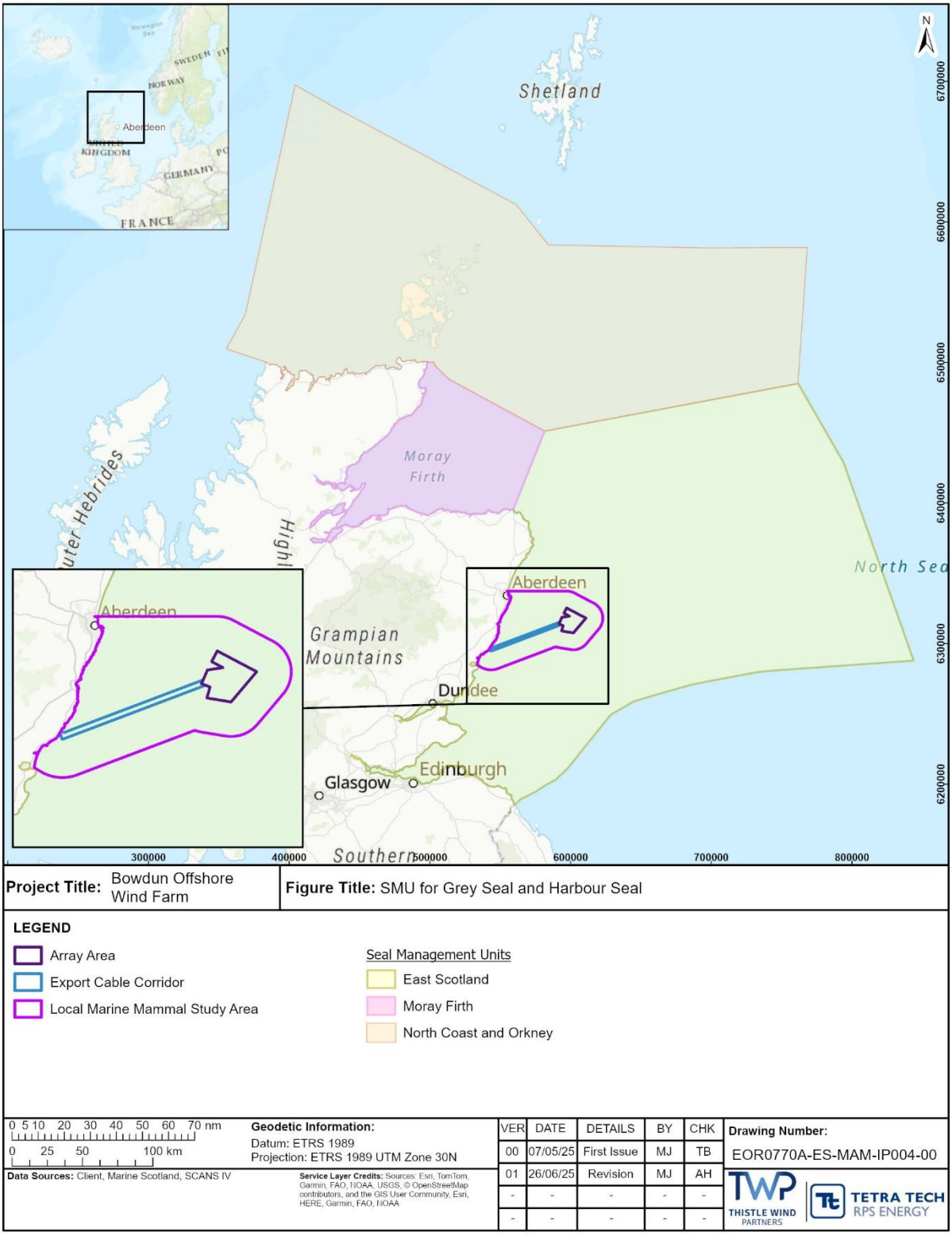

Figure 2.4: SMUs for Grey Seal and Harbour Seal (SCOS, 2022)

2.5 Demographic Parameters

2.5.1 Demographic parameters for the key species that have been used in the population models are presented in Table 2.4. These were selected from Sinclair *et al.* (2020). For bottlenose dolphin, different vital rates are available for the Coastal East Scotland MU and the GNS MU. Similarly, the vital rates for harbour seals differ between the SMUs in Sinclair *et al.* (2020), however, those associated with the Moray Firth SMU and East Scotland SMU are the same. Grey seal vital rates are the same for all SMUs in Sinclair *et al.* (2020).

Table 2.4: Marine Mammal Vital Rates Used to Parameterise iPCoD Models, from Sinclair *et al.* (2020)

Species	Calf/Pup Survival	Juvenile Survival	Adult Survival	Fertility	Age of Independence (Years)	Age of First Birth (Years)
Harbour porpoise	0.8455	0.85	0.925	0.34	1	5
Bottlenose dolphin (Coastal East Scotland MU)	0.925	0.962	0.98	0.24	3	9
Bottlenose dolphin (all other MUs)	0.80	0.94	0.94	0.25	2	9
Minke whale	0.70	0.77	0.96	0.91	1	9
Grey seal (all SMUs)	0.222	0.94	0.94	0.84	1	6
Harbour seal (both the Moray Firth SMU and East Scotland SMU)	0.40	0.78	0.92	0.85	1	4

2.6 Residual Days Disturbance

2.6.1 Empirical evidence from the constructed Beatrice and Horns Rev 2 offshore wind farms (Brandt *et al.*, 2011; Graham *et al.*, 2019) suggests that the detection of animals returns to baseline levels in the hours following disturbance from piling and therefore, for the most part, it can be assumed that the disturbance occurs only on the day (24 hours) that piling takes place.

2.6.2 Due to the potential duration of piling occurring at the Proposed Development in a 24-hour period (see Section 2.2), 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.

2.7 Number of Animals Experiencing Injury and Disturbance

2.7.1 The number of animals predicted to experience disturbance or auditory injury as a result of piling at the Proposed Development was based on the density values provided as part of the individual species baseline assessments in Volume 3, Technical Appendix 10.1: Marine Mammal Technical Report.

2.7.2 For the assessment of auditory injury an average density value was applied to the potential area of effect; calculated from the range out to which the injury threshold was modelled to be exceeded for each marine mammal hearing group.

Table 2.5: Summary of Species Densities Used in Calculating Numbers of Animals at Risk of Disturbance

Species	Density (Animals per km^2)	Source
Harbour porpoise	0.635	Design-based (absolute) density estimates from DAS
Bottlenose dolphin	0.007	Lacey *et al.* (2022)
Minke whale	0.030	Gilles *et al.* (2025)
Grey seal	0.560	Carter *et al.* (2022)
Harbour seal	0.009	Carter *et al.* (2025)

2.7.3 To estimate the number of animals potentially disturbed during piling at the Proposed Development, the sound contours were mapped, and a dose-response approach applied to calculate the number of animals within each 5 dB isopleth using the density values as described in Table 2.5. For both seal species rather than using the single density estimate, the quantitative assessment was undertaken by overlaying the unweighted SEL_{ss} contours on at-sea density maps (Figure 2.5 and Figure 2.6) produced by Carter *et al.* (2022) and Carter *et al.* (2025). The number of animals in each 5x5 km grid cell was summed for each isopleth and corrected using the proportional response as per Whyte *et al.* (2020).

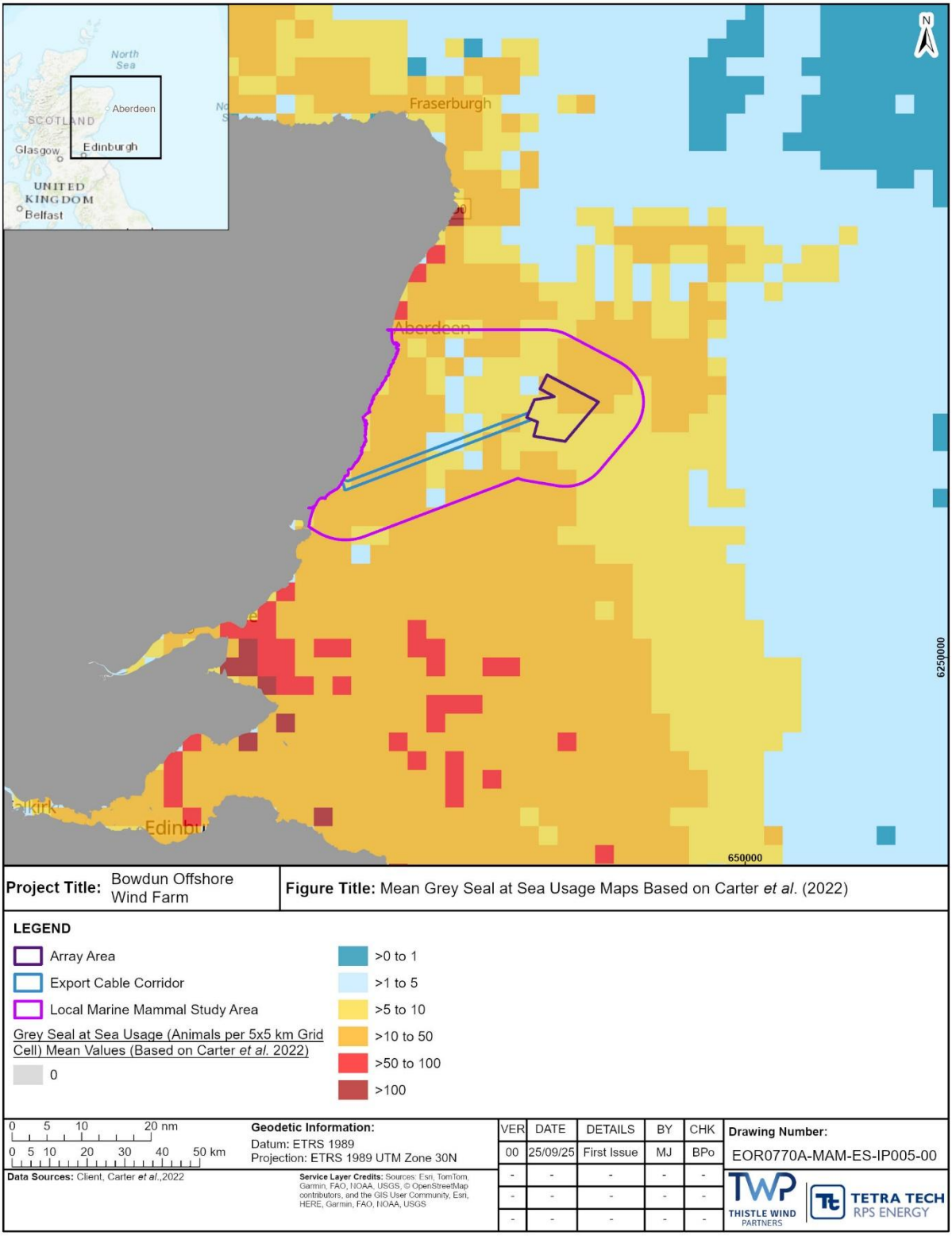

Figure 2.5: Mean Grey seal at Sea Usage Maps based on Carter *et al.* (2022)

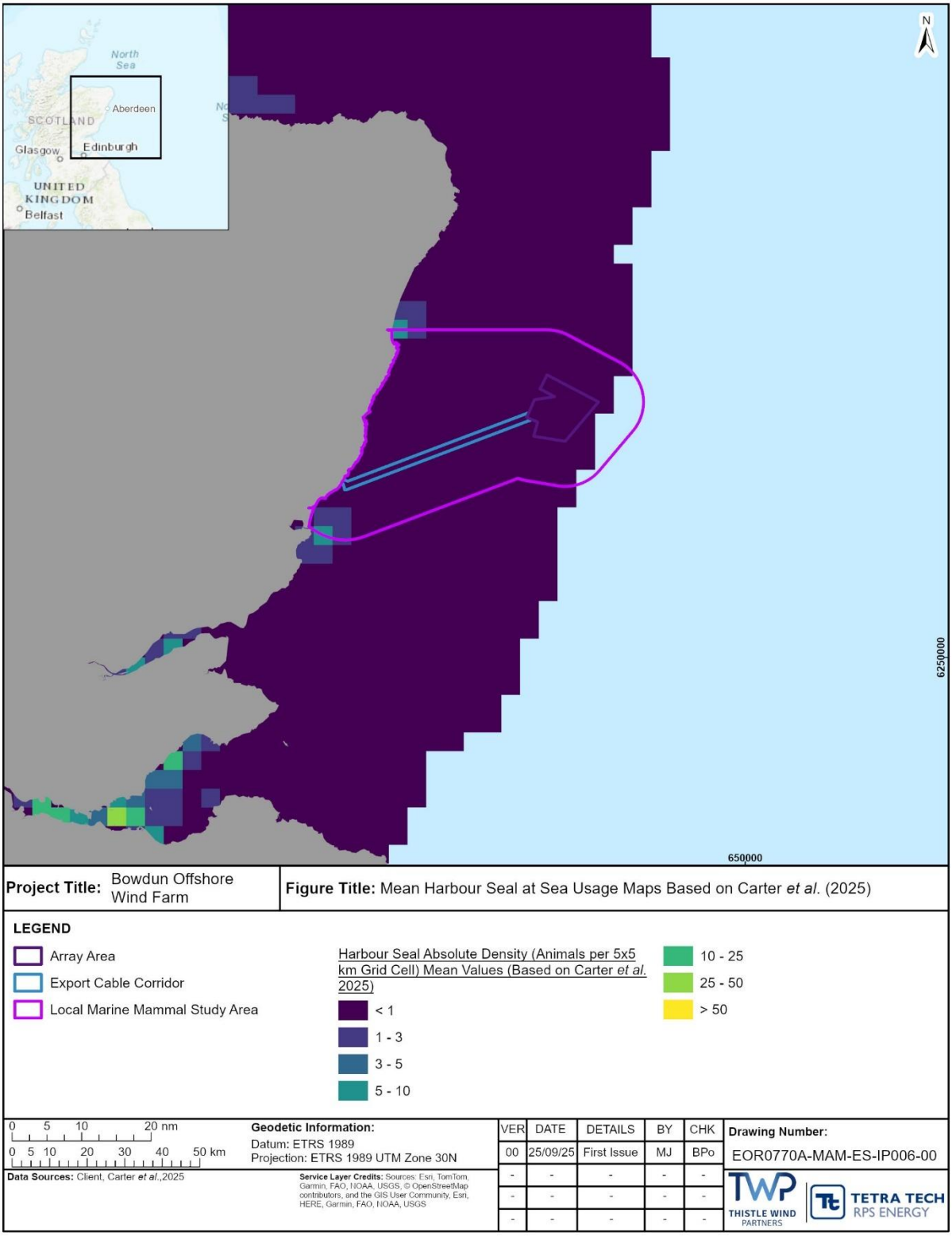

Figure 2.6: Mean Harbour seal at Sea Usage Maps based on Carter *et al.* (2025)

2.7.4 Maximum potential numbers of animals disturbed for the maximum temporal scenario are presented in Table 2.6 and maximum numbers of animals disturbed for the maximum spatial scenario are presented in Table 2.7.

Table 2.6: Maximum Temporal Scenario: Estimated Number of Animals Predicted to be Disturbed at Any One Time During Piling (Number of Animals Rounded Up to Whole Numbers)

Species	Activity	Potential Number of Animals Disturbed
Harbour porpoise	Wind Turbine foundation: single piling of the 15 MW four-legged jacket option	2,829
	OSP jacket foundation: single piling	2,829
Bottlenose dolphin	Wind Turbine foundation: single piling of the 15 MW four-legged jacket option	32
	OSP jacket foundation: single piling	32
Minke whale	Wind Turbine foundation: single piling of the 15 MW four-legged jacket option	134
	OSP jacket foundation: single piling	134
Grey seal	Wind Turbine foundation: single piling of the 15 MW four-legged jacket option	904
	OSP jacket foundation: single piling	904
Harbour seal	Wind Turbine foundation: single piling of the 15 MW four-legged jacket option	7
	OSP jacket foundation: single piling	7

Table 2.7: Maximum Spatial Scenario: Estimated Number of Animals Predicted to be Disturbed at Any One Time During Piling (Number of Animals Rounded Up to Whole Numbers)

Species	Activity	Potential Number of Animals Disturbed
Harbour porpoise	Wind Turbine foundation: concurrent piling of the 25 MW monopile option	5,215
	OSP jacket foundation: concurrent piling	4,439
Bottlenose dolphin	Wind Turbine foundation: concurrent piling of the 25 MW monopile option	58
	OSP jacket foundation: concurrent piling	49
Minke whale	Wind Turbine foundation: concurrent piling of the 25 MW monopile option	247
	OSP jacket foundation: concurrent piling	210
Grey seal	Wind Turbine foundation: concurrent piling of the 25 MW monopile option	1,772
	OSP jacket foundation: concurrent piling	1,467
Harbour seal	Wind Turbine foundation: concurrent piling of the 25 MW monopile option	9
	OSP jacket foundation: concurrent piling	8

2.8 Indicative Piling Schedule

2.8.1 The piling schedule used in the iPCoD modelling was developed from Volume 1, Chapter 3: Project Description. This provides an estimate of the maximum number of days of piling required for installation of the Wind Turbine and OSP foundations, within a defined piling window.

2.8.2 All piling at the Proposed Development is currently planned to take place over three calendar years, from 2031 to the end of 2033. Within these three years, piling for the Proposed Development is expected to occur within an 18-month piling period for Wind Turbines (Q4 2031 to Q1 2033, inclusive) and within a three-month piling period for OSPs (Q4 2033).

2.8.3 For the purposes of developing the piling schedule for iPCoD (a required input for all models) indicative programmes were specifically developed for the maximum temporal scenario, maximum spatial scenario, and cumulative scenarios, tailored to each species and based on a realistic installation approach, with piling spread across the years. It is important to note, however, that while indicative piling schedules are intended to provide a realistic basis on which iPCoD models are run, these schedules are not intended to reflect the actual final piling operations for an individual project. Fine-scale variability such as seabed composition, environmental factors (such as weather conditions) and transit time between piling locations would be too complex to predict at this stage in the project development process, and the iPCoD framework does not facilitate such nuance.

2.8.4 For the maximum temporal scenario, piling was assumed to occur over the greatest time frame. The 304 total piling days for Wind Turbine and OSP foundations (see Table 2.1) have therefore been spread evenly across the piling periods for each (as described in Paragraph 2.8.2). For the Wind Turbines, an interval of two days between piling events was calculated across the 18-month piling period, and an interval of two to three days was calculated between piling events for OSPs across the three-month piling period.

2.8.5 For the maximum spatial scenario, piling was assumed to generate greater levels of underwater noise, but to occur over a shorter time frame than for the maximum temporal scenario due to concurrent piling events. The 29 total piling days for Wind Turbine and OSP foundations (see Table 2.2) have therefore been spread evenly across the piling periods for each (as described in Paragraph 2.8.2). For the Wind Turbines, an interval of 27.35 days between piling events was calculated across the 18-month piling period, and an interval of 10.22 days was calculated between piling events for OSPs across the three-month piling period.

2.8.6 A summary of the piling schedules for the maximum temporal scenario and maximum spatial scenario used in the iPCoD models is presented in Table 2.8, and the time points selected from the iPCoD model outputs are summarised in Table 2.9.

Table 2.8: Indicative Piling Programme for Each Piling Scenario for the Proposed Development Within the Three-Year Piling Phase

<table>
<tr><th rowspan="3">Year</th><th rowspan="3">Quarter</th><th colspan="4">Number of Piling Days</th></tr>
<tr><th colspan="2">Maximum Temporal Scenario</th><th colspan="2">Maximum Spatial Scenario</th></tr>
<tr><th>Wind Turbine (Single Piling)</th><th>OSP (Single Piling)</th><th>Wind Turbine (Concurrent Piling)</th><th>OSP (Concurrent Piling)</th></tr>
<tr><td rowspan="3">2031</td><td>Q1</td><td colspan="2" rowspan="3">No piling</td><td colspan="2" rowspan="3">No piling</td></tr>
<tr><td>Q2</td></tr>
<tr><td>Q3</td></tr>
<tr><td>Q4</td><td rowspan="5">268</td><td rowspan="6">No piling</td><td rowspan="5">20</td><td rowspan="6">No piling</td></tr>
<tr><td rowspan="4">2032</td><td>Q1</td></tr>
<tr><td>Q2</td></tr>
<tr><td>Q3</td></tr>
<tr><td>Q4</td></tr>
<tr><td rowspan="4">2033</td><td>Q1</td></tr>
<tr><td>Q2</td><td>No piling</td><td>No piling</td></tr>
<tr><td>Q3</td><td rowspan="2"></td><td rowspan="2"></td></tr>
<tr><td>Q4</td><td>36</td><td>9</td></tr>
</table>

Table 2.9: Selected Time Points from iPCoD Simulation Output and Corresponding Events

Time Point	Indicative Year	Corresponding Event
2	2031	1st year of piling
3	2032	2nd year of piling
4	2033	End of 3rd year of piling
7	2038	Six years after start of piling
11	2042	Ten years after start of piling
16	2047	15 years after start of piling
26	2056	25 years after start of piling: maximum extent of model predictions

2.9 Cumulative Projects

2.9.1 Cumulative projects for marine mammal species were considered across the Regional Marine Mammal Study Area. Screening in of cumulative projects for iPCoD included those projects for which their piling phase is expected to temporally overlap directly with piling for the Proposed Development (2031 to 2033, inclusive). In addition, projects which were not piling in 2031 to 2033, but where continuous years of piling occurred in one year before or after was also included (i.e. 2030 to 2034). In order to capture multiple years of continuous piling at other projects, the cumulative model run began in 2028 to incorporate the beginning of piling at Aspen OWF and Caledonia North and South OWF.

2.9.2 Projects for which quantitative information was not available were not included in models as any estimate would be unlikely to reflect realised piling programmes.

Piling Schedules

2.9.3 To capture the offshore construction phase for the other cumulative projects identified, the cumulative iPCoD models included additional years before piling at the Proposed Development commenced. A summary of cumulative projects and an indicative overview of offshore piling schedules (by year) is provided in Table 2.10. A more detailed Gantt chart is presented in Figure 2.7, and is useful in the interpretation of model results in Section 3.

Table 2.10: Indicative Overview of Offshore Piling Programmes and Schedules for Cumulative iPCoD Modelling. Red Line Denotes One Year Before and After the Piling Period for the Proposed Development

Project	Operation	Number of piles	Total Piling Days	Indicative Year										
				2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Proposed Development	Wind Turbine	268	268				■	■	■					
	OSP	36	36						■					
Aspen	Wind Turbine	324	162	■	■	■								
	OSP	24	12		■	■								
Berwick Bank	Wind Turbine	1,432	95				■							
	OSP	192	28				■							
Caledonia	Wind Turbine	404	105	■	■	■	■	■						
	Anchors	702	410			■	■	■						
Cenos	Wind Turbine	855	285				■	■	■					
	OSP	12	8				■							
Dogger Bank South West	Wind Turbines and platforms	104	104			■	■	■						
Muir Mhòr	Wind Turbine	603	151		■	■	■							
	Offshore Electrical Platform (OEP)	12	24		■	■	■							
Ossian	Wind Turbine	1,590	530				■	■	■	■	■	■	■	
	OSP	216	72				■	■	■	■	■	■	■	■

Proposed Development

2.9.4 The Proposed Development piling scenario carried forward to the cumulative assessment was the maximum temporal scenario, as this represented the largest potential effect from piling from the model simulations for the Proposed Development alone. Although the number of animals potentially affected was greater for the maximum spatial scenario (Table 2.6 and Table 2.7), the results of the iPCoD model based upon the maximum temporal scenario predicted a greater effect on the respective impacted populations due to extended temporal impact.

Aspen OWF

2.9.5 Piling for the Wind Turbine and OSP foundations at Aspen OWF is expected to occur over a total of 162 days and 12 days, respectively. The Wind Turbine foundations will be piled from April to September (inclusive) in 2028, 2029, and 2030, while the OSP foundations will be piled from April to September (inclusive) in 2029 and 2030. The iPCoD modelling undertaken for Aspen OWF included an evenly spaced piling schedule for the three years of Wind Turbine foundation piling, while for OSPs, two thirds were modelled as installed in 2029 and one third in 2030 (Cerulean Winds, 2025). Therefore, the cumulative piling schedule created for the cumulative modelling for the Proposed Development included piling days spread across these time periods (see Figure 2.7).

Berwick Bank OWF

2.9.6 Berwick Bank OWF's piling schedule is in two phases (2026 to 2027 and 2031). Since the duration of predictions from iPCoD modelling is limited to 25 years, to maintain focus on predictions from the Array only the second phase was included in the cumulative iPCoD models (2031). For Berwick Bank OWF, the second piling phase comprises one third of the total piling programme (one year out of a total of three piling years across both phases), so this has been modelled as one third of the total piling days (SSE Renewables, 2022).

2.9.7 The maximum temporal scenario for piling at Berwick Bank OWF is expected to take place for 95 days between April and December 2031 for Wind Turbine foundations and for 28 days between January to March 2031 for OSPs, and therefore piling days were spread evenly across these time periods for the Cumulative Effects Assessment (CEA) model (see Figure 2.7).

Caledonia OWF

2.9.8 The maximum temporal scenario for piling at Caledonia OWF is expected to take place for 65 days between October 2028 and February 2030 for fixed jacket foundations, 40 days between March 2030 to February 2032 for bottom-mounted jackets and for 17 days between March and December 2031 for OSPs, and therefore piling days were spread evenly across these time periods for the CEA model (see Figure 2.7).

Cenos OWF

2.9.9 The maximum temporal scenario for piling at Cenos OWF is expected to take place for 285 days between April 2031 to August 2033 for floating Wind Turbine foundations and for eight days in March 2031 for OSPs, and therefore piling days were spread evenly across these time periods for the CEA model (see Figure 2.7).

Dogger Bank South West OWF

2.9.10 Piling of monopiles at Dogger Bank South West OWF is expected to take place for a total of 104 days in the summer months between Q2 2030 to Q3 2032 (inclusive), and therefore piling days were spread evenly across these time periods for the CEA model (see Figure 2.7).

Muir Mhòr OWF

2.9.11 The maximum temporal scenario for piling at Muir Mhòr OWF is expected to take place for 151 days for fixed jacket foundations and for 24 days for OEPs between March 2029 to October 2031, and therefore piling days were spread evenly across these time periods for the CEA model (see Figure 2.7).

Ossian OWF

2.9.12 The maximum temporal scenario for piling at Ossian OWF (taken from the Ossian iPCoD modelling report (Ossian OWFL, 2024)) is expected to take place for 530 days between Q2 to Q4 2031 to 2037 for Wind Turbine foundations and for 72 days between Q2 to Q4 2031 to 2038 for OSPs, and therefore piling days were spread across these time periods for the CEA model (see Figure 2.7).

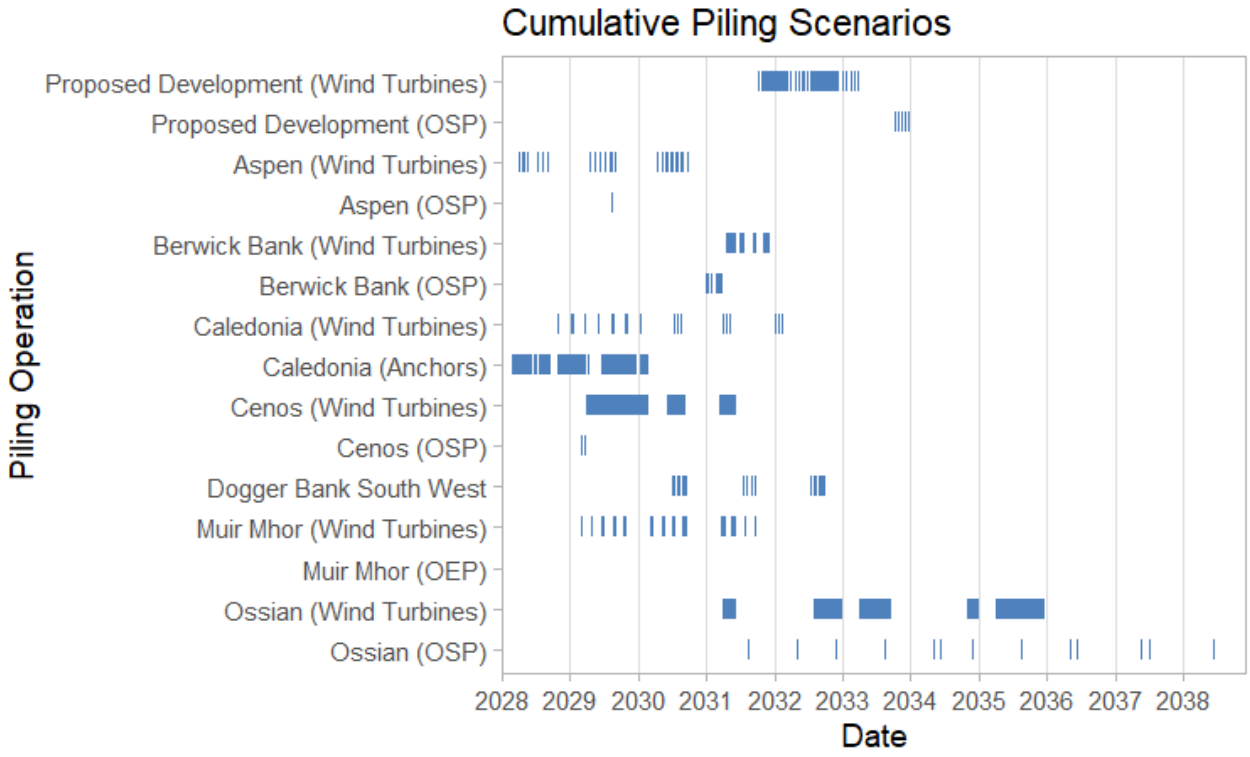

Figure 2.7: Gantt Chart of Detailed Piling Schedules for CEA Projects used in Cumulative iPCoD Modelling

Number of Animals Experiencing Injury and Disturbance

2.9.13 Due to the use of standard mitigation measures (e.g., Marine Mammal Observers, Acoustic Deterrents, etc.,) that are required for all projects (under European Protected Species licensing) there is no potential for significant cumulative impacts from auditory injury due to elevated underwater noise during piling for the cumulative projects presented in Table 2.11. Due to the use of these standard mitigation measures, the iPCoD simulations for these projects have not included any animals with the potential to experience auditory injury.

2.9.14 The iPCoD models were set up as described in Sections 2.4 and 2.5 for reference populations and demographic parameters, respectively, and with the same number of days of residual disturbance and number of animals experiencing disturbance and injury specified in Section 2.7.

2.9.15 Cumulative projects were only included in species' models if they overlap spatially with the species-specific MUs described in Table 2.3 and were included in each specific project's assessment. For harbour porpoise and minke whale this included all of the projects screened into the cumulative model (i.e. Aspen, Berwick Bank, Caledonia, Cenos, Dogger Bank South West, Muir Mhòr, and Ossian OWFs). For bottlenose dolphin this included all projects except Cenos OWF, as this project did not include bottlenose dolphin from either MU in their iPCoD modelling (Cenos Offshore Windfarm Limited, 2024). For grey seal, all of the cumulative projects were included, except for the Dogger Bank South West OWF which did not include the SMUs highlighted in Table 2.3. Finally, for harbour seal, the following projects were included as they had included harbour seal

from the Moray Firth SMU and/or East Scotland SMU in their modelling: Aspen, Berwick Bank, Caledonia, and Muir Mhòr OWFs.

2.9.16 The number of animals affected for each of the key species, and the number of days on which piling occurred was taken from the iPCoD modelling for each of the cumulative projects (Caledonia OWF Limited, 2024; Cenos Offshore Windfarm Limited, 2024; Cerulean Winds, 2025; Muir Mhòr Offshore Wind Farm, 2024; Ossian OWFL, 2024; RWE Renewables UK, 2024; SSE Renewables, 2022). A summary of the number of animals for each species predicted to be affected and number of piling days for each cumulative project is provided in Table 2.11. In cases where less than one animal was predicted to experience disturbance, this was rounded up to one animal for the relevant models.

Table 2.11: Summary of Number of Animals Predicted to Experience Disturbance for Cumulative iPCoD Scenario

Project	Foundation Type	Piling Days	Harbour Porpoise	Bottlenose Dolphin		Minke Whale	Grey Seal	Harbour Seal
				Coastal East Scotland MU	Greater North Sea MU			
Aspen	Wind Turbine	162	10,652	5	40	1,368	348	1
	OSP	12	10,285	4	40	1,321	336	1
Berwick Bank	Wind Turbine	95	2,815	5	MU not included	132	1,450	3
	OSP	28	1,828	4		86	720	1
Caledonia	Jacket foundation (includes 4 OSP)	105	8,201	52	35	502	5,381	144
	Anchors	410	6,648	46	27	415	3,337	45
Cenos	Semi-sub	285	8,863	Bottlenose dolphin not included in Cenos iPCoD modelling		358	127	Species not included in modelling
	OSP	8	9,529			384	137	
Dogger Bank South West	Wind Turbines and platforms	104	5,098	MU not included	1	57	Relevant SMU(s) not included	
Muir Mhòr	Wind Turbine	151	14,630	8	74	735	1,156	
	OEP	24	15,245	7	75	777	1,176	1
Ossian	Wind Turbine	530	3,857	2	MU not included	169	131	1
	OSP	72	7,310	4		319	344	Species not included in modelling

2.9.17 The model was run for 25 years, corresponding to the time points in Table 2.12. Time points selected in reporting of results in Section 3 from the iPCoD model outputs coincide with key periods in the piling schedule, and with statutory reporting periods of six years for Special Areas of Conservation (SACs) and these time points are summarised in Table 2.12.

Table 2.12: Selected Time Points from iPCoD Simulation Output and Corresponding Events for Cumulative Scenario. Shaded Out Time Points Represent Year with No Corresponding Event

Time Point	Indicative Year	Corresponding Event
1	2028	Piling at Aspen and Caledonia OWFs begins.
2	2029	Piling at Aspen and Caledonia OWFs continues. Piling at Muir Mhòr OWF begins.
3	2030	Piling at Caledonia and Muir Mhòr OWFs continues. Piling at Dogger Bank South West OWF begins. Piling ends at Aspen OWF.
4	2031	**Piling at the Proposed Development begins.** Piling at Ossian and Cenos OWFs begins. Piling at Berwick Bank OWF starts and ends. Piling continues at Caledonia and Dogger Bank South West OWFs. Piling ends at Muir Mhòr OWF.
5	2032	**2nd year of piling at the Proposed Development.** Piling continues at Ossian and Cenos OWFs. Piling ends at Caledonia and Dogger Bank South West OWFs.
6	2033	**3rd and final year of piling at the Proposed Development.** Piling continues at Ossian OWF. Piling ends at Cenos OWF.
7	2034	1 year following cessation of piling at the Proposed Development. Piling continues at Ossian OWF.
8	2035	2 years following cessation of piling at the Proposed Development. Piling continues at Ossian OWF.
9	2036	3 years following cessation of piling at the Proposed Development. Piling continues at Ossian OWF.
10	2037	4 years following cessation of piling at the Proposed Development. Piling continues at Ossian OWF (OSPs only).
11	2038	5 years following cessation of piling at the Proposed Development. Piling ends at Ossian OWF (OSPs only).
12	2039	6 years following cessation of piling at the Proposed Development. Piling for all CEA projects has ended.
13	2040	
14	2041	

Time Point	Indicative Year	Corresponding Event
15	2042	
16	2043	10 years following cessation of piling at the Proposed Development.
17	2044	
18	2045	
19	2046	
20	2047	
21	2048	15 years following cessation of piling at the Proposed Development.
22	2049	
23	2050	
24	2051	
25	2052	
26	2053	20 years following cessation of piling at the Proposed Development.

2.10 Summary of iPCoD Scenarios

2.10.1 A total of 19 iPCoD modelling scenarios were run for the Proposed Development alone and the cumulative assessment, and these are summarised in Table 2.13 for each of the five key species for which iPCoD modelling has been possible. As illustrated in Table 2.4, two different sets of vital rates were available for bottlenose dolphin applicable to the relevant MU populations. Therefore, the bottlenose dolphin models were run twice, using the different vital rates, against the combined population of the Coastal East Scotland MU and GNS MU (i.e. 2,111 animals; Table 2.13).

Table 2.13: Summary of iPCoD Scenarios Modelled for Key Species Associated with the Proposed Development and Relevant Cumulative Projects

Scenario		Population Unit	Population Estimate (Number of Animals)
Harbour porpoise			
HP01	Maximum temporal scenario	North Sea MU	159,632
HP02	Maximum spatial scenario		
HPC1	Cumulative scenario, incorporating: the Proposed Development, Aspen, Berwick Bank, Caledonia, Cenos, Dogger Bank South West, Muir Mhòr, and Ossian OWFs		

Scenario		Population Unit	Population Estimate (Number of Animals)
HPC2	Cumulative scenario excluding the Proposed Development, incorporating: Aspen, Berwick Bank, Caledonia, Cenos, Dogger Bank South West, Muir Mhòr, and Ossian OWFs		
Bottlenose dolphin			
BND01	Maximum temporal scenario (using the vital rates for the Coastal East Scotland MU)	Coastal East Scotland MU and GNS MU combined	2,111
BND02	Maximum spatial scenario (using the vital rates for the Coastal East Scotland MU)		
BNDC1	Cumulative scenario, incorporating: Proposed Development, Aspen, Berwick Bank, Caledonia, Dogger Bank South West, Muir Mhòr, and Ossian OWFs (using the vital rates for the Coastal East Scotland MU)		
BND03	Maximum temporal scenario (using the vital rates for all other MUs)		
BND04	Maximum spatial scenario (using the vital rates for all other MUs)		
BNDC2	Cumulative scenario, incorporating: Proposed Development, Aspen, Berwick Bank, Caledonia, Dogger Bank South West, Muir Mhòr, and Ossian OWFs (using the vital rates for all other MUs)		
Minke whale			
MW01	Maximum temporal scenario	CGNS MU	10,288
MW02	Maximum spatial scenario		
MWC1	Cumulative scenario, incorporating: Proposed Development, Aspen, Berwick Bank, Caledonia, Cenos, Dogger Bank South West, Muir Mhòr, and Ossian OWFs		
Grey seal			
GS01	Maximum temporal scenario	North Coast and Orkney SMU, Moray Firth SMU, and East Scotland SMU	52,355
GS02	Maximum spatial scenario		
GSC1	Cumulative scenario, incorporating: Proposed Development, Aspen, Berwick Bank, Caledonia, Cenos, Muir Mhòr, and Ossian OWFs		
Harbour seal			
HS01	Maximum temporal scenario	Moray Firth SMU and	1,322
HS02	Maximum spatial scenario		

Scenario		Population Unit	Population Estimate (Number of Animals)
HSC1	Cumulative scenario, incorporating: Proposed Development, Aspen, Berwick Bank, Caledonia, and Muir Mhòr OWFs	East Scotland SMU	

2.11 Model Outputs

2.11.1 The outputs of the iPCoD models are focussed on describing the potential impact on a given marine mammal population under the relevant development scenario, relative to the population in the absence of the development. An estimate is provided for every time step in the scenario (here given as 25 years after commencement of piling), for each simulation (n = 1,000) and is presented in Figure 3.1 to Figure 3.19. The ratio of the simulated impacted population to the un-impacted population sizes can then be expressed as a ratio, termed the 'counterfactual' of population size. A counterfactual of one would therefore correspond to a prediction of no difference in size between the impacted and un-impacted populations. Counterfactuals of <1 would correspond to the impacted population being smaller than the un-impacted population.

2.11.2 The mean estimate (plus 95% confidence interval) of impacted and un-impacted population sizes across all simulations, and the corresponding counterfactuals, are reported for each species, and each scenario (Table 3.1 to Table 3.19). The median counterfactual is also presented since this measure can be less sensitive to outliers. However, it is important to note that the median counterfactual may not always be representative of overall projections, and should be interpreted with caution, since this is calculated simply as the central value in the ordered set of counterfactuals from all simulations.

3 Results

3.1 Harbour Porpoise

Scenario HP01: Maximum Temporal Scenario

3.1.1 Results for the maximum temporal scenario indicate a slight difference in the growth trajectory of harbour porpoise between the impacted and un-impacted population (Figure 3.1). Throughout the model run, the maximum difference in the mean size of the impacted and un-impacted populations was 731 individuals (approximately 0.46% of the UK portion of the North Sea MU reference population) at time point 4 (2033) (Table 3.1).

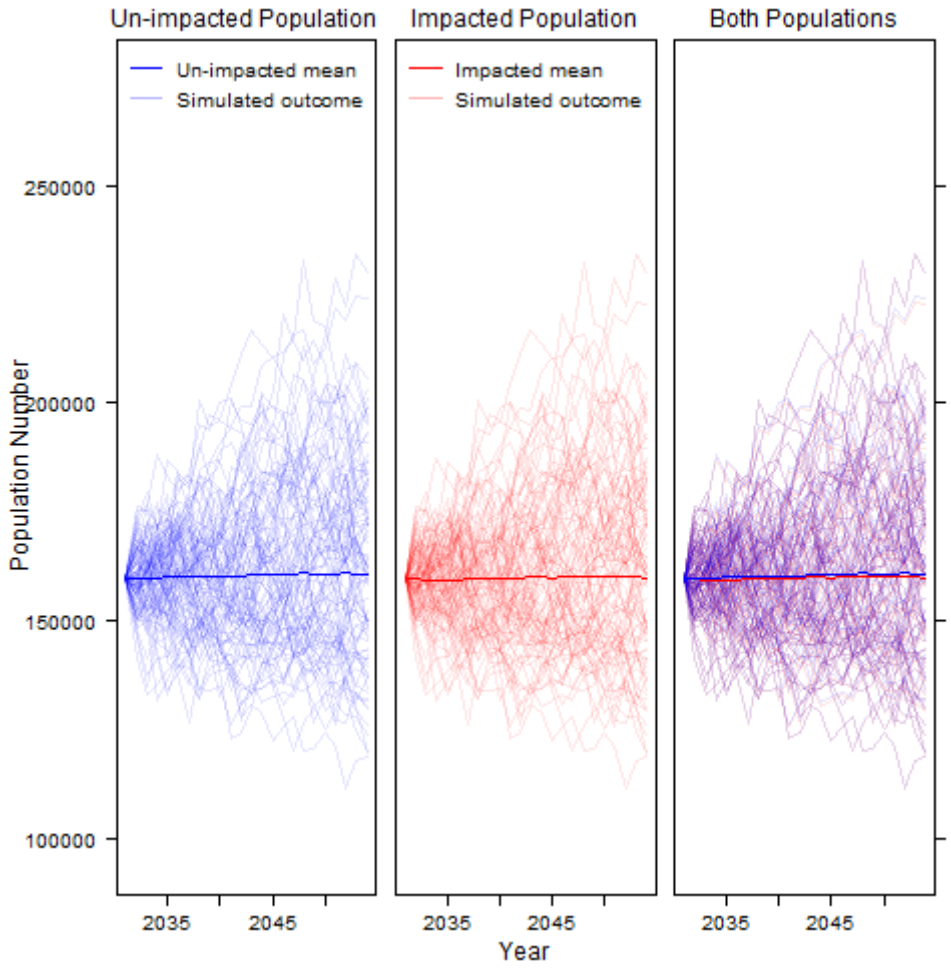

Figure 3.1: Simulated Harbour Porpoise Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Temporal Scenario HP01

3.1.2 At time point 11, which corresponds with ten years after the start of the piling phase (2042), the difference between the impacted and un-impacted populations was 564 animals, approximately 0.35% of the reference population.

Table 3.1: Modelled Estimates for the Un-impacted and Impacted Harbour Porpoise Populations and Counterfactuals of Population Size for the Maximum Temporal Scenario HP01

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	159,531	146,080	171,571	159,531	146,080	171,571	1.0000	1.0000
3	159,697	141,722	176,053	159,369	141,449	175,632	0.9991	0.9979
4	159,844	138,450	179,797	159,113	138,115	178,869	0.9978	0.9954
7	160,017	134,715	186,503	159,482	134,525	185,472	0.9986	0.9967
11	160,245	127,904	196,484	159,681	127,904	195,659	0.9985	0.9965
16	160,844	124,419	202,492	160,282	124,170	201,846	0.9985	0.9965
26	160,384	113,998	211,598	159,823	113,688	211,463	0.9984	0.9965

3.1.3 At time point 26 (2056), which represents the population at the end point of the iPCoD modelling, 25 years after the start of piling (and 22 years after the completion of the piling phase), this difference is 561 animals, corresponding to approximately 0.35% of the reference population (Table 3.1). This suggests that there would not be a long term effect from piling at the Proposed Development upon the harbour porpoise population within the North Sea MU.

3.1.4 The median counterfactual for this scenario fluctuated between 1.0000 and 0.9978 throughout the 26-year simulation, whereas the mean counterfactual was 0.9965 by the end of the simulation. Therefore, given that the differences in impacted and un-impacted populations approach a ratio of one there is not considered to be a potential for a long term effect from this piling scenario upon harbour porpoise within the North Sea MU.

Scenario HP02: Maximum Spatial Scenario

3.1.5 Results for the maximum spatial scenario indicate a slight difference in the growth trajectory of harbour porpoise between the impacted and un-impacted populations (Figure 3.2). Across the model run, the maximum difference in the mean size of the impacted and un-impacted populations was 77 individuals (approximately 0.05% of the UK portion of the North Sea MU reference population) at time point 5 (2034).

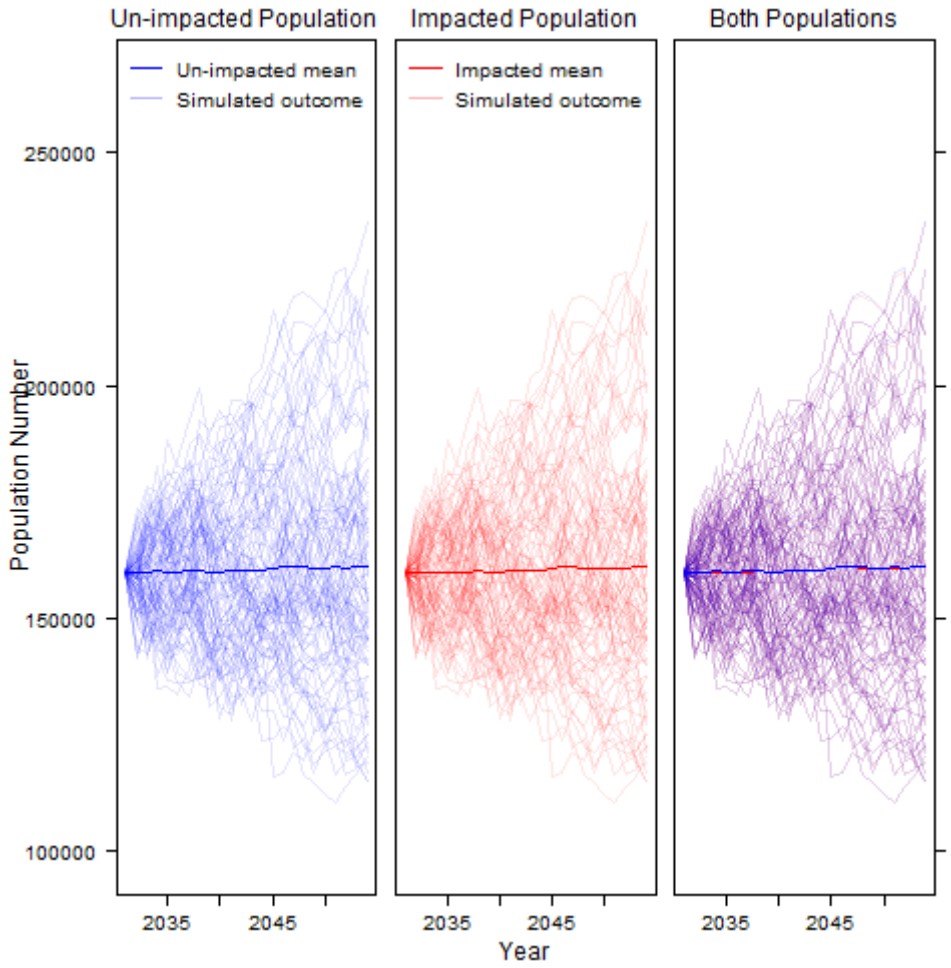

Figure 3.2: Simulated Harbour Porpoise Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Spatial Scenario HP02

3.1.6 At time point 11, which corresponds to ten years after the start of the piling phase (2042), the difference between the impacted and un-impacted populations was 59 animals, approximately 0.04% of the reference population.

Table 3.2: Modelled Estimates for the Un-impacted and Impacted Harbour Porpoise Populations and Counterfactuals of Population Size for the Maximum Spatial Scenario HP02

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
1	159,634	159,634	159,634	159,634	159,634	159,634	1.0000	1.0000
2	159,821	146,763	171,959	159,821	146,763	171,959	1.0000	1.0000
3	159,808	144,614	176,231	159,780	144,604	176,221	1.0000	0.9998
4	160,035	141,621	180,115	159,976	141,620	180,114	1.0000	0.9996
7	160,026	136,068	186,279	159,968	136,058	186,222	1.0000	0.9996
11	160,217	130,378	193,453	160,158	130,349	193,385	1.0000	0.9996
16	161,214	124,398	201,663	161,155	124,398	201,601	1.0000	0.9996
26	161,265	115,759	216,626	161,206	115,750	216,526	1.0000	0.9996

3.1.7 At time point 26 (2056), which represents the population at the end point of the iPCoD modelling, 25 years after the start of piling (and 22 years after the completion of the piling phase), this difference is 59 animals, corresponding to approximately 0.04% of the reference population (Table 3.2). This suggests that there would not be a long term effect from piling at the Proposed Development upon the harbour porpoise population within the North Sea MU.

3.1.8 The median counterfactual for this scenario remained at 1.0000 throughout the model run, while the mean counterfactual was 0.9996 by the end of the simulation. Given that the differences in impacted to un-impacted populations approach a ratio of one there is considered to be no potential for a long term effect from this piling scenario upon the North Sea MU population of harbour porpoise.

Scenario HPC1: Cumulative Scenario with the Proposed Development

3.1.9 For scenario HPC1, the simulated trajectories of harbour porpoise between the impacted and un-impacted populations demonstrate that a reduction in the impacted population at the beginning of the model run until the mid to late 2030s, after which the population stabilised and showed signs of steady recovery (Figure 3.3).

3.1.10 Table 3.3 presents the modelled population estimates for the impacted and un-impacted harbour porpoise populations, alongside the median and mean counterfactuals and years of piling per project (shaded blue). Results are interpreted focusing on key time points in the model (Table 2.12), which gives context to the modelled scenarios.

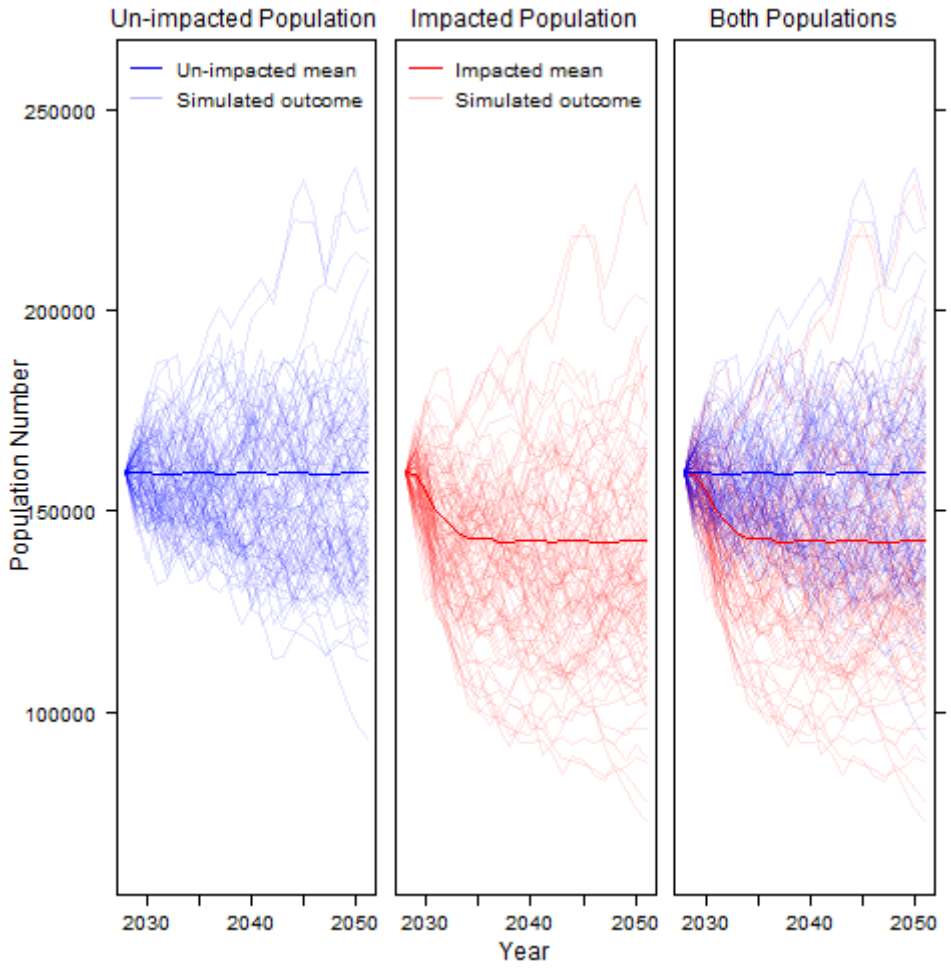

Figure 3.3: Simulated Harbour Porpoise Population Trajectories in an Un-impacted Versus Impacted Population, for Cumulative Scenario HPC1

Table 3.3: Modelled Estimates for the Un-impacted and Impacted Harbour Porpoise Populations and Counterfactuals of Population Size for Cumulative Scenario HPC1. Bold lines indicate piling years at the Proposed Development

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Cenos (Semi-sub)	Cenos (OSP)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
1	159,634	159,634	1.000	1.000	2028			■				■								
2	159,581	159,010	0.998	0.996	2029			■	■			■					■	■		
3	159,667	155,190	0.978	0.972	2030			■	■			■	■			■	■	■		
4	159,269	150,049	0.952	0.942	2031	■				■	■	■	■	■	■	■	■	■	■	■
5	159,067	147,305	0.938	0.926	2032	■						■	■			■			■	■
6	159,337	144,944	0.922	0.910	2033	■	■							■					■	■
7	159,679	143,419	0.911	0.899	2034														■	■
8	159,588	143,232	0.912	0.898	2035														■	■
9	159,497	143,036	0.913	0.897	2036														■	■
10	159,366	142,375	0.911	0.894	2037														■	■
11	159,271	142,086	0.911	0.893	2038															■
12	159,571	142,478	0.911	0.894	2039															
13	159,601	142,598	0.912	0.894	2040															
14	159,634	142,665	0.912	0.894	2041															
15	159,383	142,425	0.911	0.894	2042															
16	159,599	142,614	0.911	0.894	2043															

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Cenos (Semi-sub)	Cenos (OSP)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
17	159,546	142,557	0.911	0.894	2044															
18	159,480	142,488	0.911	0.894	2045															
19	159,204	142,214	0.911	0.894	2046															
20	158,993	142,025	0.911	0.894	2047															
21	159,287	142,303	0.911	0.894	2048															
22	159,560	142,562	0.911	0.894	2049															
23	159,478	142,493	0.911	0.894	2050															
24	159,507	142,504	0.911	0.894	2051															
25	159,672	142,671	0.911	0.894	2052															
26	159,863	142,801	0.911	0.894	2053															

3.1.11 At time point 4 (2031), which corresponds to the 1st year of piling at the Proposed Development and also piling at Berwick Bank, Caledonia, Cenos, Dogger Bank South West, Muir Mhòr and Ossian OWFs, the difference between impacted and un-impacted populations is 9,220 animals (which equates to 5.78% of the UK portion of the MU reference population/2.66% of the full MU) (Table 3.3). The median counterfactual of population size at time point 4 was 0.952, while the mean counterfactual was 0.942. It is important to highlight that the three years prior also includes piling at Aspen, Caledonia, Dogger Bank South West, and Muir Mhòr OWFs, and therefore there is already an increased cumulative effect on harbour porpoise prior to the start of Proposed Development's piling campaign with a difference between the impacted and un-impacted populations of 4,477 animals (2.80% of the UK portion of the MU reference population/1.29% of the full MU) before piling commences at Proposed Development (Table 3.3).

3.1.12 At time point 5 (2032), which corresponds to the 2nd year of piling at the Proposed Development and includes piling at Caledonia, Cenos, Dogger Bank South West and Ossian OWFs, the difference between impacted and un-impacted populations is 11,762 animals (which equates to 7.37% of the UK portion of the MU reference population/3.39% of the full MU) (Table 3.3). It is important to note that a fixed reference population (see Table 2.3) is used to calculate proportions of the MU impacted and does not reflect any possible increase in MU size. Given both the un-impacted population and impacted population for harbour porpoise appears to increase over time, it is considered possible that this could be the case for the total number of animals in the reference MUs, and this is not reflected in the proportion of MU impacted when calculated using the fixed MU value from time point 1. The median counterfactual of population size at time point 5 was 0.938, while the mean counterfactual was 0.926.

3.1.13 At time point 6 (2033), which corresponds to the final year of piling at the Proposed Development and Cenos OWF, includes piling at Ossian OWF, and following the end of piling at Aspen OWF (in 2030), Berwick Bank and Muir Mhòr (in 2031) and Caledonia and Dogger Bank South West OWFs (in 2032), the difference between impacted and un-impacted populations is 14,393 animals (which equates to 9.02% of the UK portion of the MU reference population/4.15% of the full MU) (Table 3.3). The median counterfactual of population size at time point 6 was 0.922, while the mean counterfactual was 0.910.

3.1.14 At time point 12 (2039), six years after the end of piling at the Proposed Development and end of all piling at the other projects, the difference between impacted and un-impacted populations is 17,093 animals (which equates to 10.71% of the UK portion of the MU reference population/4.93% of the full MU) (Table 3.3). The median counterfactual of population size at time point 12 was 0.911, while the mean counterfactual was 0.894.

3.1.15 At time point 26 (2053) (the final year modelled), 20 years after the end of piling at the Proposed Development, the difference between impacted and un-impacted populations is 17,062 animals (which equates to 10.69% of the UK portion of the MU reference population/4.92% of the full MU, (Table 3.3). The median counterfactual of population size at time point 26 was 0.911, while the mean counterfactual was 0.894.

3.1.16 Given the results of the modelling for Scenario HPC1, there is considered to be potential for a long term population-level effect from this cumulative piling scenario upon harbour porpoise within the North Sea MU. However, it is important to highlight the Proposed Development's relative contribution to this cumulative effect, given the high level of activity expected in the Regional Marine Mammal Study Area.

Scenario HPC2: Cumulative Scenario Without the Proposed Development

3.1.17 Based on the above, Scenario HPC2 modelled the cumulative projects without the inclusion of the Proposed Development (Figure 3.4). For scenario HPC2 the simulated trajectories of harbour porpoise between the un-impacted population and impacted population is almost identical to Scenario HPC1 (see Figure 3.3 and Figure 3.4). The results comparing HPC1 against HPC2 indicate that the potential cumulative impact arises from the simultaneous aggregation of multiple projects rather than from any single project in isolation.

3.1.18 At time point 4 (2031), the difference between impacted and un-impacted harbour porpoise populations is 10,086 animals (6.32% of the UK MU portion). Median and mean counterfactual population sizes were 0.944 and 0.937, respectively.

3.1.19 At time point 5 (2032), the difference between impacted and un-impacted harbour porpoise populations is 13,201 animals (8.27% of the UK MU portion). Median and mean counterfactuals were 0.927 and 0.918.

3.1.20 At time point 6 (2033), the difference between impacted and un-impacted harbour porpoise populations is 14,996 animals (9.39% of the UK MU portion). Median and mean counterfactual population sizes were 0.917 and 0.907.

3.1.21 At time point 12 (2039), the difference between impacted and un-impacted harbour porpoise populations is 16,032 animals (10.04% of the UK MU portion). Median and mean counterfactuals were 0.914 and 0.901.

3.1.22 At time point 26 (2053), the difference between impacted and un-impacted harbour porpoise populations is 16,001 animals (10.02% of the UK MU portion). Median and mean counterfactuals were 0.915 and 0.902.

3.1.23 Therefore, when comparing HPC1 with HPC2, a similar pattern is observed, with a short term decrease in animals followed by a steady population recovery.

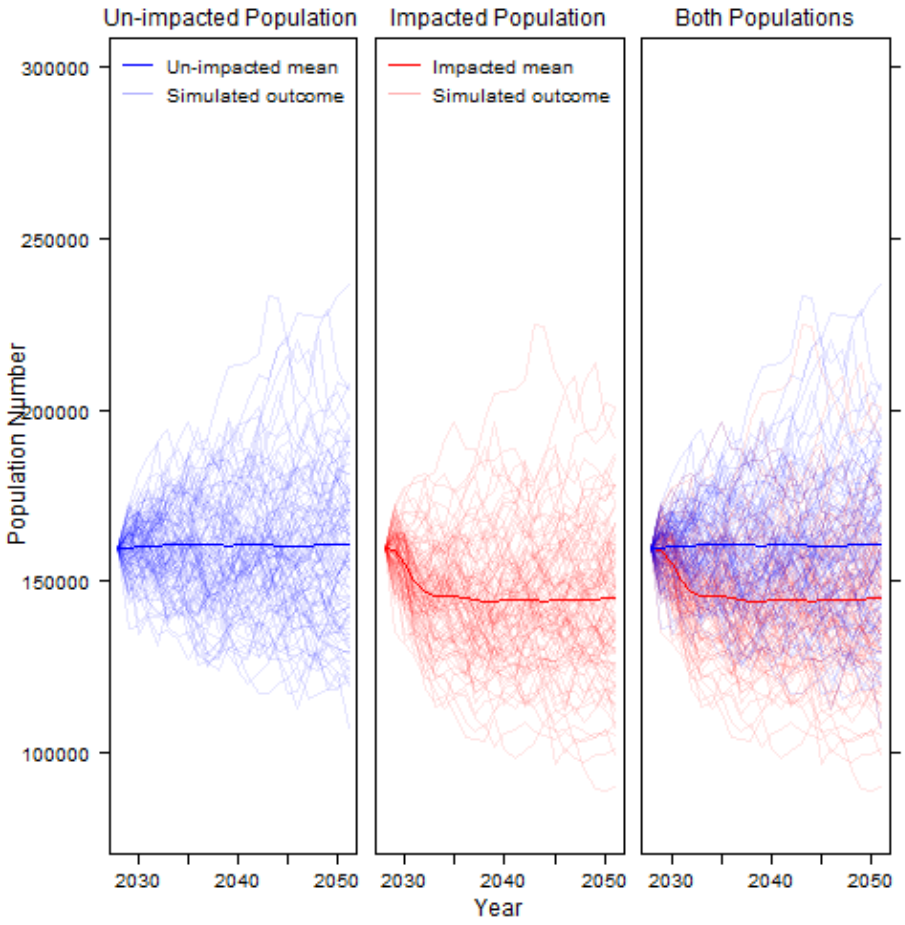

Figure 3.4: Simulated Harbour Porpoise Population Trajectories in an Un-impacted Versus Impacted Population, for Cumulative Scenario HPC2 (without Proposed Development)

Table 3.4: Comparison of Modelled Estimates for the Un-impacted and Impacted Harbour Porpoise Populations and Counterfactuals of Population Size for Cumulative Scenario HPC1 and HPC2. Bold lines indicate piling years at the Proposed Development

Year	Time Point	Scenario HPC1 - all CEA projects					Scenario HPC2 - Without Proposed Development				
		Un-impacted Pop Mean	Impacted Pop Mean	Difference in Mean Number of Animals	Median	Mean	Un-impacted Pop Mean	Impacted Pop Mean	Difference in Mean Number of Animals	Median	Mean
2028	1	159,634	159,634	0	1.000	1.000	159,634	159,634	0	1.000	1.000
2029	2	159,581	159,010	-571	0.998	0.996	159,595	158,972	-623	0.998	0.996
2030	3	159,667	155,190	-4,477	0.978	0.972	160,056	155,042	-5,014	0.975	0.969
2031	4	159,269	150,049	-9,220	0.952	0.942	160,199	150,113	-10,086	0.944	0.937
2032	5	159,067	147,305	-11,762	0.938	0.926	160,288	147,087	-13,201	0.927	0.918
2033	6	159,337	144,944	-14,393	0.922	0.910	160,590	145,594	-14,996	0.917	0.907
2034	7	159,679	143,419	-16,260	0.911	0.899	160,820	145,978	-14,842	0.919	0.909
2035	8	159,588	143,232	-16,356	0.912	0.898	160,738	145,917	-14,821	0.921	0.909
2036	9	159,497	143,036	-16,461	0.913	0.897	160,782	145,470	-15,312	0.918	0.906
2037	10	159,366	142,375	-16,991	0.911	0.894	160,770	144,840	-15,930	0.915	0.902
2038	11	159,271	142,086	-17,185	0.911	0.893	160,541	144,335	-16,206	0.914	0.900
2039	12	159,571	142,478	-17,093	0.911	0.894	160,406	144,374	-16,032	0.914	0.901
2040	13	159,601	142,598	-17,003	0.912	0.894	160,763	144,784	-15,979	0.915	0.902
2041	14	159,634	142,665	-16,969	0.912	0.894	160,589	144,644	-15,945	0.915	0.902
2042	15	159,383	142,425	-16,958	0.911	0.894	160,690	144,712	-15,978	0.915	0.902

Year	Time Point	Scenario HPC1 - all CEA projects					Scenario HPC2 - Without Proposed Development				
		Un-impacted Pop Mean	Impacted Pop Mean	Difference in Mean Number of Animals	Median	Mean	Un-impacted Pop Mean	Impacted Pop Mean	Difference in Mean Number of Animals	Median	Mean
2043	16	159,599	142,614	-16,985	0.911	0.894	160,558	144,563	-15,995	0.915	0.902
2044	17	159,546	142,557	-16,989	0.911	0.894	160,303	144,319	-15,984	0.915	0.902
2045	18	159,480	142,488	-16,992	0.911	0.894	160,433	144,457	-15,976	0.915	0.902
2046	19	159,204	142,214	-16,990	0.911	0.894	160,387	144,424	-15,963	0.915	0.902
2047	20	158,993	142,025	-16,968	0.911	0.894	160,382	144,401	-15,981	0.915	0.902
2048	21	159,287	142,303	-16,984	0.911	0.894	160,578	144,574	-16,004	0.915	0.902
2049	22	159,560	142,562	-16,998	0.911	0.894	160,727	144,711	-16,016	0.915	0.902
2050	23	159,478	142,493	-16,985	0.911	0.894	160,967	144,950	-16,017	0.915	0.902
2051	24	159,507	142,504	-17,003	0.911	0.894	161,006	144,980	-16,026	0.915	0.902
2052	25	159,672	142,671	-17,001	0.911	0.894	161,061	145,031	-16,030	0.915	0.902
2053	26	159,863	142,801	-17,062	0.911	0.894	160,860	144,859	-16,001	0.915	0.902

3.2 Bottlenose Dolphin

Scenario BND01: Maximum Temporal Scenario (Using the Coastal East Scotland MU Vital Rates)

3.2.1 Results for the maximum temporal scenario indicate a slight difference in the growth trajectory of bottlenose dolphin between the un-impacted population and impacted population (Figure 3.5). As the model progressed, the maximum difference in the mean size of the impacted and un-impacted populations was 57 individuals (approximately 2.70% of the UK portion of the combined Coastal East Scotland MU and GNS MU reference populations) at time point 26 (2056), corresponding to the end of the model run (Table 3.5). This suggests that there would not be a long term effect from piling at the Proposed Development upon the bottlenose dolphin population within the Coastal East Scotland MU and GNS MU.

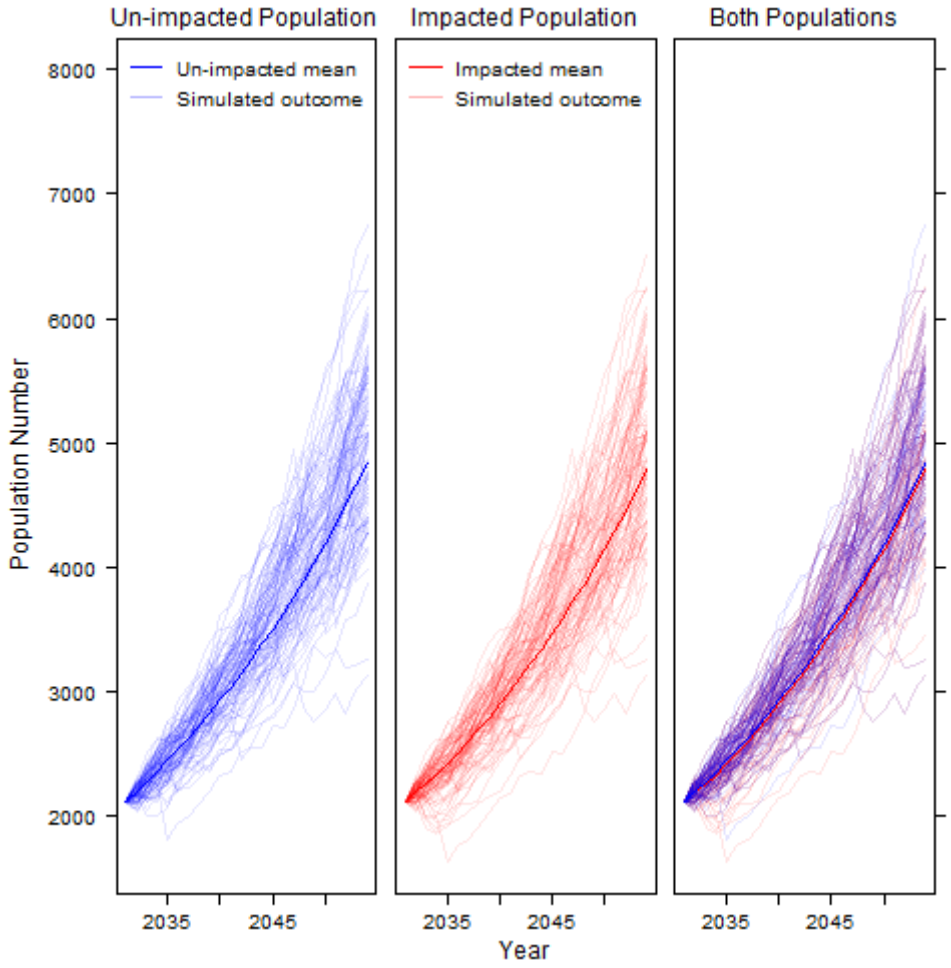

Figure 3.5: Simulated Bottlenose Dolphin Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Temporal Scenario BND01

3.2.2 At time point 11, which corresponds with ten years after the start of piling (2042), the difference between the impacted and un-impacted populations was 31 animals, approximately 1.38% of the UK portion of the combined Coastal East Scotland MU and GNS MU reference population.

Table 3.5: Modelled Estimates for the Un-impacted and Impacted Bottlenose Dolphin Populations and Counterfactuals of Population Size for the Maximum Temporal Scenario BND01

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	2,185	1,988	2,324	2,185	1,988	2,324	1.0000	1.0000
3	2,266	2,020	2,444	2,249	1,978	2,442	1.0000	0.9924
4	2,352	2,060	2,598	2,317	1,954	2,588	1.0000	0.9851
7	2,618	2,200	2,982	2,586	2,162	2,954	1.0000	0.9878
11	3,025	2,408	3,556	2,994	2,384	3,526	1.0000	0.9896
16	3,621	2,802	4,438	3,580	2,782	4,424	1.0000	0.9888
26	5,179	3,664	6,729	5,122	3,621	6,716	1.0000	0.9890

3.2.3 The median counterfactual for scenario BND01 remained at 1 throughout the 26-year simulation, whereas the mean counterfactual was 0.9890 by the end of the simulation (Table 3.5). Given that the differences in impacted to un-impacted populations approaches a ratio of one there is considered to be no potential for a long term effect from this piling scenario upon bottlenose dolphin within the Coastal East Scotland MU and GNS MU.

Scenario BND02: Maximum Spatial Scenario (Using the Coastal East Scotland MU Vital Rates)

3.2.4 Results for the maximum spatial scenario indicated a difference in the growth trajectory of bottlenose dolphin between the un-impacted population and impacted population (Figure 3.6). Across the model run, the maximum difference in the mean size of the impacted and un-impacted populations was four individuals (approximately 0.19% of the UK portion of the combined Coastal East Scotland MU and GNS MU reference populations) at time points 20, 21, 23, 25, and 26 (Table 3.6). This indicates that there would not be a long term effect from piling at the Proposed Development upon the bottlenose dolphin population within the Coastal East Scotland MU and GNS MU.

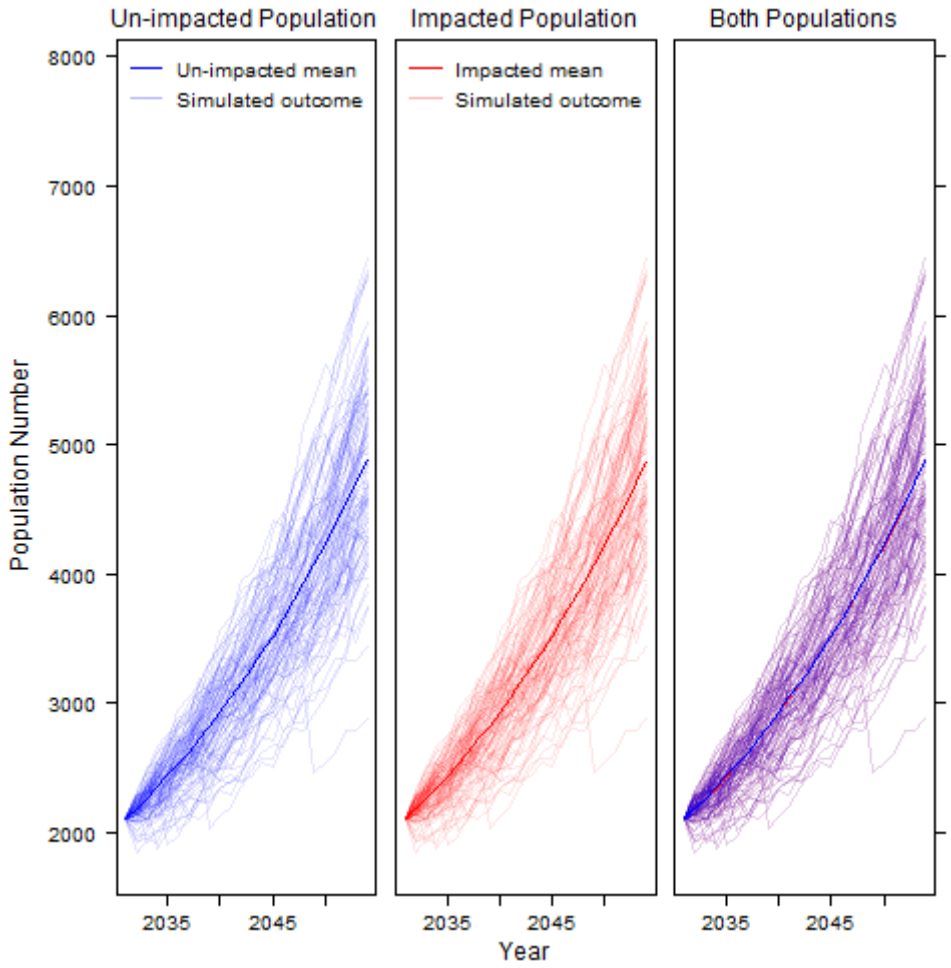

Figure 3.6: Simulated Bottlenose Dolphin Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Spatial Scenario BND02

3.2.5 At time point 11, which corresponds to ten years after the start of the piling phase (2042), there was a difference of two animals between the impacted and un-impacted populations (approximately 0.09% of the combined Coastal East Scotland MU and GNS MU reference population).

Table 3.6: Modelled Estimates for the Un-impacted and Impacted Bottlenose Dolphin Populations and Counterfactuals of Population Size for the Maximum Spatial Scenario BND02

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	2,187	1,990	2,328	2,187	1,990	2,328	1.0000	1.0000
3	2,266	1,986	2,476	2,265	1,980	2,476	1.0000	0.9996
4	2,352	2,042	2,610	2,350	2,040	2,602	1.0000	0.9992
7	2,626	2,168	3,014	2,624	2,168	3,014	1.0000	0.9991
11	3,048	2,428	3,632	3,046	2,428	3,632	1.0000	0.9992
16	3,656	2,766	4,494	3,653	2,764	4,494	1.0000	0.9992
26	5,231	3,682	6,814	5,227	3,678	6,814	1.0000	0.9992

3.2.6 The median counterfactual for scenario BND02 remained at 1.0000 throughout the 26-year simulation, whereas the mean counterfactual was 0.9992 by the end of the simulation (Table 3.6). Given that the differences in impacted to un-impacted populations approaches a ratio of one there is considered to be no potential for a long term effect from this piling scenario upon bottlenose dolphin.

Scenario BNDC1: Cumulative Scenario (Using the Coastal East Scotland MU Vital Rates)

3.2.7 For scenario BNDC1, the simulated trajectories of bottlenose dolphin between the un-impacted population and impacted population (Figure 3.7) suggest there may be a short term impact at the beginning of the model run (i.e. in the mid to late 2030s), but not at a level that is expected to cause long term population-level effects.

3.2.8 Table 3.3 presents the modelled population estimates for the impacted and un-impacted bottlenose dolphin populations, alongside the median and mean counterfactuals and years of piling per project (shaded blue). Results are interpreted focusing on key time points in the model (Table 2.12), which gives context to the modelled scenarios.

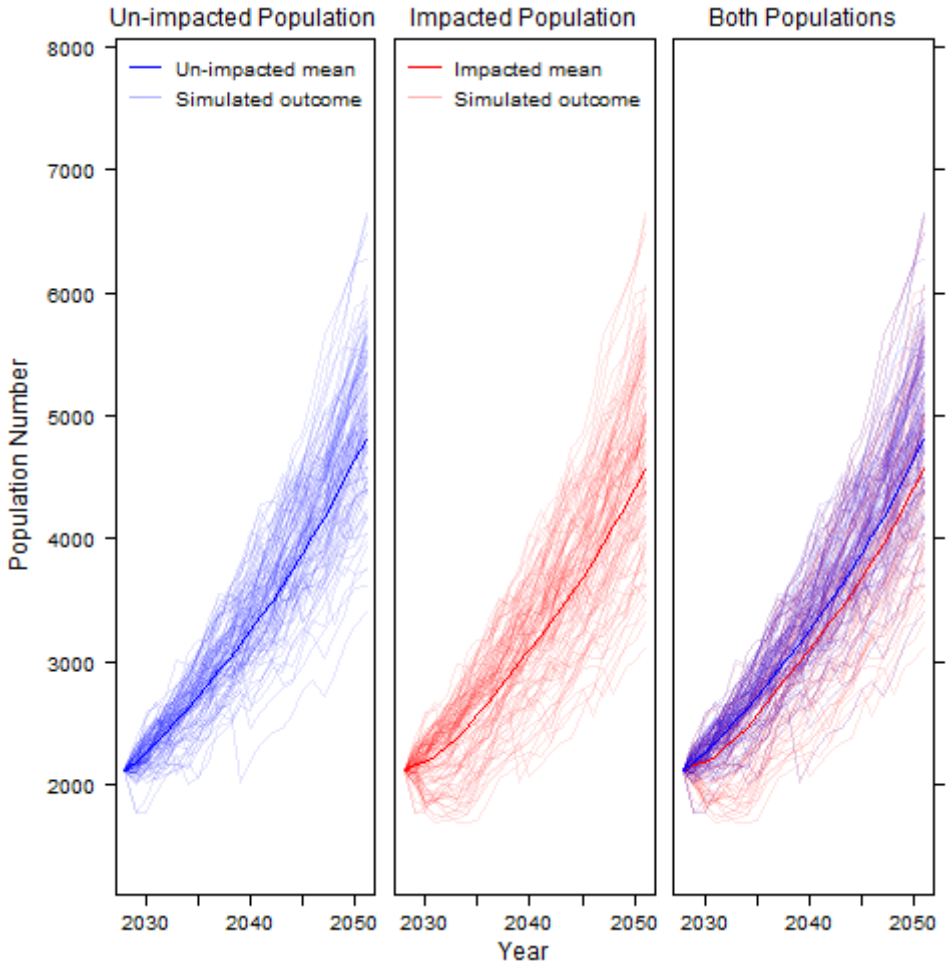

Figure 3.7: Simulated Bottlenose Dolphin Population Trajectories in an Un-impacted Versus Impacted Population, for Cumulative Scenario BNDC1

Table 3.7: Modelled Estimates for the Un-impacted and Impacted Bottlenose Dolphin Populations and Counterfactuals of Population Size for Cumulative Scenario BNDC1. Bold lines indicate piling years at the Proposed Development

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
1	2,110	2,110	1.000	1.000	2028													
2	2,184	2,162	1.000	0.990	2029													
3	2,263	2,182	0.998	0.964	2030													
4	2,346	2,232	0.996	0.952	2031													
5	2,432	2,306	0.997	0.949	2032													
6	2,517	2,375	0.997	0.944	2033													
7	2,616	2,463	0.997	0.942	2034													
8	2,716	2,566	0.997	0.945	2035													
9	2,819	2,673	0.998	0.949	2036													
10	2,927	2,782	0.998	0.951	2037													
11	3,032	2,885	0.998	0.952	2038													
12	3,140	2,988	0.998	0.952	2039													
13	3,256	3,097	0.998	0.952	2040													
14	3,372	3,206	0.997	0.951	2041													
15	3,491	3,316	0.997	0.950	2042													
16	3,622	3,439	0.997	0.950	2043													

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
17	3,748	3,558	0.998	0.950	2044													
18	3,883	3,686	0.998	0.950	2045													
19	4,019	3,816	0.998	0.950	2046													
20	4,166	3,956	0.998	0.950	2047													
21	4,317	4,100	0.998	0.950	2048													
22	4,477	4,252	0.998	0.950	2049													
23	4,641	4,408	0.998	0.950	2050													
24	4,810	4,569	0.998	0.950	2051													
25	4,986	4,737	0.998	0.950	2052													
26	5,168	4,909	0.998	0.950	2053													

3.2.9 At time point 4 (2031), which corresponds to the 1st year of piling at the Proposed Development and also piling at Berwick Bank, Caledonia, Dogger Bank South West, Muir Mhòr, and Ossian OWFs, the difference between impacted and un-impacted populations is 114 animals (which equates to 5.40% of the UK portion of the combined MUs reference population/5.07% of the combined full MUs) (Table 3.3). It is important to highlight that the three years prior also includes piling at Aspen, Caledonia, Dogger Bank South West, and Muir Mhòr OWFs, and therefore there is already an increased cumulative effect on bottlenose dolphin prior to the start of Proposed Development's piling campaign with a difference between the impacted and un-impacted populations of 81 animals (3.84% of the UK portion of the combined MUs reference population/3.60% of the full combined MUs) at time point 3 (2030), before piling commences at the Proposed Development (Table 3.3). The median counterfactual of population size at time point 4 was 0.996, while the mean counterfactual was 0.952.

3.2.10 At time point 5 (2032), which corresponds to the 2nd year of piling at the Proposed Development, the final year of piling at Caledonia and Dogger Bank South West OWFs, and continuous piling at Ossian OWF, the difference between impacted and un-impacted populations is 126 animals (which equates to 5.97% of the UK portion of the combined MUs reference population/5.60% of the full combined MUs) (Table 3.3). The median counterfactual of population size at time point 5 was 0.997, while the mean counterfactual was 0.949.

3.2.11 At time point 6 (2033), which corresponds to the final year of piling at the Proposed Development, continuous piling at Ossian OWF, and following the end of piling at Aspen OWF (in 2030), Berwick Bank and Muir Mhòr OWFs (in 2031) and Caledonia and Dogger Bank South West OWFs (in 2032), the difference between impacted and un-impacted populations is 142 animals (which equates to 6.73% of the UK portion of the combined MU reference population/6.32% of the full combined MUs) (Table 3.3). The median counterfactual of population size at time point 6 was 0.997, while the mean counterfactual was 0.944.

3.2.12 At time point 12 (2039), six years after the end of piling at the Proposed Development and end of all piling at the cumulative projects, the difference between impacted and un-impacted populations is 152 animals (which equates to 7.20% of the UK portion of the combined MUs reference population/6.76% of the full combined MUs) (Table 3.3). The median counterfactual of population size at time point 12 was 0.998, while the mean counterfactual was 0.952.

3.2.13 At time point 26 (2053) (the final year modelled), 20 years after the end of piling at the Proposed Development, the difference between impacted and un-impacted populations is 259 animals (which equates to 12.27% of the UK portion of the combined MUs reference population/11.52% of the full combined MUs) (Table 3.7). The median counterfactual of population size at time point 26 was 0.998, while the mean counterfactual was 0.950.

3.2.14 Given that the mean and median counterfactuals in the differences in impacted to un-impacted populations is near to 1.000 at 20 years after the end of piling at the Proposed Development, there is considered to be no potential for a long term population-level effect from this cumulative piling scenario upon bottlenose dolphin within the reference population.

Scenario BND03: Maximum Temporal Scenario (Using the GNS MU Vital Rates)

3.2.15 Results for the maximum temporal scenario indicate a difference in the growth trajectory of bottlenose dolphin between the un-impacted population and impacted population (Figure 3.8). Across the model run, the maximum difference in the mean size of the impacted and un-impacted populations was 23 individuals (approximately 1.09% UK portion of the combined MUs reference populations) at time point 4 (2033), corresponding to the end of the third year of piling (Table 3.8).

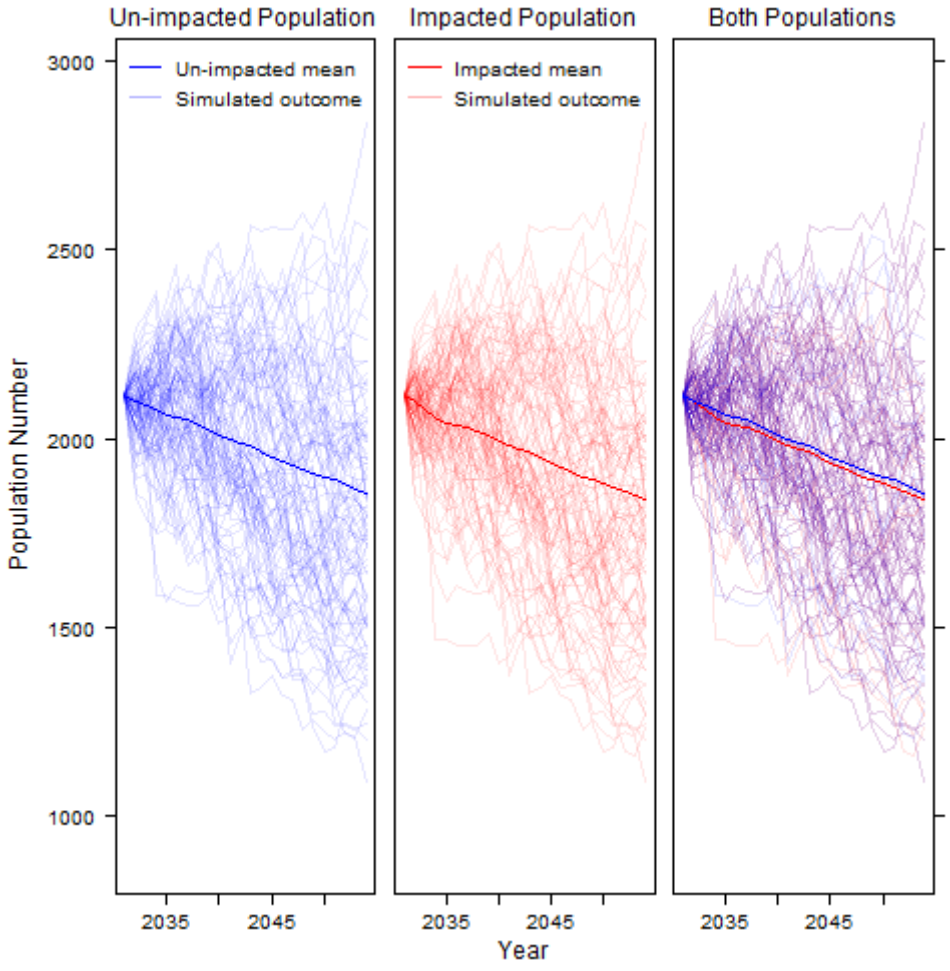

Figure 3.8: Simulated Bottlenose Dolphin Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Temporal Scenario BND03

3.2.16 At time point 11 (ten years after the start of piling; 2042) and time point 26 (the end of the model run; 2056), the difference between the impacted and un-impacted populations was 16 animals, approximately 0.76% of the UK portion of the MUs reference population. This suggests that there would not be a long term effect from piling at the Proposed Development upon the bottlenose dolphin population within the Coastal East Scotland MU and GNS MU.

Table 3.8: Modelled Estimates for the Un-impacted and Impacted Bottlenose Dolphin Populations and Counterfactuals of Population Size for the Maximum Temporal Scenario BND03

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	2,097	1,866	2,244	2,097	1,866	2,244	1.0000	1.0000
3	2,087	1,802	2,280	2,075	1,784	2,280	1.0000	0.9944
4	2,077	1,776	2,322	2,054	1,738	2,304	1.0000	0.9890
7	2,048	1,690	2,358	2,029	1,662	2,350	1.0000	0.9908
11	1,997	1,548	2,406	1,981	1,538	2,386	1.0000	0.9920
16	1,940	1,438	2,438	1,923	1,416	2,432	1.0000	0.9910
26	1,834	1,272	2,484	1,818	1,244	2,484	1.0000	0.9911

3.2.17 The median counterfactual for scenario BND03 remained at 1 throughout the 26-year simulation, whereas the mean counterfactual was 0.9911 by the end of the simulation (Table 3.8). Given that the differences in impacted to un-impacted populations approaches a ratio of one there is considered to be no potential for a long term effect from this piling scenario upon bottlenose dolphin within the Coastal East Scotland MU and GNS MU.

Scenario BND04: Maximum Spatial Scenario (Using the GNS MU Vital Rates)

3.2.18 Results for the maximum spatial scenario indicate a slight difference in the growth trajectory of bottlenose dolphin between the un-impacted population and impacted population (Figure 3.9). There was a maximum difference in the mean size of the impacted and un-impacted populations of two individuals (approximately 0.09% of the combined Coastal East Scotland MU and GNS MU reference populations) at time points 5, 8, 9, 25, and 26.

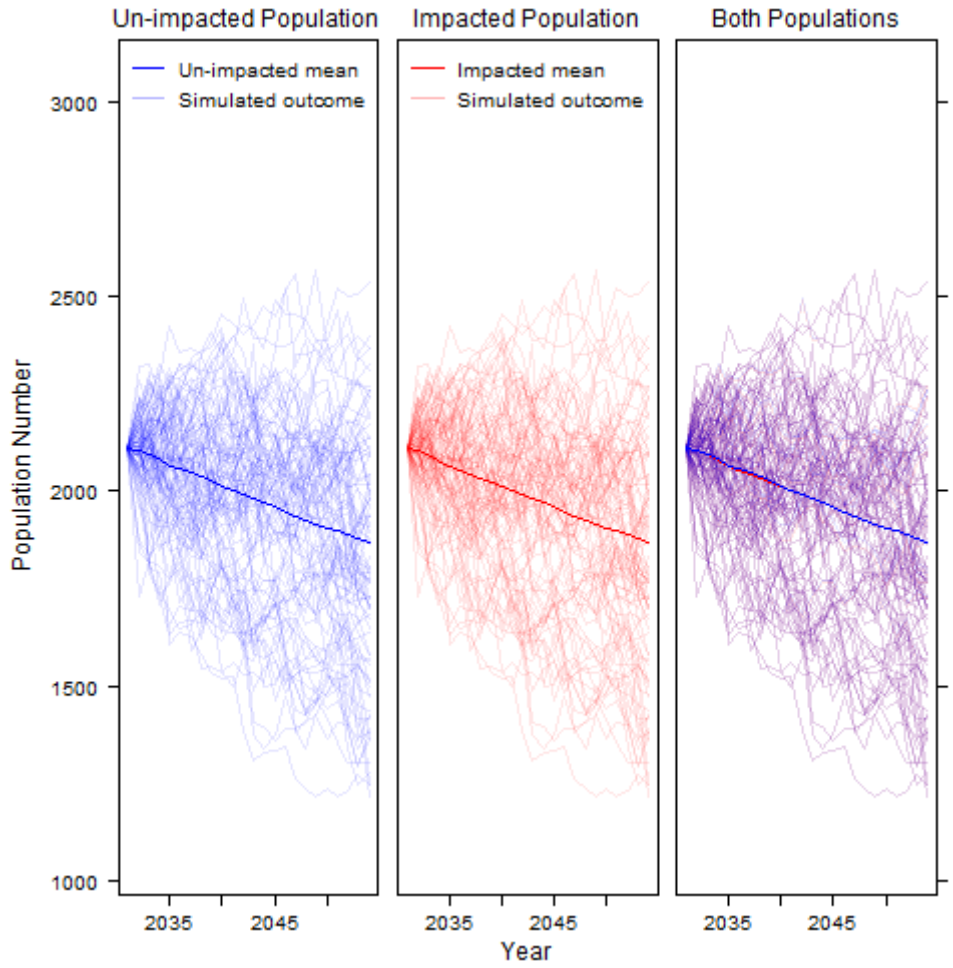

Figure 3.9: Simulated Bottlenose Dolphin Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Spatial Scenario BND04

3.2.19 At time point 11 (ten years after the start of piling; 2042) and time point 26 (the end of the model run; 2056), the difference between the impacted and un-impacted populations was one and two animals, respectively, approximately 0.05% and 0.09% of the UK portion of the combined Coastal East Scotland MU and GNS MU reference population (Table 3.9). This suggests that there would not be a long term effect from piling at the Proposed Development upon the bottlenose dolphin population within the Coastal East Scotland MU and GNS MU.

Table 3.9: Modelled Estimates for the Un-impacted and Impacted Bottlenose Dolphin Populations and Counterfactuals of Population Size for the Maximum Spatial Scenario BND04

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	2,104	1,922	2,240	2,104	1,922	2,240	1.0000	1.0000
3	2,095	1,830	2,278	2,094	1,830	2,276	1.0000	0.9997
4	2,082	1,798	2,292	2,081	1,794	2,292	1.0000	0.9994
7	2,046	1,692	2,350	2,045	1,692	2,350	1.0000	0.9993
11	2,005	1,604	2,416	2,004	1,604	2,406	1.0000	0.9995
16	1,945	1,474	2,468	1,944	1,474	2,468	1.0000	0.9994
26	1,842	1,268	2,470	1,840	1,258	2,458	1.0000	0.9994

3.2.20 The median counterfactual for scenario BND04 remained at one throughout the 26-year simulation, whereas the mean counterfactual was 0.9994 by the end of the simulation (Table 3.9). Given that the differences in impacted to un-impacted populations approaches a ratio of one there is considered to be no potential for a long term effect from this piling scenario upon bottlenose dolphin within the Coastal East Scotland MU and GNS MU.

Scenario BNDC2: Cumulative Scenario (Using the GNS MU Vital Rates)

3.2.21 For scenario BNDC2, the simulated trajectories of bottlenose dolphin between the un-impacted population and impacted population (Figure 3.10) suggest there may be a short term impact at the beginning of the model run (i.e. in the mid to late 2030s), but not at a level that is expected to cause long term population-level effects.

3.2.22 Table 3.10 presents the modelled population estimates for the impacted and un-impacted bottlenose dolphin populations, alongside the median and mean counterfactuals and years of piling per project (shaded blue). Results are interpreted focusing on key time points in the model (Table 2.12), which gives context to the modelled scenarios.

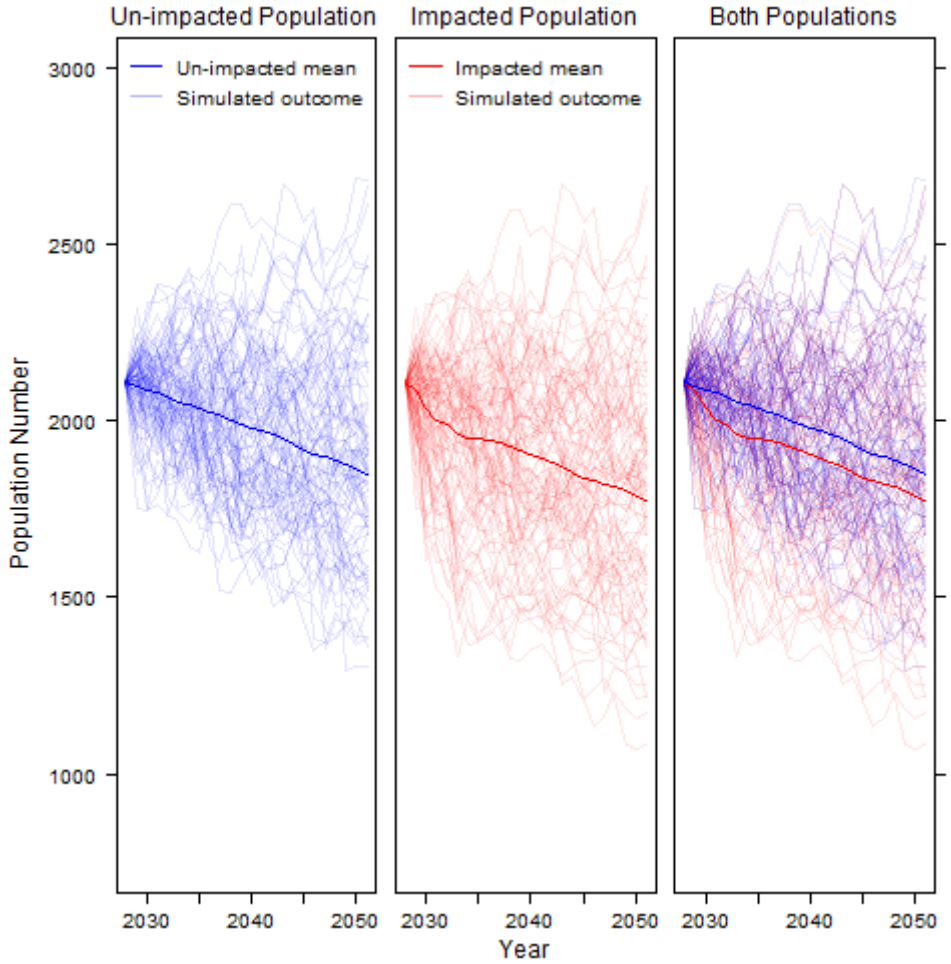

Figure 3.10: Simulated Bottlenose Dolphin Population Trajectories in an Un-impacted Versus Impacted Population, for Cumulative Scenario BNDC2

Table 3.10: Modelled Estimates for the Un-impacted and Impacted Bottlenose Dolphin Populations and Counterfactuals of Population Size for Cumulative Scenario BNDC2. Bold lines indicate piling years at the Proposed Development

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
1	2,112	2,112	1.000	1.000	2028			■				■						
2	2,100	2,087	1.000	0.994	2029			■	■			■			■	■		
3	2,088	2,036	0.998	0.975	2030			■	■			■	■	■	■	■		
4	2,079	2,004	0.997	0.964	2031	■				■	■	■	■	■	■	■	■	■
5	2,069	1,989	0.997	0.961	2032	■						■	■	■			■	■
6	2,055	1,964	0.998	0.956	2033	■	■										■	■
7	2,045	1,952	0.998	0.955	2034												■	■
8	2,036	1,949	0.998	0.957	2035												■	■
9	2,026	1,944	0.998	0.960	2036												■	■
10	2,019	1,940	0.998	0.961	2037												■	■
11	2,005	1,927	0.998	0.961	2038													■
12	1,991	1,914	0.998	0.962	2039													
13	1,981	1,903	0.998	0.961	2040													
14	1,973	1,894	0.998	0.961	2041													
15	1,961	1,882	0.998	0.960	2042													
16	1,948	1,869	0.998	0.960	2043													

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
17	1,936	1,856	0.998	0.960	2044													
18	1,918	1,840	0.999	0.960	2045													
19	1,907	1,829	0.998	0.960	2046													
20	1,898	1,821	0.999	0.960	2047													
21	1,890	1,813	0.999	0.960	2048													
22	1,879	1,803	0.999	0.960	2049													
23	1,864	1,788	0.999	0.960	2050													
24	1,849	1,774	0.999	0.960	2051													
25	1,840	1,766	0.999	0.960	2052													
26	1,833	1,759	0.999	0.960	2053													

3.2.23 At time point 4 (2031), which corresponds to the 1st year of piling at the Proposed Development and also piling at Berwick Bank, Caledonia, Dogger Bank South West, Muir Mhòr, and Ossian OWFs, the difference between impacted and un-impacted populations is 75 animals (which equates to 3.55% of the UK portion of the combined MUs reference population/3.34% of the combined full MUs population) (Table 3.10). It is important to highlight that the three years prior also includes piling at Aspen, Caledonia, Dogger Bank South West, and Muir Mhòr OWFs, and therefore there is already an increased cumulative effect on bottlenose dolphin prior to the start of Proposed Development's piling campaign with a difference between the impacted and un-impacted populations of 52 animals (2.46% of the UK portion of the combined MUs reference population/2.31% of the full combined MUs) at time point 3 (2030), before piling commences at Proposed Development (Table 3.10). The median counterfactual of population size at time point 4 was 0.997, while the mean counterfactual was 0.964.

3.2.24 At time point 5 (2032), which corresponds to the 2nd year of piling at the Proposed Development, the final year of piling at Caledonia and Dogger Bank South West OWFs, and continuous piling at Ossian OWF, the difference between impacted and un-impacted populations is 80 animals (which equates to 3.79% of the UK portion of the combined MUs reference population/3.56% of the combined full MUs population) (Table 3.10). The median counterfactual of population size at time point 5 was 0.997, while the mean counterfactual was 0.961.

3.2.25 At time point 6 (2033), which corresponds to the final year of piling at the Proposed Development, continuous piling at Ossian OWF, and following the end of piling at Berwick Bank and Muir Mhòr OWFs (in 2031) and Caledonia and Dogger Bank South West OWFs (in 2032), the difference between impacted and un-impacted populations is 91 animals (which equates to 4.31% of the UK portion of the MU reference population/4.05% of the combined full MUs) (Table 3.10). The median counterfactual of population size at time point 6 was 0.998, while the mean counterfactual was 0.956.

3.2.26 At time point 12 (2039), six years after the end of piling at the Proposed Development and end of all piling at the cumulative projects, the difference between impacted and un-impacted populations is 77 animals (which equates to 3.65% of the UK portion of the MU reference population/3.43% of the combined full MUs) (Table 3.10). The median counterfactual of population size at time point 12 was 0.998, while the mean counterfactual was 0.962.

3.2.27 At time point 26 (2053) (the final year modelled), 20 years after the end of piling at the Proposed Development, the difference between impacted and un-impacted populations is 74 animals (which equates to 3.51% of the UK portion of the MU reference population/3.29% of the full MU) (Table 3.10). The median counterfactual of population size at time point 26 was 0.999, while the mean counterfactual was 0.960.

3.2.28 Given that the mean and median counterfactuals in the differences in impacted to un-impacted populations is near to 1.000 at 20 years after the end of piling at the Proposed Development, there is considered to be no potential for a long term population-level effect from this cumulative piling scenario upon bottlenose dolphin within the reference population.

3.3 Minke Whale

Scenario MW01: Maximum Temporal Scenario

3.3.1 Results for the maximum temporal scenario indicate a difference in the growth trajectory of minke whale between the un-impacted population and impacted population (Figure 3.11). Across the model run, there was a maximum difference in the mean size of the impacted and un-impacted populations of one individual at time points 4, 6, 7, 12, 15, and 22 (0.01% of the UK portion of the CGNS MU reference population) (Table 3.11). At all other time points, there was no difference between impacted and un-impacted populations (Table 3.11).

3.3.2 This suggests that there would not be a long term effect from piling at the Proposed Development upon the minke whale population within the CGNS MU.

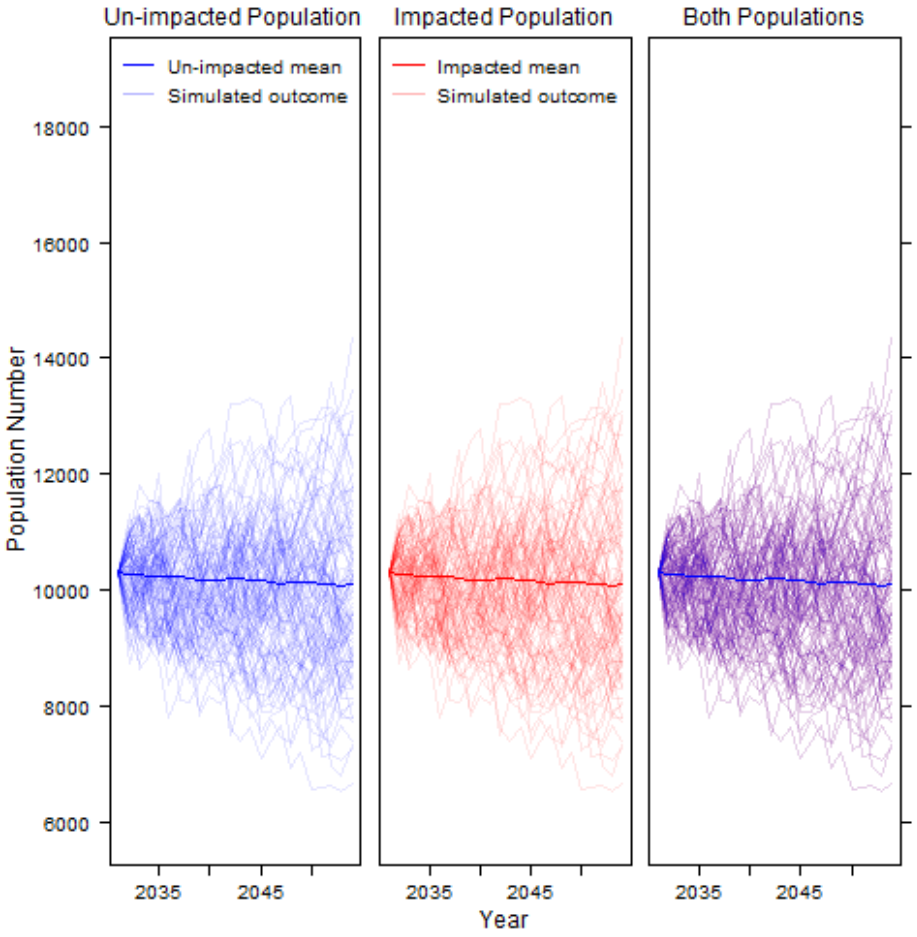

Figure 3.11: Simulated Minke Whale Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Temporal Scenario MW01

Table 3.11: Modelled Estimates for the Un-impacted and Impacted Minke Whale Populations and Counterfactuals of Population Size for the Maximum Temporal Scenario MW01

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	10,274	9,186	11,156	10,274	9,186	11,156	1.0000	1.0000
3	10,262	9,030	11,552	10,262	9,030	11,552	1.0000	1.0000
4	10,228	8,752	11,736	10,227	8,752	11,736	1.0000	0.9999
7	10,227	8,570	11,938	10,226	8,570	11,938	1.0000	1.0000
11	10,167	8,267	12,484	10,167	8,267	12,484	1.0000	1.0000
16	10,131	7,704	13,004	10,131	7,704	13,004	1.0000	1.0000
26	10,095	7,263	13,669	10,095	7,263	13,669	1.0000	1.0000

3.3.3 The median counterfactual remained at 1.0000 throughout the model run, while the mean fluctuated between 1.0000 and 0.9999 (Table 3.11). Therefore, given that the differences in impacted and un-impacted populations approach a ratio of one there is not considered to be a potential for a long term population level effect from this piling scenario upon minke whale within the CGNS MU.

Scenario MW02: Maximum Spatial Scenario

3.3.4 Results for the maximum spatial scenario indicate a difference in the growth trajectory of minke whale between the un-impacted population and impacted population (Figure 3.12). Across the model run, there was a maximum difference in the mean size of the impacted and un-impacted populations of one individual at time point 6 (2037) (0.01% of the UK portion of the CGNS MU reference population) (Table 3.12). At all other time points, there was no difference between impacted and un-impacted populations (Table 3.12). This suggests that there would not be a long term effect from piling at the Proposed Development upon the minke whale population within the CGNS MU.

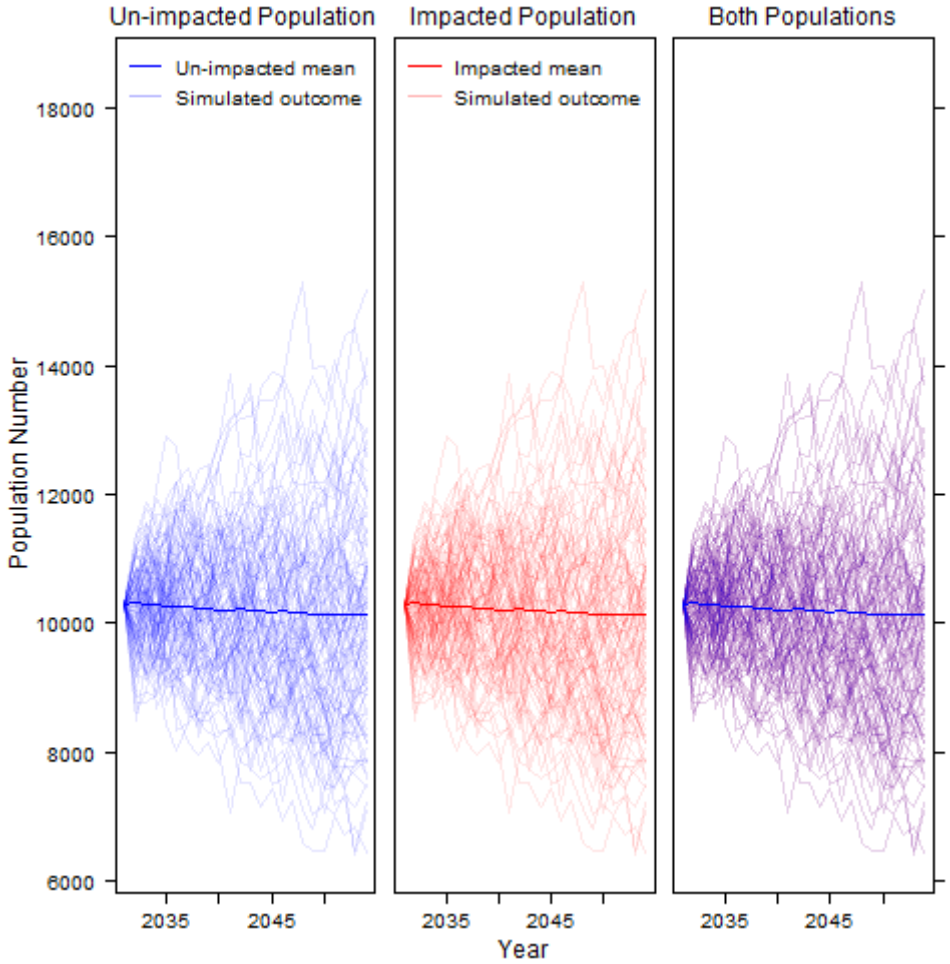

Figure 3.12: Simulated Minke Whale Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Spatial Scenario MW02

Table 3.12: Modelled Estimates for the Un-impacted and Impacted Minke Whale Populations and Counterfactuals of Population Size for the Maximum Spatial Scenario MW02

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	10,318	9,168	11,160	10,318	9,168	11,160	1.0000	1.0000
3	10,308	8,877	11,538	10,308	8,877	11,538	1.0000	1.0000
4	10,278	8,717	11,698	10,278	8,717	11,698	1.0000	1.0000
7	10,263	8,564	12,148	10,263	8,564	12,148	1.0000	1.0000
11	10,214	8,332	12,549	10,214	8,332	12,549	1.0000	1.0000
16	10,188	7,952	12,986	10,188	7,952	12,986	1.0000	1.0000
26	10,120	7,326	13,842	10,120	7,326	13,842	1.0000	1.0000

3.3.5 The median and mean counterfactuals remained at 1.0000 throughout the model run (Table 3.11). Given that the differences in impacted and un-impacted populations approaches a ratio of one there is not considered to be a potential for a long term effect from this piling scenario upon minke whale.

Scenario MWC1: Cumulative Scenario

3.3.6 For scenario MWC1, the simulated trajectories of minke whale between the un-impacted population and impacted population (Figure 3.13) demonstrate that there is potential for a short term impact at the beginning of the model run until the mid-2030s, with the impacted population showing recovery from 2035 and a stable trajectory.

3.3.7 Table 3.13 presents the modelled population estimates for the impacted and un-impacted minke whale populations, alongside the median and mean counterfactuals and years of piling per project (shaded blue). Results are interpreted focusing on key time points in the model (Table 2.12), which give context to the modelled scenarios.

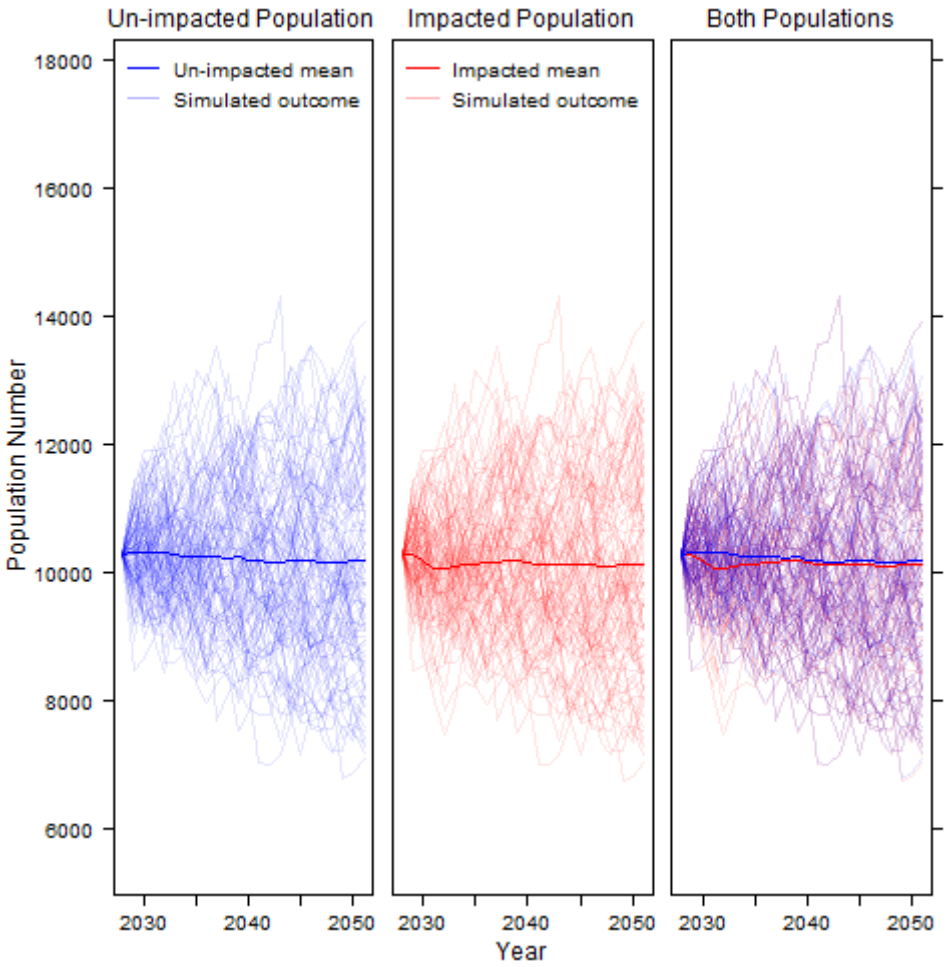

Figure 3.13: Simulated Minke Whale Population Trajectories in an Un-impacted Versus Impacted Population, for Cumulative Scenario MWC1

Table 3.13: Modelled Estimates for the Un-impacted and Impacted Minke Whale Populations and Counterfactuals of Population Size for Cumulative Scenario MWC1. Bold lines indicate piling years at the Proposed Development

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Cenos (Semi-sub)	Cenos (OSP)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
1	10,288	10,288	1.000	1.000	2028			■				■								
2	10,297	10,293	1.000	1.000	2029			■	■			■					■	■		
3	10,297	10,193	1.000	0.990	2030			■	■			■	■			■	■	■		
4	10,301	10,065	0.998	0.977	2031	■				■	■	■	■	■	■	■	■	■	■	■
5	10,299	10,073	0.999	0.978	2032	■						■	■	■		■			■	■
6	10,270	10,081	0.999	0.982	2033	■	■							■					■	■
7	10,265	10,119	0.999	0.986	2034														■	■
8	10,246	10,135	0.999	0.989	2035														■	■
9	10,234	10,149	1.000	0.992	2036														■	■
10	10,235	10,169	1.000	0.994	2037														■	■
11	10,230	10,179	1.000	0.995	2038															■
12	10,239	10,196	1.000	0.996	2039															
13	10,202	10,158	1.000	0.996	2040															
14	10,182	10,133	1.000	0.995	2041															
15	10,166	10,113	1.000	0.995	2042															
16	10,166	10,110	1.000	0.995	2043															

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Cenos (Semi-sub)	Cenos (OSP)	Dogger Bank South West	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
17	10,190	10,132	1.000	0.994	2044															
18	10,192	10,134	1.000	0.994	2045															
19	10,182	10,123	1.000	0.994	2046															
20	10,159	10,101	1.000	0.994	2047															
21	10,158	10,100	1.000	0.994	2048															
22	10,170	10,113	1.000	0.994	2049															
23	10,180	10,123	1.000	0.994	2050															
24	10,190	10,133	1.000	0.994	2051															
25	10,156	10,099	1.000	0.994	2052															
26	10,129	10,073	1.000	0.994	2053															

3.3.8 At time point 4 (2031), which corresponds to the 1st year of piling at the Proposed Development and also piling at all cumulative projects except Aspen OWF, the difference between impacted and un-impacted populations was 236 animals (which equates to 2.29% of the UK portion of the MU reference population/1.17% of the full MU) (Table 3.13). It is important to highlight that the three years prior also includes piling at Aspen, Caledonia, Dogger Bank South West and Muir Mhòr OWFs, and therefore there is an increased cumulative effect on minke whale prior to the start of Proposed Development's piling campaign (see Figure 3.13), with a difference between the impacted and un-impacted populations of 104 animals (1.01% of the UK portion of the MU reference population/0.52% of the full MU) at time point 3 (2030) before piling commences at Proposed Development (Table 3.13). The median counterfactual of population size at time point 4 was 0.998, while the mean counterfactual was 0.977.

3.3.9 At time point 5 (2032), which corresponds to the 2nd year of piling at the Proposed Development and consecutive piling at Caledonia, Cenos, Dogger Bank South West, and Ossian OWFs, the difference between impacted and un-impacted populations is 226 animals (which equates to 2.20% of the UK portion of the MU reference population/1.12% of the full MU) (Table 3.13). It is important to note that a fixed reference population (see Table 2.3) is used to calculate proportions of the MU impacted and does not reflect any possible increase in MU size. The median counterfactual of population size at time point 5 was 0.999, while the mean counterfactual was 0.978.

3.3.10 At time point 6 (2033), which corresponds to the final year of piling at the Proposed Development and consecutive piling at Ossian and Cenos OWFs, and following the end of piling at Aspen OWF (in 2030), Berwick Bank OWF (in 2031) and Caledonia and Dogger Bank South West OWFs (both in 2032), the difference between impacted and un-impacted populations is 189 animals (which equates to 1.84% of the UK portion of the MU reference population/0.94% of the full MU) (Table 3.13). The median counterfactual of population size at time point 6 was 0.999, while the mean counterfactual was 0.982.

3.3.11 At time point 12 (2039), six years after the end of piling at the Proposed Development and end of all piling at CEA projects, the difference between impacted and un-impacted populations is 43 animals (which equates to 0.42% of the UK portion of the MU reference population/0.21% of the full MU) (Table 3.13), showing some recovery between the impacted and un-impacted populations. The median counterfactual of population size at time point 12 was 1.000, while the mean counterfactual was 0.996.

3.3.12 At time point 26 (2053) (the final year modelled), 20 years after the end of piling at the Proposed Development, the difference between impacted and un-impacted populations is 56 animals (which equates to 0.54% of the UK portion of the MU reference population/0.28% of the full MU) (Table 3.13). The median counterfactual of population size at time point 26 was 1.000, while the mean counterfactual was 0.994.

3.3.13 Given that the differences in impacted to un-impacted populations is a median ratio of close to one throughout, there is considered to be no potential for a long term population-level effect from this cumulative piling scenario upon minke whale within the MU.

3.4 Grey Seal

Scenario GS01: Maximum Temporal Scenario

3.4.1 Results for the maximum temporal scenario indicate that there was no difference in the population trajectory of grey seal between the un-impacted population and impacted populations (Figure 3.14). At all time points, there is no difference in the mean size of the impacted and un-impacted populations (Table 3.14). Therefore, the median and mean counterfactuals for this scenario stayed at 1.0000 through the 26-year simulation (Table 3.14). There is not considered to be a potential for a long term effect from this piling scenario upon grey seal within the North Coast and Orkney SMU, Moray Firth SMU, and East Scotland SMU.

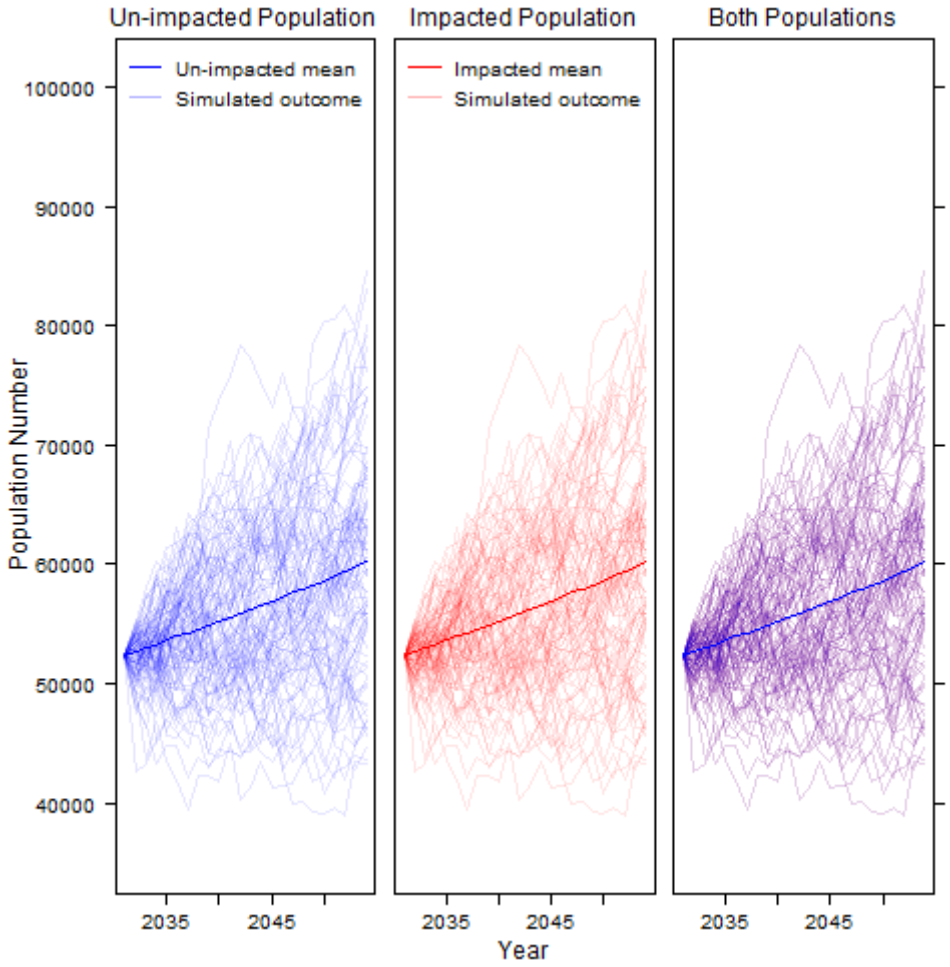

Figure 3.14: Simulated Grey Seal Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Temporal Scenario GS01

Table 3.14: Modelled Estimates for the Un-impacted and Impacted Grey Seal Populations and Counterfactuals of Population Size for the Maximum Temporal Scenario GS01

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	52,636	47,971	55,878	52,636	47,971	55,878	1.0000	1.0000
3	52,945	46,698	57,486	52,945	46,698	57,486	1.0000	1.0000
4	53,217	46,507	58,672	53,217	46,507	58,672	1.0000	1.0000
7	54,267	45,705	61,956	54,267	45,705	61,956	1.0000	1.0000
11	55,498	44,660	66,132	55,498	44,660	66,132	1.0000	1.0000
16	57,192	43,907	70,876	57,192	43,907	70,876	1.0000	1.0000
26	60,953	43,110	82,426	60,953	43,110	82,426	1.0000	1.0000

Scenario GS02: Maximum Spatial Scenario

3.4.2 Results for the maximum spatial scenario indicate no difference in the population trajectory of grey seal between the un-impacted population and impacted populations (Figure 3.15). At all time points, there was no difference in the mean size of the impacted and un-impacted populations (Table 3.15). This indicates that there would not be a long term effect from piling at the Proposed Development upon the grey seal population within the SMUs considered.

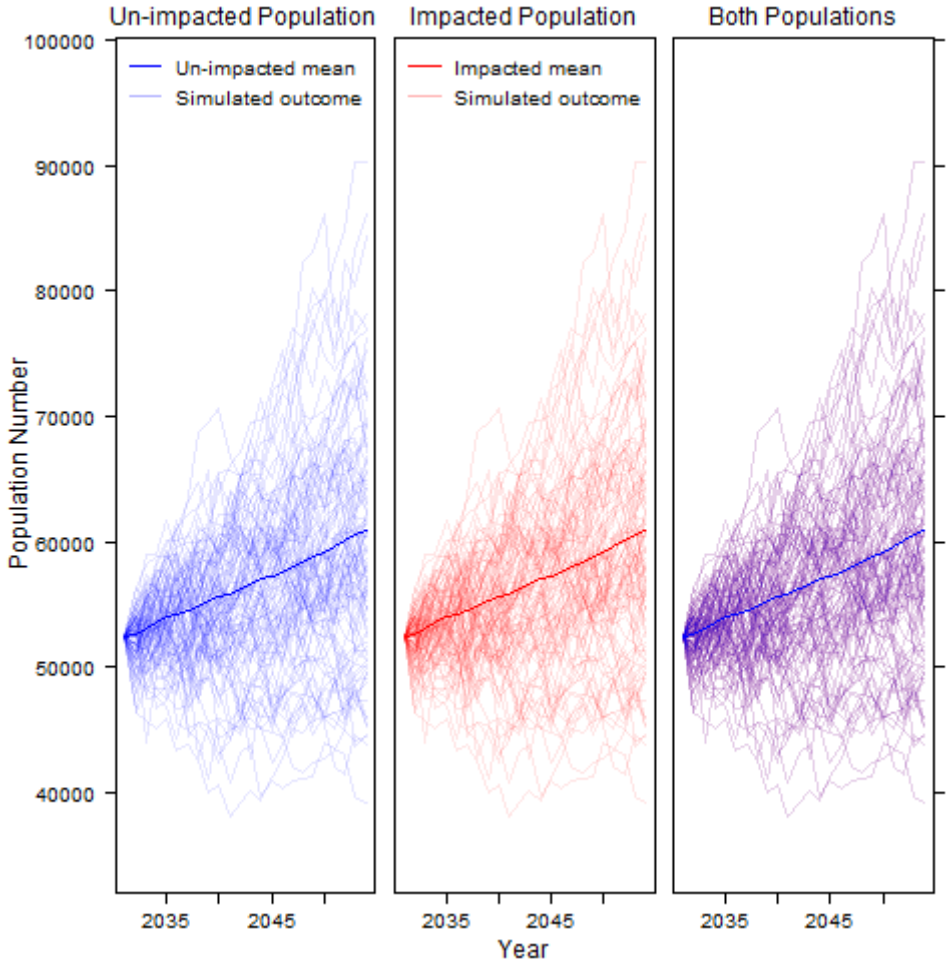

Figure 3.15: Simulated Grey Seal Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Spatial Scenario GS02

Table 3.15: Modelled Estimates for the Un-impacted and Impacted Grey Seal Populations and Counterfactuals of Population Size for the Maximum Spatial Scenario GS02

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	52,610	47,909	56,034	52,610	47,909	56,034	1.0000	1.0000
3	53,060	47,231	57,474	53,060	47,231	57,474	1.0000	1.0000
4	53,494	46,994	58,779	53,494	46,994	58,779	1.0000	1.0000
7	54,454	45,479	62,677	54,454	45,479	62,677	1.0000	1.0000
11	55,855	44,376	67,342	55,855	44,376	67,342	1.0000	1.0000
16	57,536	43,662	72,584	57,536	43,662	72,584	1.0000	1.0000
26	61,676	43,094	83,424	61,676	43,094	83,424	1.0000	1.0000

3.4.3 The median and mean counterfactuals for scenario GS02 remained at 1.0000 throughout the 26-year simulation. This is equal to the corresponding counterfactual from the maximum temporal scenario, suggesting that the maximum spatial scenario may result in a similar impact. Given that the differences in impacted to un-impacted populations approaches a ratio of one there is considered to be no potential for a long term effect from this piling scenario upon grey seal.

Scenario GSC1: Cumulative Scenario

3.4.4 For scenario GSC1, the simulated trajectories of grey seal between the un-impacted population and impacted population (Figure 3.16) demonstrate that there is a difference between the two scenarios, with both the impacted and non-impacted scenario showing an increase in population size.

3.4.5 Table 3.16 presents the modelled population estimates for the impacted and un-impacted grey seal populations, alongside the median and mean counterfactuals and years of piling per project (shaded blue). Results are interpreted focusing on key time points in the model (Table 2.12), which gives context to the modelled scenarios.

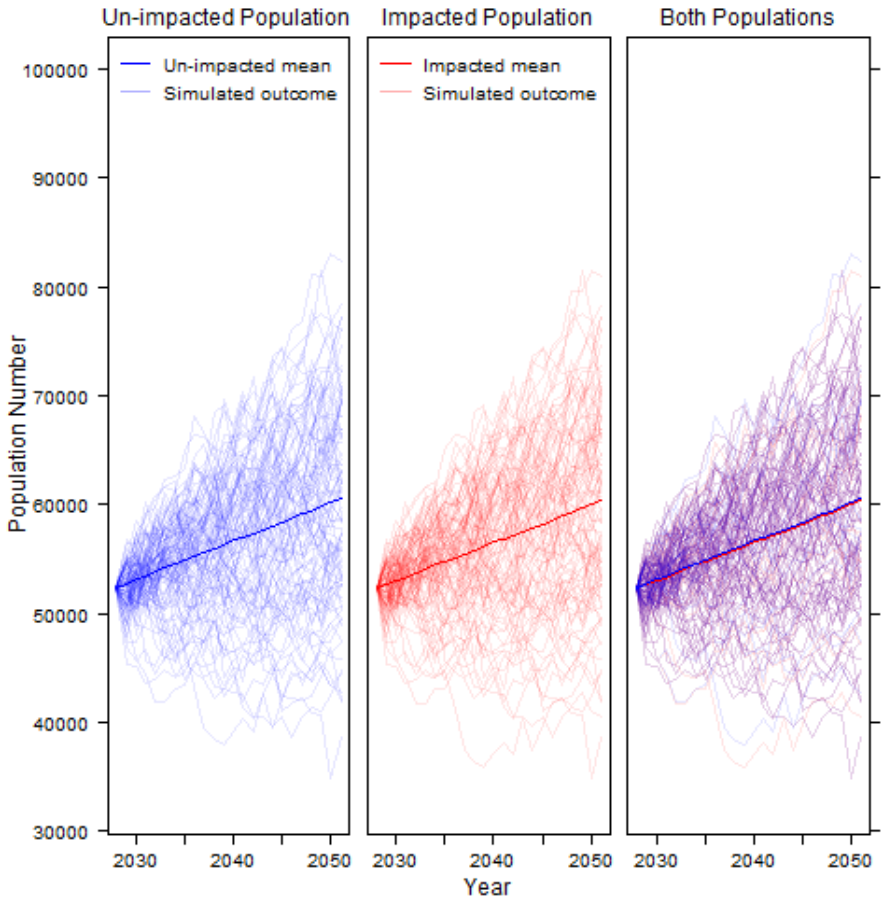

Figure 3.16: Simulated Grey Seal Population Trajectories in an Un-impacted Versus Impacted Population, for Cumulative Scenario GSC1

Table 3.16: Modelled Estimates for the Un-impacted and Impacted Grey Seal Populations and Counterfactuals of Population Size for Cumulative Scenario GSC1. Bold lines indicate piling years at the Proposed Development

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Cenos (Semi-sub)	Cenos (OSP)	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
1	52,356	52,356	1.000	1.000	2028			■				■							
2	52,600	52,599	1.000	1.000	2029			■	■			■				■	■		
3	53,090	52,995	1.000	0.998	2030			■	■			■	■			■	■		
4	53,415	53,252	1.000	0.997	2031	■				■	■	■	■	■	■	■	■	■	■
5	53,822	53,668	1.000	0.997	2032	■						■	■	■				■	■
6	54,265	54,117	1.000	0.997	2033	■	■							■				■	■
7	54,617	54,478	1.000	0.997	2034													■	■
8	54,866	54,706	1.000	0.997	2035													■	■
9	55,272	55,094	1.000	0.997	2036													■	■
10	55,642	55,463	1.000	0.997	2037													■	■
11	55,992	55,814	1.000	0.997	2038														■
12	56,305	56,126	1.000	0.997	2039														
13	56,755	56,577	1.000	0.997	2040														
14	57,022	56,844	1.000	0.997	2041														
15	57,268	57,091	1.000	0.997	2042														
16	57,647	57,468	1.000	0.997	2043														

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Cenos (Semi-sub)	Cenos (OSP)	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)	Ossian (Wind Turbine)	Ossian (OSP)
17	57,979	57,799	1.000	0.997	2044														
18	58,269	58,088	1.000	0.997	2045														
19	58,679	58,498	1.000	0.997	2046														
20	59,122	58,938	1.000	0.997	2047														
21	59,406	59,223	1.000	0.997	2048														
22	59,895	59,710	1.000	0.997	2049														
23	60,281	60,096	1.000	0.997	2050														
24	60,584	60,398	1.000	0.997	2051														
25	61,011	60,823	1.000	0.997	2052														
26	61,439	61,250	1.000	0.997	2053														

3.4.6 At time point 4 (2031), which corresponds to the 1st year of piling at the Proposed Development and also piling at all cumulative projects except Aspen OWF, the difference between impacted and un-impacted populations was 163 animals (which equates to 0.31% of the combined SMUs reference population) (Table 3.16). It is important to highlight that the three years prior also includes piling at Aspen, Caledonia, and Muir Mhòr OWFs, and therefore there is an increased cumulative effect on grey seal prior to the start of Proposed Development's piling campaign (see Figure 3.16), with a difference between the impacted and un-impacted populations of 95 animals (0.18% of the combined SMUs reference population) at time point 3 (2030) before piling commences at Proposed Development (Table 3.16). The median counterfactual of population size at time point 4 was 1.000, while the mean counterfactual was 0.997.

3.4.7 At time point 5 (2032), which corresponds to the 2nd year of piling at the Proposed Development and consecutive piling at Caledonia, Cenos, and Ossian OWFs, the difference between impacted and un-impacted populations is 154 animals (which equates to 0.29% of the combined SMUs reference population) (Table 3.16). It is important to note that a fixed reference population (see Table 2.3) is used to calculate proportions of the MU impacted and does not reflect any possible increase in MU size. The median counterfactual of population size at time point 5 was 1.000, while the mean counterfactual was 0.997.

3.4.8 At time point 6 (2033), which corresponds to the final year of piling at the Proposed Development and consecutive piling at Ossian and Cenos OWFs, and following the end of piling at Berwick Bank OWF (in 2031) and Caledonia OWF (in 2032), the difference between impacted and un-impacted populations is 148 animals (which equates to 0.28% of the combined SMUs reference population) (Table 3.16). The median counterfactual of population size at time point 6 was 1.000, while the mean counterfactual was 0.997.

3.4.9 At time point 12 (2039), six years after the end of piling at the Proposed Development and end of all piling at CEA projects, the difference between impacted and un-impacted populations is 179 animals (which equates to 0.34% of the combined SMUs reference population) (Table 3.16). The median counterfactual of population size at time point 12 was 1.000, while the mean counterfactual was 0.997.

3.4.10 At time point 26 (2053) (the final year modelled), 20 years after the end of piling at the Proposed Development, the difference between impacted and un-impacted populations is 189 animals (which equates to 0.36% of the combined SMUs reference population (Table 3.16). The median counterfactual of population size at time point 26 was 1.000, while the mean counterfactual was 0.997.

3.4.11 Given that the difference in the impacted to un-impacted populations approaches a median and mean ratio of one throughout, there is considered to be no potential for a long term population-level effect from this cumulative piling scenario upon grey seal.

3.5 Harbour Seal

Scenario HS01: Maximum Temporal Scenario

3.5.1 Results for the maximum temporal scenario indicate no difference in the population trajectory of harbour seal between the un-impacted population and impacted populations (Figure 3.17). At all time points, there was no difference in the mean size of the impacted and un-impacted populations (Table 3.17). Therefore, the median and mean counterfactuals for this scenario stayed at one through the 26-year simulation (Table 3.17). There is not considered to be a potential for a long term effect from this piling scenario upon harbour seal within the Moray Firth SMU and East Scotland SMU.

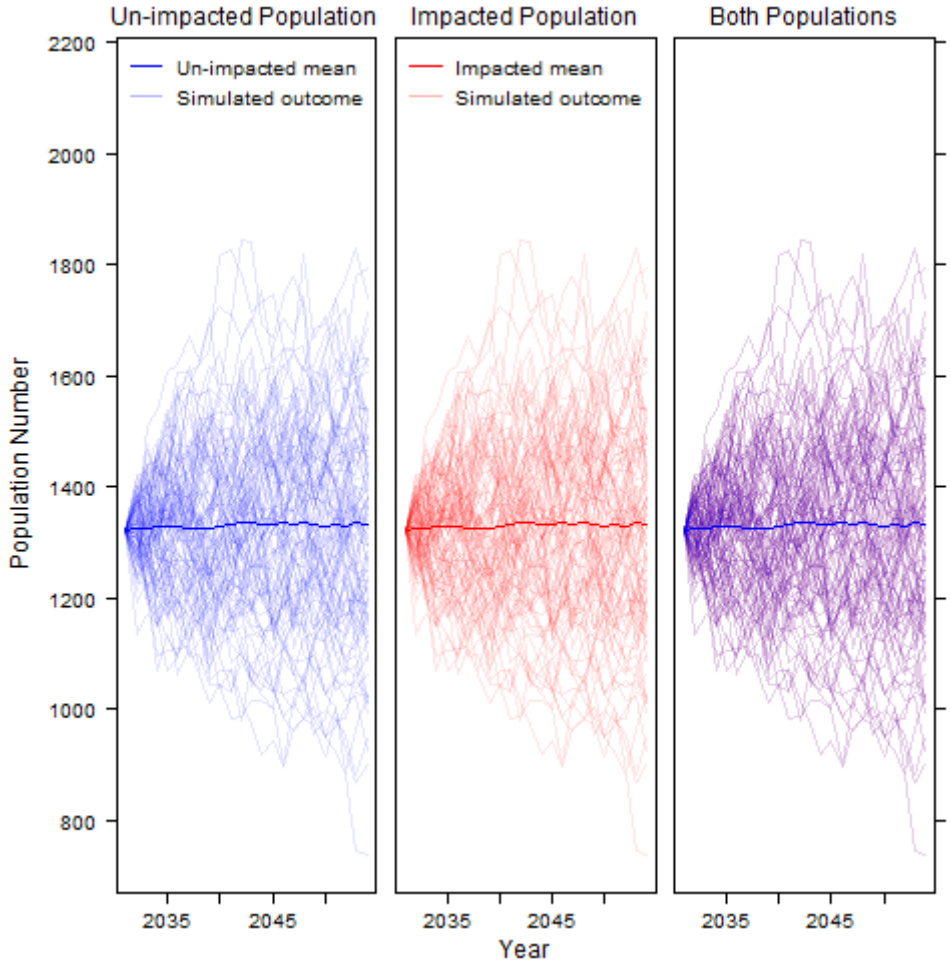

Figure 3.17: Simulated Harbour Seal Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Temporal Scenario HS01

Table 3.17: Modelled Estimates for the Un-impacted and Impacted Harbour Seal Populations and Counterfactuals of Population Size for the Maximum Temporal Scenario GS01

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	1,324	1,200	1,428	1,324	1,200	1,428	1.0000	1.0000
3	1,326	1,186	1,464	1,326	1,186	1,464	1.0000	1.0000
4	1,328	1,170	1,490	1,328	1,170	1,490	1.0000	1.0000
7	1,327	1,122	1,566	1,327	1,122	1,566	1.0000	1.0000
11	1,332	1,062	1,642	1,332	1,062	1,642	1.0000	1.0000
16	1,335	1,016	1,710	1,335	1,016	1,710	1.0000	1.0000
26	1,331	914	1,802	1,331	914	1,802	1.0000	1.0000

Scenario HS02: Maximum Spatial Scenario

3.5.2 Results for the maximum spatial scenario indicate no difference in the population trajectory of harbour seal between the un-impacted population and impacted populations (Figure 3.18). At all time points, there was no difference in the size of the impacted and un-impacted populations (Table 3.18). This indicates that there would not be a long term effect from piling at the Proposed Development upon the harbour seal population within the Moray Firth SMU and East Scotland SMU.

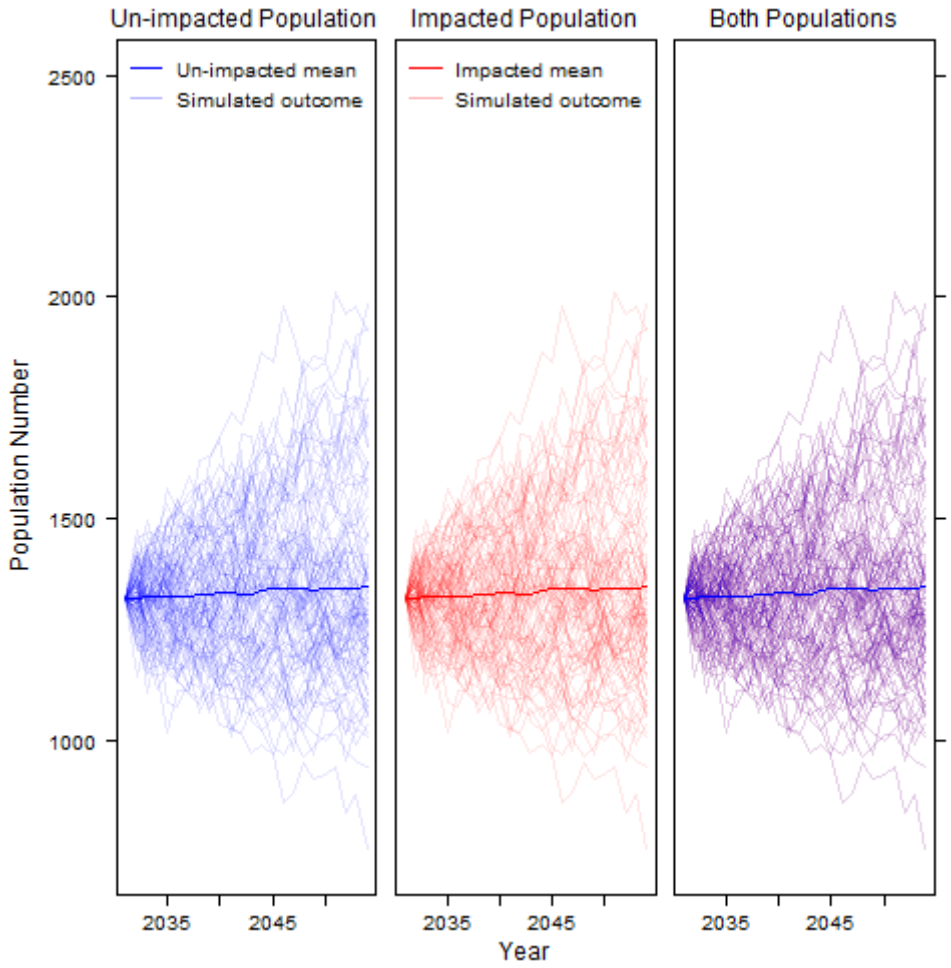

Figure 3.18: Simulated Harbour Seal Population Trajectories in an Un-impacted Versus Impacted Population, for the Maximum Spatial Scenario GS02

Table 3.18: Modelled Estimates for the Un-impacted and Impacted Harbour Seal Populations and Counterfactuals of Population Size for the Maximum Spatial Scenario GS02

Time Point	Un-impacted Population (Number of Animals)			Impacted Population (Number of Animals)			Counterfactual	
	Mean	Lower 2.5%	Upper 97.5%	Mean	Lower 2.5%	Upper 97.5%	Median	Mean
2	1,323	1,206	1,434	1,323	1,206	1,434	1.0000	1.0000
3	1,325	1,180	1,468	1,325	1,180	1,468	1.0000	1.0000
4	1,323	1,158	1,488	1,323	1,158	1,488	1.0000	1.0000
7	1,327	1,106	1,564	1,327	1,106	1,564	1.0000	1.0000
11	1,333	1,050	1,648	1,333	1,050	1,648	1.0000	1.0000
16	1,343	1,010	1,722	1,343	1,010	1,722	1.0000	1.0000
26	1,347	960	1,828	1,347	960	1,828	1.0000	1.0000

3.5.3 The median and mean counterfactuals for scenario HS02 remained at 1.0000 throughout the 26-year simulation. Given that the differences in impacted to un-impacted populations approaches a ratio of one there is considered to be no potential for a long term effect from this piling scenario upon harbour seal.

Scenario HSC1: Cumulative Scenario

3.5.4 For scenario HSC1, the simulated trajectories of harbour seal between the un-impacted population and impacted population (Figure 3.19) demonstrate that there is difference between the two scenarios, with populations showing recovery from 2038. Across the model run, the difference between the mean impacted and un-impacted population was between zero to two animals throughout (which equates to 0.15% of the combined SMUs reference population).

3.5.5 Table 3.19 presents the modelled population estimates for the impacted and un-impacted harbour seal populations, alongside the median and mean counterfactuals and years of piling per project (shaded blue). Results are interpreted focusing on key time points in the model (Table 2.12), which gives context to the modelled scenarios.

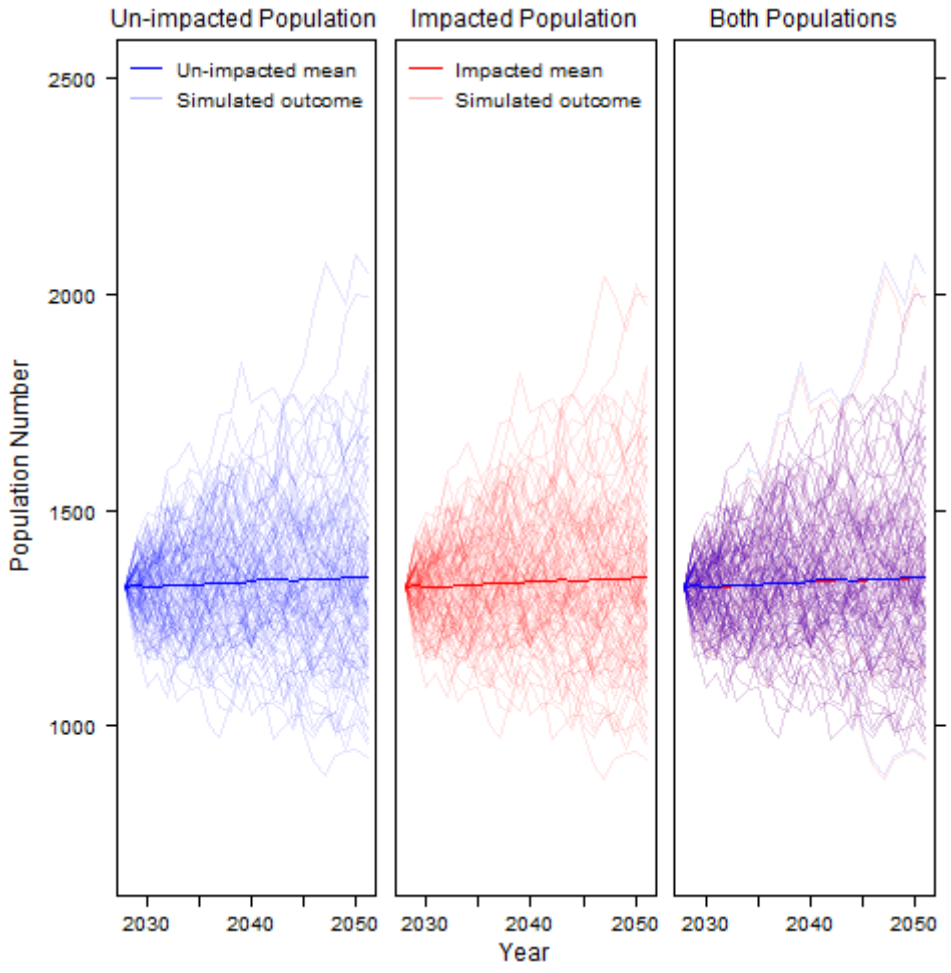

Figure 3.19: Simulated Harbour Seal Population Trajectories in an Un-impacted Versus Impacted Population, for Cumulative Scenario HSC1

Table 3.19: Modelled Estimates for the Un-impacted and Impacted Harbour Seal Populations and Counterfactuals of Population Size for Cumulative Scenario HSC1. Bold lines indicate piling years at the Proposed Development

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)
1	1,322	1,322	1.000	1.000	2028										
2	1,325	1,325	1.000	1.000	2029										
3	1,324	1,322	1.000	0.999	2030										
4	1,324	1,322	1.000	0.998	2031										
5	1,326	1,324	1.000	0.999	2032										
6	1,327	1,325	1.000	0.999	2033										
7	1,328	1,326	1.000	0.999	2034										
8	1,328	1,327	1.000	0.999	2035										
9	1,331	1,329	1.000	0.999	2036										
10	1,332	1,330	1.000	0.999	2037										
11	1,333	1,332	1.000	0.999	2038										
12	1,334	1,332	1.000	0.999	2039										
13	1,336	1,335	1.000	0.999	2040										
14	1,339	1,337	1.000	0.999	2041										
15	1,340	1,338	1.000	0.999	2042										
16	1,341	1,339	1.000	0.999	2043										

Time Point	Un-impacted population mean	Impacted population mean	Median counterfactual	Mean counterfactual	Year	Proposed Development (Wind Turbine)	Proposed Development (OSP)	Aspen (Wind Turbine)	Aspen (OSP)	Berwick Bank (Jacket Foundation)	Berwick Bank (OSP)	Caledonia (Jacket)	Caledonia (Anchors)	Muir Mhòr (Wind Turbine)	Muir Mhòr (OEP)
17	1,338	1,337	1.000	0.999	2044										
18	1,339	1,338	1.000	0.999	2045										
19	1,340	1,339	1.000	0.999	2046										
20	1,343	1,341	1.000	0.999	2047										
21	1,341	1,340	1.000	0.999	2048										
22	1,343	1,342	1.000	0.999	2049										
23	1,345	1,343	1.000	0.999	2050										
24	1,345	1,343	1.000	0.999	2051										
25	1,344	1,343	1.000	0.999	2052										
26	1,347	1,345	1.000	0.999	2053										

3.5.6 At time point 4 (2031), which corresponds to the 1st year of piling Proposed Development and also piling at Berwick Bank, Caledonia and Muir Mhòr OWFs, the difference between impacted and un-impacted populations is two animals (which equates to 0.15% of the combined SMUs reference population) (Table 3.19). It is important to highlight that the three years prior also includes piling at Aspen, Caledonia and Muir Mhòr OWFs and therefore there is already an increased cumulative effect on harbour seal prior to the start of Proposed Development's piling campaign (see Figure 3.19). The median counterfactual of population size at time point 4 was 1.000, while the mean counterfactual was 0.998.

3.5.7 At time point 5 (2032), which corresponds to the 2nd year of piling Proposed Development and the final year of piling at Caledonia OWF, the difference between impacted and un-impacted populations is two animals (which equates to 0.15% of the combined SMUs reference population) (Table 3.19). It is important to note that a fixed reference population (see Table 2.3) is used to calculate proportions of the MU impacted and does not reflect any possible increase in MU size. The median counterfactual of population size at time point 5 was 1.000, while the mean counterfactual was 0.999.

3.5.8 At time point 6 (2033), which corresponds to the final year of Proposed Development and following the end of piling at Berwick Bank and Muir Mhòr OWFs (both in 2031) and Caledonia OWF (in 2032), the difference between impacted and un-impacted populations is two animals (which equates to 0.15% of the combined SMUs reference population) (Table 3.19). The median counterfactual of population size at time point 6 was 1.000, while the mean counterfactual was 0.999.

3.5.9 At time point 12 (2039), six years after the end of piling at the Proposed Development and end of all piling at CEA projects, the difference between impacted and un-impacted populations is two animals (which equates to 0.15% of the combined SMUs reference population) (Table 3.19). The median counterfactual of population size at time point 12 was 1.000, while the mean counterfactual was 0.999.

3.5.10 At time point 26 (2053) (the final year modelled), 20 years after the end of piling at the Proposed Development, the difference between impacted and un-impacted populations is also two animals (which equates to 0.15% of the combined SMUs reference population) (Table 3.19). The median counterfactual of population size at time point 26 was 1.000, while the mean counterfactual was 0.999.

3.5.11 Given that the difference in the impacted to un-impacted populations approaches a median and mean ratio of one throughout, there is considered to be no potential for a long term population-level effect from this cumulative piling scenario upon harbour seal.

4 Summary

4.1.1 This Technical Report presents the results of iPCoD modelling for harbour porpoise, bottlenose dolphin, minke whale, grey seal and harbour seal populations as a result of Proposed Development alone and cumulatively with other projects. The numbers of animals potentially experiencing disturbance were based on two MDSs. The maximum temporal scenario was of a combination of Wind Turbine and OSP jacket foundation piling at 4,500 kJ across 304 days (Table 2.1). The maximum spatial scenario was for monopile installation for Wind Turbine foundations, with a maximum hammer energy of 6,250 kJ, and jacket foundation piling for OSPs with a maximum hammer energy of 4,500 kJ, over a total of 29 days (Table 2.2). The iPCoD modelling presented represents a conservative precautionary assessment, which uses maximum hammer energies for the different foundation types at all piling locations as the MDS.

4.1.2 The results suggest that, even with the conservative assumptions made, there would be no population-level effects for any of the species investigated as a result of piling at the Proposed Development alone or for all species, except harbour porpoise, when considered alongside cumulative projects.

4.1.3 There is considered potential for a long term population-level effect from this cumulative piling scenario upon harbour porpoise within the North Sea MU. However, it is important to highlight the Proposed Development's negligible relative contribution to this cumulative effect, given the high level of activity expected in the Regional Marine Mammal Study Area.

4.1.4 The assessment adopted a precautionary approach throughout, considering the MDS, precautionary demographic parameters for each species, conservative assumptions in the noise modelling and conservative estimates for the densities of key species to apply to the quantitative assessment.

4.1.5 Variation in demographic rates between years may exist as a result of changes in environmental conditions, as a result of random processes or chance events which impact vital rates (e.g. survival, fertility, etc.), or other sources of heterogeneity. In two, otherwise identical populations that experience exactly the same sequence of environmental conditions, demographic stochasticity will mean populations could follow slightly different trajectories over time.

4.1.6 These models assume that the effects of environmental variation on survival and fertility are adequately reflected by the range of values obtained from the expert elicitation (and shown in the spread of simulated trajectories around the means). In addition, the models assume that survival and fertility rates are not density-dependent and are therefore not affected by population size.

4.1.7 While it is understood that iPCoD is a relatively simple population model (simulating the link between days of disturbance and changes in individual vital rates), the most obvious sources of uncertainty are considered to have been adequately captured in the development of these models. In addition, the precautionary approach applied throughout the marine mammal assessment has been adopted to buffer the uncertainties with respect to how animals respond to repeated piling over time.

References

Booth, C. and Heinis, F. (2018). Updating the Interim PCoD Model: Workshop Report - New transfer functions for the effects of permanent threshold shifts on vital rates in marine mammal species. Report Code SMRUC-UOA-2018-006, submitted to the University of Aberdeen and Department for Business, Energy and Industrial Strategy (BEIS), June 2018 (unpublished) pp.34.

Booth, C., Heinis, F. 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. SMRU Consulting pp.28.

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, pp.205-216. DOI:10.3354/meps08888.

Caledonia OWF Limited (2024). Volume 7B Proposed Development (Offshore) Appendices. Appendix 7-4 Marine Mammals Population Modelling (iPCoD). Caledonia Offshore Wind Farm Environmental Impact Assessment. Ocean Winds pp.116.

Carter, M. I. D., Bivins, M., Duck, C. D., Hastie, G. D., Morris, C. D., Moss, S. E. W., Thompson, D., Thompson, P. M., Vincent, C. and Russell, D. J. F. (2025). Updated Habitat-Based At-Sea Distribution Maps for Harbour and Grey Seals in Scotland. Sea Mammal Research Unit. University of St Andrews

Carter, M. I. D., Boehme, L., Cronin, M. A., Duck, C. D., Grecian, W. J., Hastie, G. D., Jessopp, M., Matthiopoulos, J., McConnell, B. J., Miller, D. L., Morris, C. D., Moss, S. E. W., Thompson, D., Thompson, P. M. and Russell, D. J. F. (2022). Sympatric Seals, Satellite Tracking and Protected Areas: Habitat-Based Distribution Estimates for Conservation and Management. Frontiers in Marine Science, 9, pp.18. DOI:10.3389/fmars.2022.875869.

Cenos Offshore Windfarm Limited. (2024). Appendix 18 – Interim Population Consequences of Disturbance (iPCoD) Modelling Report. pp.44.

Cerulean Winds. (2025). Volume 3, Appendix 11.2: iPCoD Modelling Report. Aspen Offshore Wind Farm Offshore Environmental Impact Assessment Report pp.44.

Cheney, B. J., Arso Civil, M., Hammond, P. S. and Thompson, P. M. (2024). Site Condition Monitoring of bottlenose dolphins within the Moray Firth Special Area of Conservation 2017-2022.

Ellison, W. T., Southall, B. L., Clark, C. W. and Frankel, A. S. (2012). A new context-based approach to assess marine mammal behavioral responses to anthropogenic sounds. Conserv Biol, 26 (1), pp.21-8. DOI:10.1111/j.1523-1739.2011.01803.x.

Gilles, A., Authier, M., Pigeault, R., Ramirez-Martinez, N. C., Benoit, V., Carlström, J., Eira, C., Geelhoed, S. C. V., Laran, S., Sequeira, M., Sveegaard, S., Taylor, N. L., Saavedra, C., Vázquez-Bonales, J. A. and Hammond, P. S. (2025). Spatial models of cetacean density in European Atlantic waters based on SCANS-IV summer 2022 survey data. Final report published 14 May 2025. pp.51.

Graham, I. M., Merchant, N. D., Farcas, A., Barton, T. R., Cheney, B., Bono, S. and Thompson, P. M. (2019). Harbour porpoise responses to pile-driving diminish over time. Royal Society Open Science, 6 (6), pp.190335. DOI:doi:10.1098/rsos.190335.

Harwood, J., King, S., Schick, R., Donovan, C. and Booth, C. (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. Scottish Marine and Freshwater Science Volume 5 Number 2. Marine Scotland Science pp.90.

Houston, A. I., Prosser, E. and Sans, E. (2012). The cost of disturbance: a waste of time and energy? Oikos, 121 (4), pp.597-604.

IAMMWG. (2022). Updated abundance estimates for cetacean Management Units in UK waters. JNCC Report No. 680 (Revised March 2022). Joint Nature Conservation Committee. Peterborough. 0963-8091. pp.22.

King, S. L., Schick, R. S., Donovan, C., Booth, C. G., Burgman, M., Thomas, L., Harwood, J. and Kurle, C. (2015). An interim framework for assessing the population consequences of disturbance. Methods in Ecology and Evolution, 6 (10), pp.1150-1158. DOI:10.1111/2041-210x.12411.

Lacey, C., Gilles, A., Börjesson, P., Herr, H., Macleod, K., Ridoux, V., Santos, M. B., Scheidat, M., Teilmann, J., Sveegaard, S., Vingada, J., Viquerat, S., Øien, N. and Hammond, P. S. (2022). Modelled density surfaces of cetaceans in European Atlantic waters in summer 2016 from the SCANS-III aerial and shipboard surveys. SCANS-III project report 2. University of St Andrews. UK pp.31.

Marwood, E. M. and Stevens, A. (2024). Seal Haul-Out and telemetry data in relation to the Bowdun Offshore Wind Farm. Submitted to Tetra Tech Rps Energy Limited and Bowdun Offshore Wind Farm. Report number SMRUC-RPS-2024-015.

Muir Mhòr Offshore Wind Farm. (2024). Volume 2, Chapter 12: Marine Mammals. Muir Mhòr Offshore Wind Farm Environmental Impact Assessment Report pp.242.

Ørsted. (2018). Hornsea Project Three Offshore Wind Farm Environmental Statement: Volume 5, Annex 4.1 – Marine Mammal Technical Report. Hornsea Project Three Offshore Wind Farm Environmental Statement pp.143.

Ørsted. (2021). Hornsea Project Four: Environmental Statement Volume A5, Annex 4.1: Marine Mammal Technical Report.

Ossian OWFL. (2024). Volume 3: Appendix 10.3: Marine Mammals iPCod Modelling Report. Array EIA Report

Posit team. (2023). RStudio: Integrated Development Environment for R. Boston, MA: Posit Software, PBC.

R Core Team. (2023). R: A Language and Environment for Statistical Computing. Vienna: R Foundation for Statistical Computing.

RWE Renewables UK. (2021). PEIR: Volume 2, Chapter 7: Marine Mammals. Awel y Môr Offshore Wind Farm Preliminary Environmental Information Report. Awel y Môr Offshore Wind Farm pp.185pp.

RWE Renewables UK. (2024). Volume 7 Appendix 11-4 iPCoD Modelling. Dogger Bank South Offshore Wind Farms Environmental Statement pp.25.

SCOS. (2022). Scientific Advice on Matters Related to the Management of Seal Populations: 2022. Natural Environment Research Council, Special Committee on Seals pp.206.

Scottish Government. (2020). Sectoral Marine Plan for Offshore Wind Energy. The Scottish Government. Edinburgh, Scotland pp.78.

Sinclair, R. R., Booth, C. G., Harwood, J. and Sparling, C. E. (2019). Helpfile for the interim PCoD v5 model. SMRU Consulting pp.63.

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 Vol 11 No 14. Marine Scotland Science

SMRU Consulting. (2025). Population Consequences of Disturbance [Online]. Available at: https://www.smruconsulting.com/population-consequences-of-disturbance-pcod. Accessed on: September 2025.

SSE Renewables. (2022). Appendix 10.4: Marine mammal iPCoD modelling report. Berwick Bank Wind Farm Offshore Environmental Impact Assessment pp.33.

Whyte, K. F., Russell, D. J. F., Sparling, C. E., Binnerts, B. and Hastie, G. D. (2020). Estimating the effects of pile driving sounds on seals: Pitfalls and possibilities. The Journal of the Acoustical Society of America, 147 (6), pp.3948. DOI:10.1121/10.0001408.