Morven South Offshore Wind Array Project

Environmental Impact Assessment Report

Volume 3, Annex 10.5: Marine Mammals Interim Population Consequences of Disturbance (iPCoD) Modelling Report

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1 Introduction

1.1 Overview

1.1.1.1 The Morven South Offshore Wind Array Project (hereafter, "Morven South") is located within Scottish offshore waters (Figure 1.1). Morven South is located approximately 86.1km from the Aberdeenshire coast (at its closest point) and will comprise wind turbines, Offshore Substation Platforms (OSPs), associated foundations, inter-array and interconnector cables and cable protection. Consent for the offshore export cables of Morven South will be sought separately.

1.1.1.2 This Interim Population Consequences of Disturbance (iPCoD) Report presents the modelling undertaken to assess potential impacts upon marine mammal populations due to impact piling occurring within construction activities at Morven South alone and cumulatively with other plans, projects and activities.

1.1.1.3 Consent for Morven will be aided by the development of a separate Environmental Impact Assessment (EIA) and Habitats Regulations Appraisal (HRA). To enable the assessment of cumulative effects, modelling has been undertaken for Morven South and the Morven North Offshore Wind Array Project (hereafter "Morven North"). The modelling outcomes for Morven South are presented here.

1.1.1.4 An EIA has been undertaken to determine the potential impacts of Morven South on marine mammals. A key impact to marine mammal receptors is the potential for elevated underwater sound during piling to lead to injury and behavioural disturbance. Underwater sound modelling was undertaken to predict the potential spatial scale of the impact of piling associated within Morven South (see Volume 3, Annex 10.2: Underwater Sound Shared Technical Report).

1.1.1.5 IPCoD modelling was carried out to determine the potential for a short to medium-term exposure to piling, which could occur intermittently within a 12 month piling period, during the five year offshore construction phase (expected to occur between 2033 to 2037, inclusive), to result in long-term population level effects on any marine mammal species for which population modelling is possible within the iPCoD framework. "Short-term" in this context 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 12 months) and "long-term" refers to the period of time over which iPCoD models are able to robustly predict population trajectories (i.e. up to 25 years).

1.1.1.6 The iPCoD model (developed by the Sea Mammal Research Unit (SMRU) with a team of researchers at the University of St Andrews), was adopted to simulate the potential changes in marine mammal population over time and is described within Section 2. This approach to modelling was agreed in consultation with Marine Directorate - Licensing Operations Team (MD-LOT) and NatureScot during the initial scoping process (MD-LOT, 2023)

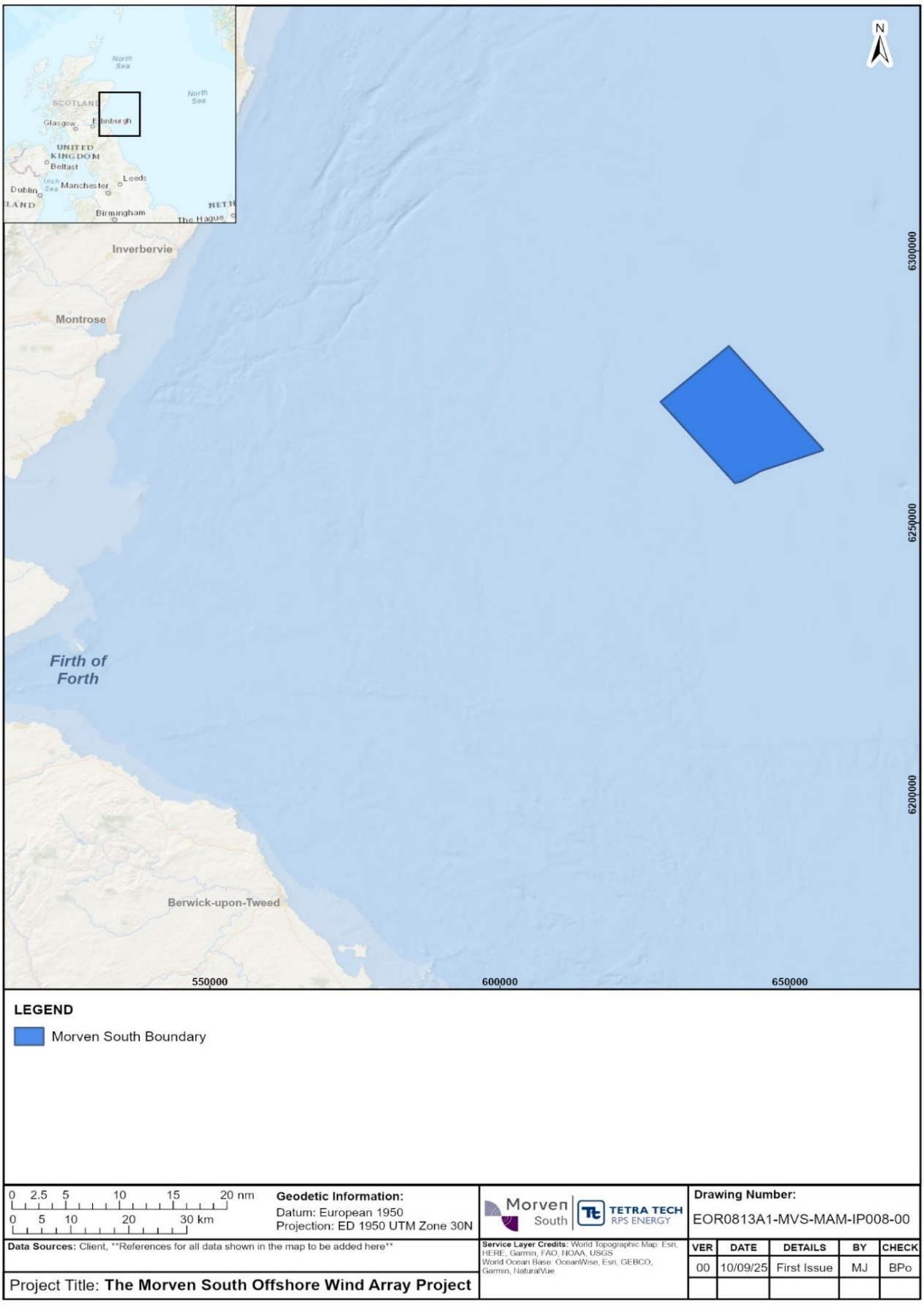

Figure 1.1: The Morven South Boundary

1.2 Background

1.2.1.1 The iPCoD model simulates the potential changes in a marine mammal population over time, for both a "impacted" and an "unimpacted population". This allows a comparison of the type of changes in a population that may result from natural environmental variation, demographic stochasticity (i.e. natural 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, including Ossian Offshore Wind Farm Limited (Ossian OWFL, 2024), Berwick Bank Wind Farm (SSE Renewables, 2022), Mona Offshore Wind Farm (Mona Offshore Wind Ltd, 2025) and the Hornsea Projects (Ørsted, 2018, 2021).

1.2.1.2 The iPCoD model is based on expert elicitation, a widely accepted process in conservation science wherein the opinions of many experts are combined when there is an urgent need for decisions to be made but a lack of empirical data with which to inform them (Donovan *et al.*, 2016). The marine mammal experts, detailed in Sinclair *et al.* (2020), were consulted on their opinion on how changes in hearing resulting from Permanent Threshold Shift (PTS) and behavioural disturbance (equivalent to a score of 5* or higher on the "behavioural severity scale" in Southall *et al.* (2007)) associated with offshore renewable energy developments and how they affect calf and juvenile survival, and the probability of giving birth (Harwood *et al.*, 2014). The marine mammal experts were then asked to estimate values for two parameters which determine the shape of the relationships between the number of days of disturbance experienced by an individual and its vital rates, thus providing parameter values for functions that form part of the iPCoD model (Harwood *et al.*, 2014).

1.2.1.3 The relationship between disturbance and survival and reproduction assumes that individual marine mammals 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 marine mammal's ability to provide care for young, evade predators or resist disease would likely be affected, and effects would be reflected in changes to vital rates. However, it should be noted 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 marine mammals that may be affected by disturbance to iteratively project the size of the population.

1.2.1.4 Following the initial development of the iPCoD model, a study was undertaken to update the transfer functions on the effects of PTS and disturbance on the probability of survival and giving birth to viable young for harbour porpoise (*Phocoena Phocoena)*, harbour seal (*Phoca vitulina)* and grey seal (*Halichoerus grypus)* (again via expert elicitation) (Booth and Heinis, 2018, Booth *et al.*, 2019). The iPCoD model has since been updated in light of additional work undertaken after 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).

1.2.1.5 A potential limitation of the iPCoD model is that 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 by Harwood *et al.* (2014), the concept of density dependence is fundamental to understanding how animal populations respond to a reduction in population size. Population growth can be limited by density dependent factors, such as resource availability or competition for space. 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 could then allow the population to expand back to previous levels at which density-dependent factors become limiting again (i.e. population remains at carrying capacity).

1.2.1.6 The limitations for assuming a simple linear ratio between the maximum net productivity level and carrying capacity of a population were highlighted by Taylor and DeMaster (1993), as simple models which demonstrated that density dependence is likely to involve several biological parameters which themselves have biological limits (e.g. fecundity and survival). However, for UK populations of

harbour porpoise (and other marine mammal species), there is no published evidence for density dependence and, therefore, density dependence assumptions are not currently included within the iPCoD protocol.

1.2.1.7 The iPCoD model v5.2 (Harwood *et al.*, 2014) was developed using the program R v4.3.1 (R Core Team, 2023) with RStudio v 2023.12.0+369 (Posit team, 2023) as the user interface. To enable the iPCoD model to run, the following data were provided:

- reference population size (Section 2.2.2) and demographic parameters (Section 2.2.3) for the key species;
- user-specified input parameters (such as residual days of disturbance Section 2.2.4);
- number of animals predicted to experience PTS and/or disturbance during piling (Section 2.2.5);
- estimated piling schedule during the proposed construction programme (Section 2.3).

2 Methodology

2.1 Maximum Design Scenario

2.1.1.1 The Maximum Design Scenario (MDS) for piling operations at Morven South has been defined on the basis that up to 528 piles would be installed. Full details of the MDS are presented in Volume 2, Chapter 10: Marine Mammals.

2.1.1.2 Note that due to the large number of options presented in Volume 1, Chapter 3: Project Description, the underwater sound modelling selected three conservative pile types to represent the suite of different options available, with further details provided in Volume 2, Chapter 10: Marine Mammals.

2.1.2 Maximum Temporal Scenario

2.1.2.1 The maximum temporal scenario, leading to the greatest number of days of piling, is based on single piling of pin piles for jacket foundations. The assessment therefore focussed on the longest duration of piling and the greatest number of days over which piling could occur and is summarised in Table 2.1.

Table 2.1: Summary of the maximum temporal scenario used in iPCoD modelling for piling at Morven South

Piling activity	Number of piled locations	Number of piles	Maximum hammer energy (kJ)	Average piles installed per 24 hours	Number of vessels	Maximum piling days (24 hours)
Wind turbine foundations: 3.7m pin pile	95	380	4,000	2	1	190
OSP (AC collector): 4.5m pin pile	4	96	4,000	2	1	48
OSP (DC collector): 5m pin pile	2	48	4,000	2	1	24
Total	**101**	**524**	N/a	N/a	N/a	**262**

2.1.3 Maximum Spatial Scenario

2.1.3.1 For the maximum spatial scenario, the largest hammer energy and maximum spacing between concurrent piling events would lead to the largest spatial area of ensonification at any one time although this would reduce the time required for piling operations overall. Modelling assumed maximum spacing between concurrent piling locations represents the highest risk of behavioural effects due to the large spatial area of ensonification whilst minimum spacing between piling locations represents the highest risk of injury to marine mammals as underwater sound from adjacent foundations could combine to produce a greater radius of effect compared to a single piling event.

2.1.3.2 It is estimated that piling will take place between Q4 2034 and Q3 2035 (inclusive) during the construction phase of Morven South. Piling could potentially take place at any point within the construction phase, however, for the purposes of developing the piling schedule for iPCoD (a

requirement of the model) an indicative piling programme was developed based on a realistic installation approach with piling spread across the two calendar years, discussed in Section 2.3.

2.1.3.3 A summary of the maximum spatial scenario for Morven South is presented in Table 2.2.

Table 2.2: Summary of the maximum spatial scenario used in the iPCoD modelling for piling at Morven South

Piling activity	Number of piled locations	Number of piles	Maximum hammer energy (kJ)	Average piles installed per 24 hours	Number of vessels	Maximum piling days (24 hours)
Wind turbine foundations: 16m monopile	67	67	6,600	1	2	34
OSP (AC collector): 16m monopile	4	4	6,600	1	2	2
OSP (DC collector): 5m pin pile	2	48	4,000	2	2	12
Total	**73**	**119**	N/a	N/a	N/a	**48**

2.2 Marine Mammals

2.2.1.1 The marine mammal species included in the iPCoD model were those that were determined to be Important Ecological Features (IEFs) within the Morven North and Morven South Regional Marine Mammal Study Area, following a detailed baseline assessment, and for which a population model in iPCoD was available.

2.2.1.2 The baseline characterisation (presented in Volume 3, Annex 10.1: Marine Mammals Shared Baseline Technical Report) identified the following marine mammal IEFs as of international importance:

- harbour porpoise;
- bottlenose dolphin (*Tursiops truncatus*);
- white-beaked dolphin (*Lagenorhynchus albirostris*);
- minke whale (*Balaenoptera acutorostrata*);
- humpback whale (*Megaptera novaeangliae*);
- grey seal;
- harbour seal.

2.2.1.3 There are currently no parameters available to construct a suitable population model for white-beaked dolphin or humpback whale in the iPCoD framework. Furthermore, humpback whale was only assessed qualitatively in the assessment and therefore, population modelling for these species was not possible for this assessment. The marine mammal IEFs included in the iPCoD modelling were:

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

2.2.2 Reference Populations

2.2.2.1 Population estimates based upon Management Units (MUs) and seal MUs were specified in the iPCoD models as the reference populations against which any effects (i.e. number of animals experiencing injury or disturbance) were assessed. Relevant MUs and seal MUs were determined by their proximity or overlap with Morven South.

2.2.2.2 For harbour porpoise, bottlenose dolphin, and minke whale, only one MU for each species was considered relevant to the assessment for Morven South, as detailed in Table 2.3. The respective population estimates for each species' MU have been used for the iPCoD modelling:

- North Sea MU for harbour porpoise (Figure 2.1);
- Greater North Sea MU for bottlenose dolphin (Figure 2.2);
- Celtic and Greater North Seas MU for minke whale (Inter-Agency Marine Mammal Working Group (IAMMWG, (2022, 2023)) (Figure 2.3).

2.2.2.3 In addition, the Coastal East Scotland MU for bottlenose dolphin is located in proximity to the Morven South Boundary, although does not overlap (see

2.2.2.4 Figure 2.2). The underwater sound contours associated with piling at Morven South did not extend to the boundary of this MU, so this was not included in the iPCoD modelling for Morven South alone. However, to ensure a precautionary approach to the cumulative models, the Coastal East Scotland and Greater North Sea MU populations were combined, given that some of the cumulative projects had included one or both of these MUs within their respective iPCoD models. Further detail is provided in paragraph 2.4.1.9, Section 3.1.3.1, and Table 2.12.

2.2.2.5 For grey seal and harbour seal, two seal MUs were considered: the East Scotland Seal MU and the Northeast England Seal MU (Figure 2.4). For the seal species, the reference population presented in Table 2.3 comprises the sum of the population estimates for both seal MUs.

Table 2.3: Reference populations applied to the iPCoD modelling

Species	MU/Seal MU	Population estimate (number of animals)	Reference
Harbour porpoise	North Sea	346,601	IAMMWG (2022)
Bottlenose dolphin	Greater North Sea	1,885	IAMMWG (2022)
	Coastal East Scotland (cumulative modelling only)	226	Cheney *et al.* (2024)
	Greater North Sea and Coastal East Scotland MUs combined	2,111	Cheney *et al.* (2024) and IAMMWG (2022)
Minke whale	Celtic and Greater North Seas	20,118	IAMMWG (2022)
Grey seal	East Scotland seal MU and Northeast England Seal MU	10,783 + 25,913 = 36,696	Stevens (2023)
Harbour seal		364 + 124 = 488	

Figure 2.1: North Sea management unit for harbour porpoise

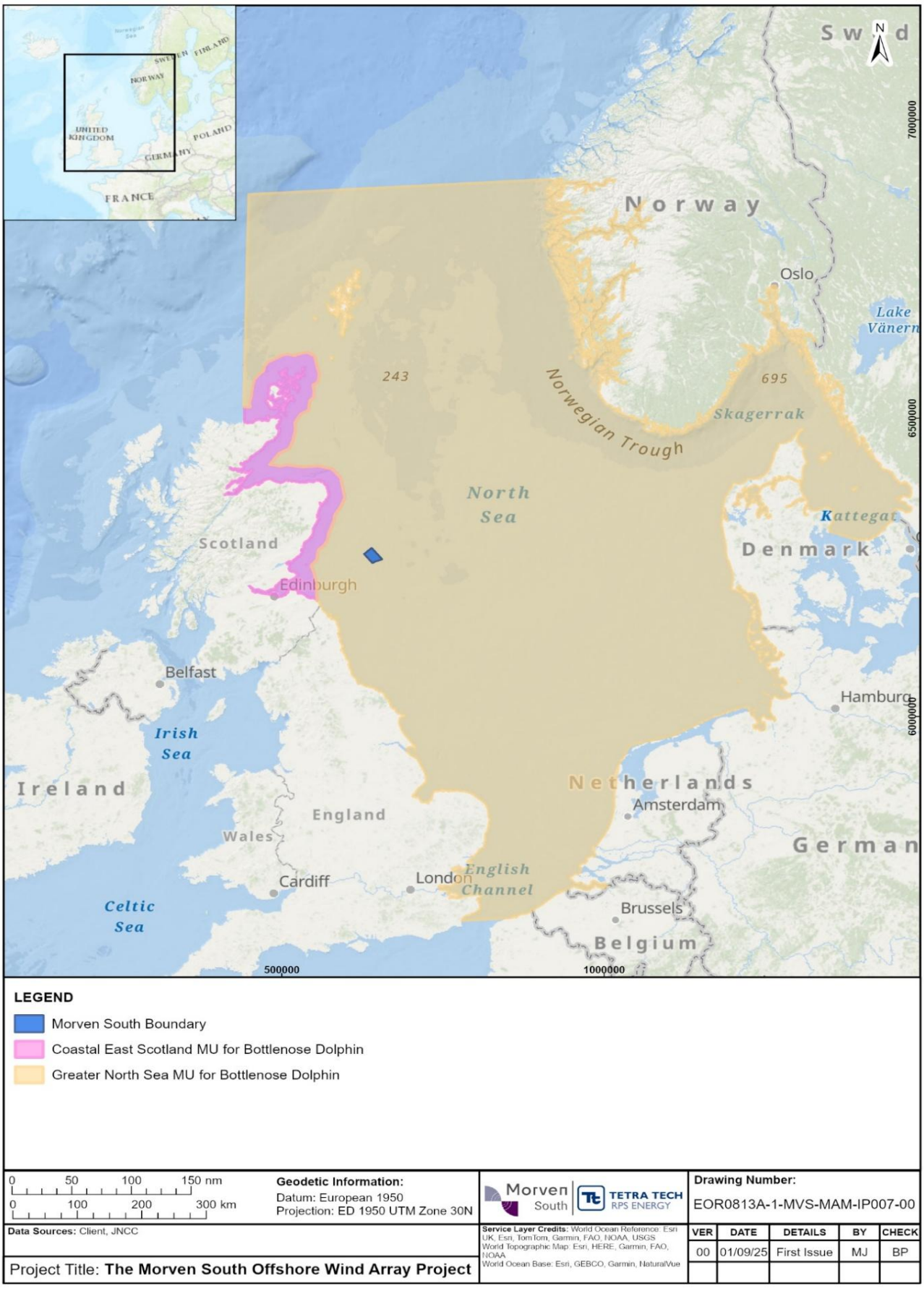

Figure 2.2: Coastal East Scotland and Greater North Sea management units for bottlenose dolphin

Figure 2.3: Celtic and Greater North Seas management units for minke whale

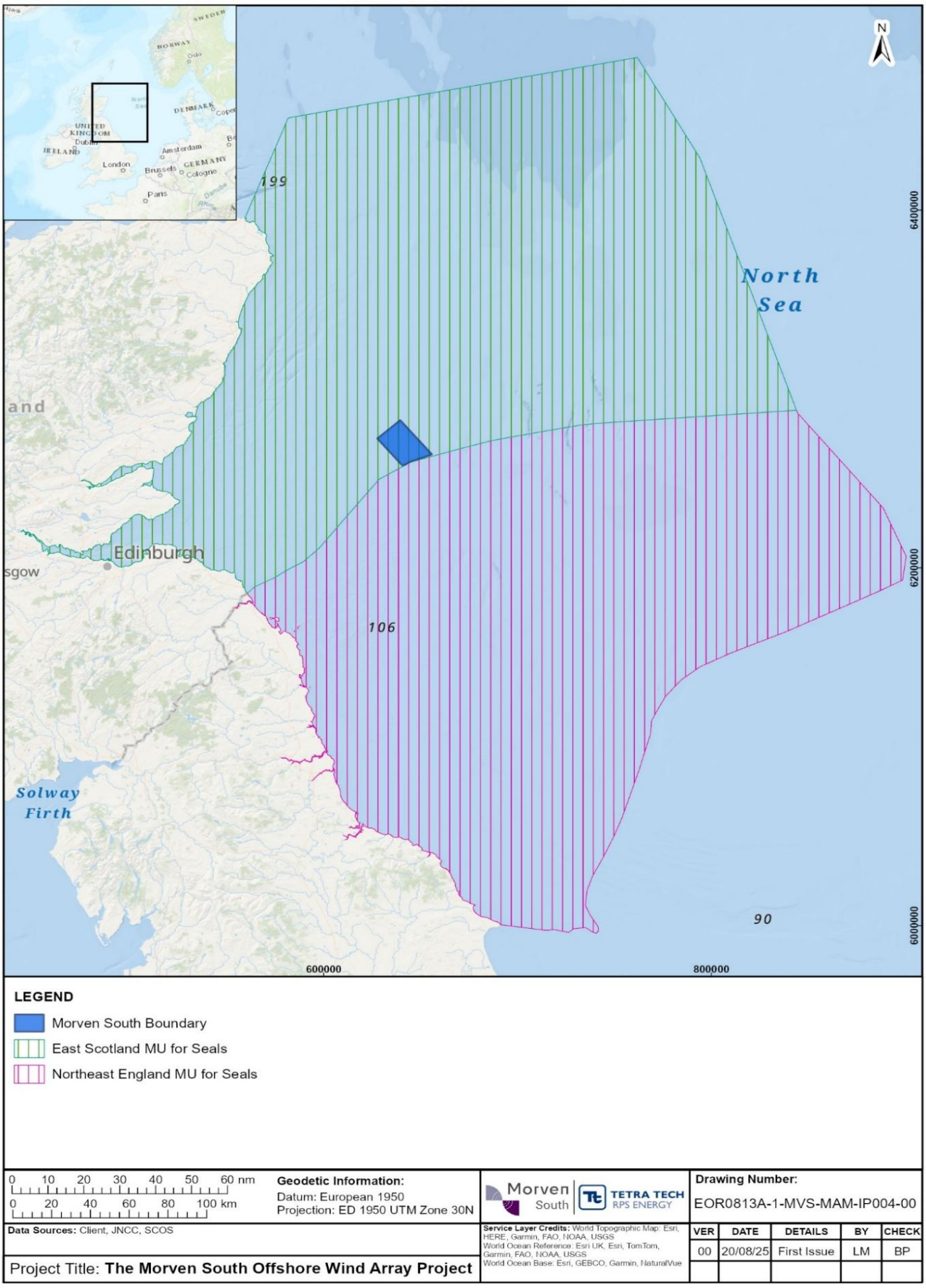

Figure 2.4: East Scotland and Northeast England seal management units for grey seal and harbour seal

2.2.3 Species Vital Rates

2.2.3.1 Vital rates for the marine mammal species modelled are presented in Table 2.4. These were derived from Sinclair *et al.* (2020). For harbour seal, there were different vital rates available for the East Scotland seal MU and Northeast England Seal MU (Sinclair *et al.*, 2020). In order to determine the most precautionary vital rates to use, the modelling scenarios (detailed in Section 2.5) were run using both sets of vital rates. The vital rates from the East Scotland seal MU (Sinclair *et al.* (2020), presented in Table 2.4) yielded the most precautionary population trajectories (see Section 3.5), and have therefore been used in this assessment for Morven South.

2.2.3.2 Similarly, the Coastal East Scotland MU and Greater North Sea MU bottlenose dolphin populations were combined as part of the cumulative modelling (see paragraph 2.2.2.3). Different vital rates were available for these MUs (Sinclair *et al.*, 2020). The cumulative model was run with each of the different vital rates for bottlenose dolphin.

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 at independence	Age at first birth
Harbour porpoise	0.8455	0.85	0.925	0.34	1	5
Bottlenose dolphin: Greater North Sea MU	0.8	0.94	0.94	0.25	2	9
Bottlenose dolphin: Coastal East Scotland MU	0.925	0.962	0.98	0.24	3	9
Minke whale	0.70	0.77	0.96	0.91	1	9
Grey seal	0.222	0.94	0.94	0.84	1	6
Harbour seal	0.40	0.78	0.92	0.85	1	4

2.2.4 Residual Days of Disturbance

2.2.4.1 There is empirical evidence from constructed offshore wind farms (Brandt *et al.*, 2011, Graham *et al.*, 2019) to suggest that the detection of marine mammals 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.

2.2.4.2 Due to the potential duration of piling occurring at Morven South (e.g. up to two piles installed over 24 hours), the number of residual days of disturbance has, conservatively, been selected as one, meaning that the model assumes that disturbance occurs on the day of piling and persists for a period of 24 hours after piling has ceased.

2.2.5 Number of Animals with the Potential to Experience Injury or Disturbance

2.2.5.1 The number of marine mammals with the potential to experience injury or disturbance as a result of piling at Morven South was based on the density values provided as part of the individual species baseline assessments in Volume 2, Chapter 10: Marine Mammals, of the Morven.

2.2.5.2 For the assessment of injury, the 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. A summary of these densities is provided in Table 2.5, with further information provided in Volume 3, Annex 10.1: Marine Mammals Shared Baseline Technical Report. The densities for harbour porpoise and minke whale were derived from the Small Cetaceans in European Atlantic waters and the North Sea (SCANS) survey IV, while the bottlenose dolphin density was derived from SCANS III (Table 2.5). The densities from the two seal species were derived from Carter *et al.* (2022) (Table 2.5).

Table 2.5: Summary of marine mammal densities used to calculate number of animals potentially injured or disturbed

Species	Source	Density (animals per km^2)	Reference
Harbour porpoise	SCANS IV mean density	0.599	Gilles *et al.* (2023)
Bottlenose dolphin	SCANS III surface density	0.005	Lacey *et al.* (2022)
Minke whale	SCANS IV mean density	0.042	Gilles *et al.* (2023)
Grey seal	Mean at-sea density	0.252	Carter *et al.* (2022)
Harbour seal		0.00000012	

2.2.5.3 To estimate the number of animals potentially disturbed during piling, the underwater sound contours were mapped, and a dose response approach applied to calculate the number of animals within each 5dB isopleth using the density values as described in Table 2.5. For grey seal and harbour seal, however, the quantitative assessment was undertaken by overlaying the unweighted SEL_{ss} contours on the at-sea density maps from Carter *et al.* (2022). The number of animals in each 5x5km grid cell was summed for each isopleth and corrected using the proportional response as per Whyte *et al.* (2020).

2.2.5.4 For all scenarios, project designed-in measures were applied (see Volume 2, Chapter 10: Marine Mammals). These include the implementation of soft-start and ramp-up measures during piling and the use of an Acoustic Deterrent Device (ADD). With these designed-in mitigation measures in place, the residual number of individuals potentially affected by PTS was taken forward for the iPCoD model. This is a conservative approach since visual and acoustic detections using Marine Mammal Observers (MMObs) and passive acoustic monitoring (PAM) will also be applied as an industry standard to further reduce the risk of injury (as per Joint Nature Conservation Committee (JNCC, 2010) guidance).

2.2.5.5 The maximum number of animals with the potential to experience injury and disturbance for the maximum temporal scenario is presented in Table 2.6 and Table 2.7 for the maximum spatial scenario.

2.2.5.6 For the maximum spatial scenario, modelling locations are detailed in Volume 3, Annex 10.2: Underwater Sound Shared Technical Report).

Table 2.6: Maximum temporal scenario: estimated number of animals predicted to be injured or disturbed at any one time

Species	Activity	Potential number of animals injured	Potential number of animals disturbed
Harbour porpoise	Wind turbine foundation piling	0	846
	OSP (AC collector) foundation piling	0	866
	OSP (DC collector) foundation piling	0	866
Bottlenose dolphin	Wind turbine foundation piling	0	8
	OSP (AC collector) foundation piling	0	8
	OSP (DC collector) foundation piling	0	8
Minke whale	Wind turbine foundation piling	0	60
	OSP (AC collector) foundation piling	0	61
	OSP (DC collector) foundation piling	0	61
Grey seal	Wind turbine foundation piling	0	153
	OSP (AC collector) foundation piling	0	161
	OSP (DC collector) foundation piling	0	161
Harbour seal	Wind turbine foundation piling	0	Up to 1
	OSP (AC collector) foundation piling	0	Up to 1
	OSP (DC collector) foundation piling	0	Up to 1

Table 2.7: Maximum spatial scenario: estimated number of animals predicted to be injured or disturbed at any one time

Species	Activity	Potential number of animals injured	Potential number of animals disturbed
Harbour porpoise	Wind turbine foundation piling	0	1,739
	OSP (AC collector) foundation piling	0	1,739
	OSP (DC collector) foundation piling	0	1,443

Species	Activity	Potential number of animals injured	Potential number of animals disturbed
Bottlenose dolphin	Wind turbine foundation piling	0	15
	OSP (AC collector) foundation piling	0	15
	OSP (DC collector) foundation piling	0	13
Minke whale	Wind turbine foundation piling	1	122
	OSP (AC collector) foundation piling	1	122
	OSP (DC collector) foundation piling	1	102
Grey seal	Wind turbine foundation piling	0	408
	OSP (AC collector) foundation piling	0	408
	OSP (DC collector) foundation piling	0	311
Harbour seal	Wind turbine foundation piling	0	Up to 1
	OSP (AC collector) foundation piling	0	Up to 1
	OSP (DC collector) foundation piling	0	Up to 1

2.3 Indicative Piling Schedule

2.3.1.1 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. The piling phase for Morven South is expected to commence at the beginning of Q4 2034 and finish at the end of Q3 2035, therefore occurring within two calendar years.

2.3.1.2 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, based on a realistic installation approach. 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 any 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.

2.3.1.3 For the maximum temporal scenario, piling was assumed to occur over the greatest time frame of up to 262 days (see Table 2.1). Therefore, these 262 days have been spread as evenly as practicable across the piling phase, with an interval of 1.4 days between piling events used. 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. Concurrent piling has been assumed at the wind turbine and OSP foundations, and all piling at these locations has subsequently been assumed to occur across 48 piling days (see Table 2.2), with an interval of 7.6 days between piling events used.

2.3.1.4 The iPCoD model outputs are generated over 26 time points, with key time points presented in Table 2.8. The differences between the impacted and unimpacted populations at these time points is discussed in Section 3 for each species. In addition, the time point(s) wherein the greatest difference in the mean impacted and unimpacted population size was recorded has also been discussed in Section 3, although this varies between species and modelling scenario.

Table 2.8: Key time points from the Morven South iPCoD model output and relevant corresponding events

Time point	Year	Corresponding event
1	2034	Piling commences in Q4 2034, however time point 1 corresponds to the beginning of 2034, thus represents the baseline environment prior to any piling.
2	2035	Piling finishes at the end of Q3 2035.
3	2036	The year after piling finishes.
7	2040	Six years after the start of piling (Q4 2034). Reporting on this time point was previously required under the Habitats Directive.
13	2046	Ten years after piling finishes.
26	2059	25 years after the start of piling, and the maximum extent of the model predictions.

2.4 Cumulative Effects

2.4.1.1 A range of other offshore wind projects were considered in the cumulative modelling scenarios (see Figure 2.5). These included projects for which piling could potentially temporally overlap (or to occur in adjacent years) with piling for the Morven South, and for which quantitative information was available. Both Tier 1 and Tier 2 projects screened in for cumulative modelling. For the Tier 1 projects, the numbers of animals disturbed, and the piling schedules were derived from the individual projects' iPCoD reports. However, as this information was not publicly available for the Tier 2 projects, the numbers of animals disturbed was calculated using the updated Effective Deterrent Ranges (EDRs) for 2025 (JNCC, 2025) and only where there was sufficient information to develop a piling scenario. Only two Tier 2 projects – Ayre and Bowdun – provided sufficient information on offshore construction schedules. For these projects, a range of foundation options were proposed in the Scoping Reports (Ayre OWF Limited, 2024, Bowdun OWF Limited, 2024) and therefore, to adopt a precautionary approach, the foundation option that could lead to the greatest potential effect was considered. Since the EDR for monopiles and pin piles is exactly the same (20km), the greatest potential effect would arise from pin piles as this would lead to a longer piling duration. As there was no information on the number of pin piles at each foundation, maximum scenario was assumed based on the MDS parameters for pin piling at Morven South (i.e. the maximum number of days required to install the maximum number of legs per foundation and maximum number of piles per leg, see paragraph 2.4.1.4 for more details). Further detail on the tier system is provided in Volume 3, Annex 6.2: Cumulative Effects Screening.

2.4.1.2 As the effects of disturbance from piling at cumulative projects may still be evident in marine mammal populations after piling has ceased, the cumulative modelling precautionarily incorporated projects with piling schedules several years earlier than those of Morven South. These projects were:

- Tier 1:
  - Morven North;
  - Berwick Bank Offshore Wind Farm (hereafter referred to as "Berwick Bank");
  - Ossian Offshore Wind Farm (hereafter referred to as "Ossian");
  - Cenos Offshore Wind Farm (hereafter referred to as "Cenos");
  - Caledonia Offshore Wind Farm (hereafter referred to as "Caledonia");
  - Muir Mhor Offshore Wind Farm (hereafter referred to as "Muir Mhor").
- Tier 2:
  - Ayre Offshore Wind Farm (hereafter referred to as "Ayre");
  - Bowdun Offshore Wind Farm (hereafter referred to as "Bowdun").

2.4.1.3 The indicative piling schedules for the cumulative projects used in the assessment are detailed in Table 2.9. Consecutive piling at Morven South (Q4 2034 to Q3 2035, inclusive) followed by Morven North (Q4 2035 to Q3 2036, inclusive) was assumed as the MDS within the cumulative iPCoD modelling[1].

2.4.1.4 For Morven South, the project alone scenario which led to the greatest population level effect was carried forward to the cumulative assessment. This was the maximum temporal scenario for all species except minke whale, where the maximum spatial scenario was incorporated into the cumulative iPCoD model. The total number of piling days for each cumulative project is presented in Table 2.9. For the Tier 2 projects, the number of piling days were calculated in-house as these were not available in the public domain. As detailed in paragraph 2.4.1.1, the total number of piling days and overall piling schedule for the Tier 2 projects were based on a combination of the publicly available parameters (i.e. potential number of turbines and preliminary overall construction period) and the MDS for Morven South. For example, in the Scoping Reports for both Ayre and Bowdun, up to 67 Wind Turbines were detailed, alongside an unspecified number of OSPs (Ayre OWF Limited, 2024, Bowdun OWF Limited, 2024). As a precaution, up to 5 OSPs was assumed for each project. As the highest number of piles in the MDS for Morven South was associated with pin piles, the pin pile parameters for Morven South were assumed for Ayre and Bowdun. Therefore, the total of 194 piling days for each Tier 2 project was calculate, as follows:

- 67 Wind Turbine foundations, with four legs and with one pin pile per leg, giving a total of 268 piles. If an average of two piles were installed per day (as per the Morven South MDS), up to 134 piling days were calculated.
- Five OSPs, with six legs and four pin piles per leg, giving a total of 120 piles. If an average of two piles were installed per day (as per the Morven South MDS), up to 60 piling days were calculated.

2.4.1.5 Therefore, the total of 194 piling days for each Tier 2 project was estimated for both Ayre and Bowdun, with the caveat that incorporation of Tier 2 projects is based on a number of assumptions to inform the iPCoD model. For other Tier 2 projects, a quantitative assessment was not possible due to the lack of information on offshore construction dates which meant that piling schedules could not be developed.

[1] The cumulative iPCoD modelling scenario assumed piling at Morven North followed by piling at Morven South. It should be noted that this is indicative at this stage, and could, in reality, be inverse (i.e. piling at Morven South followed by piling at Morven North) or with some degree of overlap between piling at both projects. However, if the piling periods were to be inverted or overlapping to some degree, the results would not largely differ from those presented in this report due to the similarities between the numbers of animals potentially disturbed at both projects and the piling parameters used in the model inputs.

2.4.1.6 The cumulative iPCoD models were set up as described in Sections 2.2.2 and 2.2.3 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 Sections 2.2.4 and 2.2.5.

2.4.1.7 The number of animals affected for each of the key species and number of days on which piling occurred, was taken from the iPCoD modelling for each of the cumulative Tier 1 projects[2]. For the Tier 2 projects, the number of animals disturbed was calculated using various published densities[3] within the updated EDRs for 2025 (JNCC, 2025). The EDR for unabated piling is given as 20km (JNCC, 2025). The number of animals potentially disturbed within these EDRs for both Ayre and Bowdun are presented in Table 2.10. While the key species and MUs/seal MUs assessed in the EIAs for Ayre and Bowdun are not publicly available, as a precaution, it has been assumed that these will align with those defined in Section 2.2.2 for Morven South.

2.4.1.8 A summary of the number of animals for each species potentially affected is provided in Table 2.10. In cases where less than one animal was expected to experience disturbance, this was rounded up to one animal for the relevant models (i.e. for harbour seal). As illustrated in Table 2.10, not all species and/or MU populations were included in the iPCoD modelling for the other offshore wind projects. Therefore, key time points discussed in Section 3 for each species are presented in Table 2.11, as these differ between species.

2.4.1.9 For bottlenose dolphin, three cumulative scenarios have been run (Table 2.12):

- BND-03: individuals disturbed for those project that consider the Greater North Sea MU population only (i.e. screening out any projects that only consider the Coastal East Scotland MU to be affected);
- BND-04: individuals disturbed from either the Greater North Sea MU or the Coastal East Scotland MU or both MUs combined – applying the vital rates for the Coastal East Scotland MU;
- BND-05: individuals disturbed from either the Greater North Sea MU or the Coastal East Scotland MU or both MUs combined – applying the vital rates for the Greater North Sea MU.

[2] The cumulative iPCoD modelling was based upon the information available at the time of undertaking the modelling, however, it is noted that since completing the cumulative iPCoD modelling there have been updates to the bottlenose dolphin assessments for Muir Mhor and Caledonia, which have now been published.

[3] For harbour porpoise and minke whale, the SCANS IV densities were the most precautionary (Gilles *et al.,* 2023), while for bottlenose dolphin, the SCANS III were the most precautionary (Hammond *et al.,* 2021) and therefore used. For grey seal and harbour seal, the most precautionary densities were from Carter *et al.* (2022).

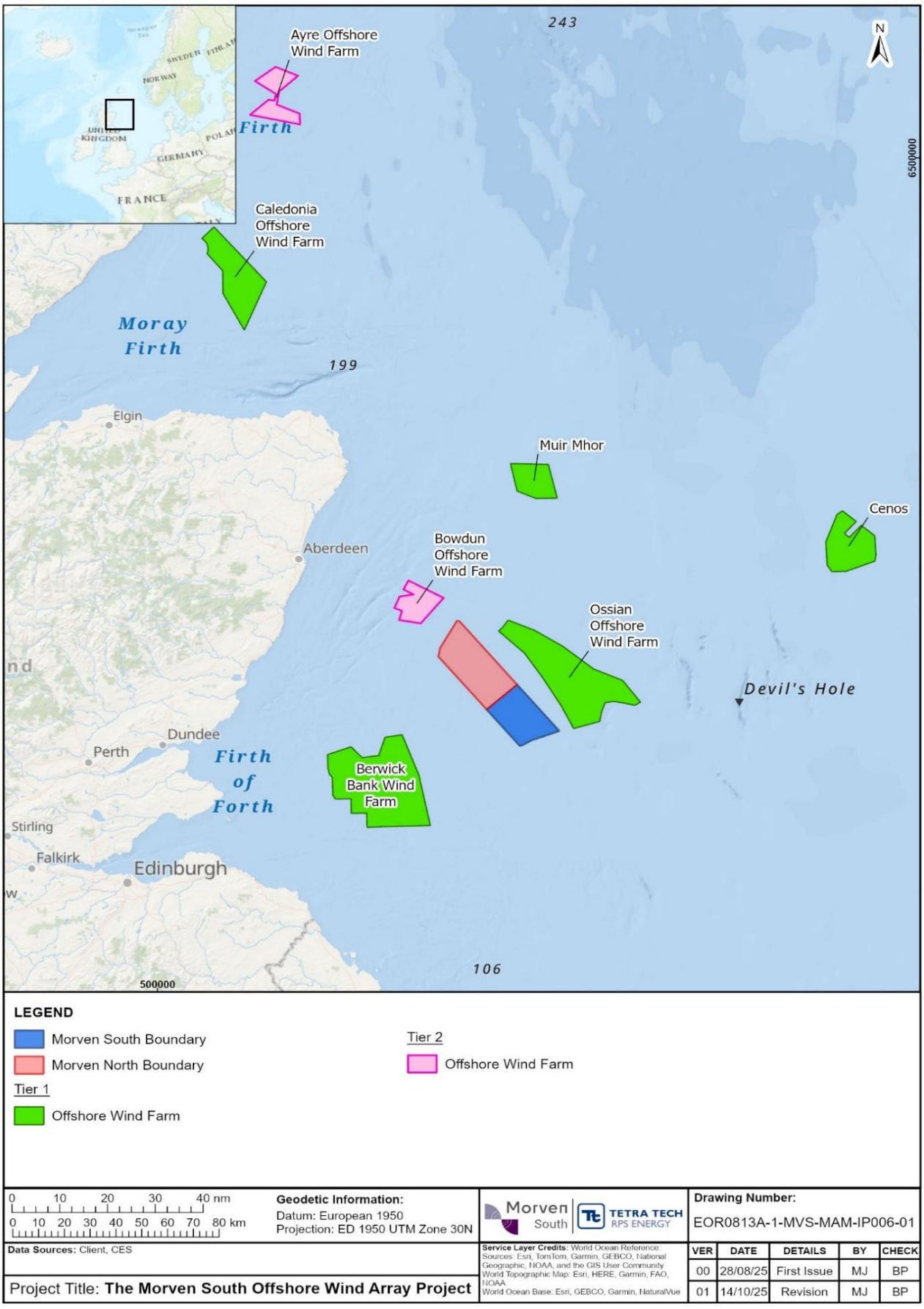

Figure 2.5: Other projects included in the cumulative iPCoD modelling assessment

Table 2.9: Indicative piling scenarios used in the cumulative iPCoD modelling ('P' indicates that piling is expected to occur within that year)

Project	Total days of piling		Piling programme										
	Maximum temporal	Maximum spatial	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038
Morven South	262	48							P	P			
Tier 1 projects													
Morven North	262	48								P	P		
Berwick Bank	112					P							
Ossian	602					P	P	P	P	P	P	P	P
Cenos	293					P	P	P					
Caledonia	515		P	P	P	P	P						
Muir Mhor	175			P	P	P							
Tier 2 projects													
Ayre	194			P	P	P	P	P					
Bowdun	194			P	P	P	P	P					

Table 2.10: Number of animals with the potential to experience disturbance

Project	Piling activity	Maximum number of animals potentially disturbed						
		Harbour porpoise	Bottlenose dolphin (Coastal East Scotland MU)	Bottlenose dolphin (Greater North Sea MU)	Bottlenose dolphin (both MUs combined)	Minke whale	Grey seal	Harbour seal
Morven South	Wind turbine	846	0	8	8	122	153	1
	OSP (AC collector)	866	0	8	8	122	161	1
	OSP (DC converter)	866	0	8	8	102	161	1
Tier 1								
Morven North	Wind turbine	808	0	7	7	119	176	1
	OSP (AC collector)	834	0	8	8	119	199	1
	OSP (DC converter)	834	0	8	8	107	199	1
Berwick Bank	Jacket wind turbine foundation - 1% conversion factor	2,815	5	MU and/or species not included in assessment	5	132	1,450	3
	Jacket OSP foundation - 1% conversion factor	1,828	4		4	86	720	1
Ossian	Wind turbine	3,857	2		2	169	131	
	OSP	7,310	4		4	319	344	

Project	Piling activity	Maximum number of animals potentially disturbed						
		Harbour porpoise	Bottlenose dolphin (Coastal East Scotland MU)	Bottlenose dolphin (Greater North Sea MU)	Bottlenose dolphin (both MUs combined)	Minke whale	Grey seal	Harbour seal
Cenos	Semi-submersible wind turbine foundation	8,863	Cenos did not include this species		Cenos did not include this species	358	127	MU and/or species not included in assessment
	Offshore Substation and Converter Platforms (OSCP)	9,529				384	137	
Caledonia	Fixed jacket wind turbine foundations	8,201	52	35	87	502	4,426	
	Anchors	6,648	46	27	73	415	2,960	
Muir Mhor	Wind turbine	14,630	8	74	82	735	1,156	1
	Offshore Electrical Platform (OEP)	15,245	7	75	82	777	1,176	1
Tier 2								
Ayre	Wind turbine	753	Only the combined MU populations were used to estimate the number of animals disturbed at the Tier 2 projects due to lack of further information for each project.		38	53	398	1
	OSP	753			38	53	398	1
Bowdun	Wind turbine	753			38	53	398	1
	OSP	753			38	53	398	1

Table 2.11: Key time points from the cumulative iPCoD model output and relevant corresponding events

Time point	Year	Corresponding event
1	2028	Piling commences at Caledonia, representing the beginning of the cumulative piling schedule.
2 to 5	2029 to 2032	Cumulative piling at a range of projects before the commencement of piling at Morven South in 2033.
6	2033	The year before piling commences at Morven South. During this year, piling is ongoing at Ossian and in the final year for Cenos. It should be noted that neither Ossian nor Cenos considered the Greater North Sea MU bottlenose dolphin population or harbour seal in their assessments.
7	2034	Commencement of piling at Morven South (in Q4)
8	2035	Piling at Morven South (finishing in Q3), commencement of piling at Morven North (Q4).
9	2036	Piling completed at Morven South (Q3), representing the end of the cumulative piling for Greater North Sea MU bottlenose dolphin (BND-03) and harbour seal.
10	2037	The year after cumulative piling completed for the Greater North Sea MU bottlenose dolphin (BND-03) and harbour seal.
11	2038	Piling completed at Ossian (end of 2038), representing the end of the cumulative piling for harbour porpoise, combined bottlenose dolphin models (BND-04 and BND-5), minke whale, and grey seal.
12	2039	The year after cumulative piling completed for harbour porpoise, combined bottlenose dolphin models (BND-04 and BND-5), minke whale, and grey seal.
20	2047	Ten years after the completion of cumulative piling for the Greater North Sea MU bottlenose dolphin (BND-03) and harbour seal.
22	2049	Ten years after the completion of cumulative piling for harbour porpoise, combined bottlenose dolphin models (BND-04 and BND-5), minke whale, and grey seal.

Time point	Year	Corresponding event
26	2053	25 years after the start of piling at the Caledonia and the maximum extent of the model predictions.

2.5 Summary of iPCoD Scenarios

2.5.1.1 A total of 17 iPCoD modelling scenarios were run for Morven South alone and the cumulative effect assessment. These are summarised in Table 2.12 for the five species.

Table 2.12: Summary of iPCoD modelling scenarios

Scenario		MU	Population estimate
Harbour porpoise			
HP-01	Maximum temporal scenario	North Sea	346,601
HP-02	Maximum spatial scenario		
HP-03	Cumulative scenario		
Bottlenose dolphin			
BND-01	Maximum temporal scenario	Greater North Sea	1,885
BND-02	Maximum spatial scenario		
BND-03	Cumulative scenario: Greater North Sea MU population only		
BND-04	Cumulative scenario: combined MU populations (Coastal East Scotland MU vital rates)	Greater North Sea MU and Coastal East Scotland MU combined	2,111
BND-05	Cumulative scenario: combined MU populations (Greater North Sea MU vital rates)		
Minke whale			
MW-01	Maximum temporal scenario	Celtic and Greater North Seas	20,118
MW-02	Maximum spatial scenario		
MW-03	Cumulative scenario		
Grey seal			
GS-01	Maximum temporal scenario	East Scotland seal MU and Northeast England Seal MU	36,696
GS-02	Maximum spatial scenario		
GS-03	Cumulative scenario		

Scenario		MU	Population estimate
Harbour seal			
HS-01	Maximum temporal scenario	East Scotland seal MU and Northeast England Seal MU	488
HS-02	Maximum spatial scenario		
HS-03	Cumulative scenario		

2.6 Model Outputs

2.6.1.1 The iPCoD model outputs describe the potential impact to a given marine mammal population under the relevant development scenario, relative to the population in the absence of Morven South. 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 Section 3 for each species modelled.

2.6.1.2 The ratio of the simulated impacted population size to the unimpacted population size can be termed the “counterfactual” of population size. A counterfactual of 1 would therefore correspond to a prediction of no difference in size between the impacted and unimpacted populations. Counterfactuals of <1 would correspond to a prediction of the impacted population being smaller than the unimpacted population.

2.6.1.3 The mean estimate (plus 95% confidence interval) of impacted and unimpacted population sizes across all simulations, and the corresponding counterfactuals, are reported for each species, and each scenario (within Section 3 for each species). 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

3.1.1 HP-01 Maximum Temporal Scenario

3.1.1.1 The results for the maximum temporal scenario are presented in Figure 3.1. These indicate a very small difference in the growth trajectory of harbour porpoise between the unimpacted population and impacted population. At all time points, there was little difference in the mean size of the impacted and unimpacted populations, with a maximum difference of 137 individuals (approximately 0.04% of the North Sea MU reference population) at time point 4 (Table 3.1).

3.1.1.2 At time point 3 (the year after piling finishes), there was a difference of 113 animals between the impacted and unimpacted populations (approximately 0.03% of the North Sea MU reference population). At time point 7, which corresponds to the six-year reporting period previously required under the Habitats Directive, the impacted population was modelled to be 96 animals smaller than the unimpacted one (approximately 0.03% of the North Sea MU reference population).

3.1.1.3 At time point 13 (corresponding to ten years after piling completion) the impacted population was modelled to be 103 animals smaller than the unimpacted one (approximately 0.03% of the North Sea MU reference population) (Table 3.1).

3.1.1.4 At time point 26 (the end of the model run), the impacted population was modelled to be 104 animals smaller than the unimpacted population (approximately 0.03% of the North Sea MU reference population) (Table 3.1). This suggests that long-term disturbance of the harbour porpoise population within the North Sea MU would not occur due to piling at Morven South.

3.1.1.5 The median and median counterfactuals began at 1 and ranged from 0.9996 and 0.9999 throughout time series (Table 3.1). Therefore, given that the differences in impacted and unimpacted populations approach a ratio of 1, there is not considered to be a potential for a long-term effect from this piling scenario upon the harbour porpoise population within the North Sea MU.

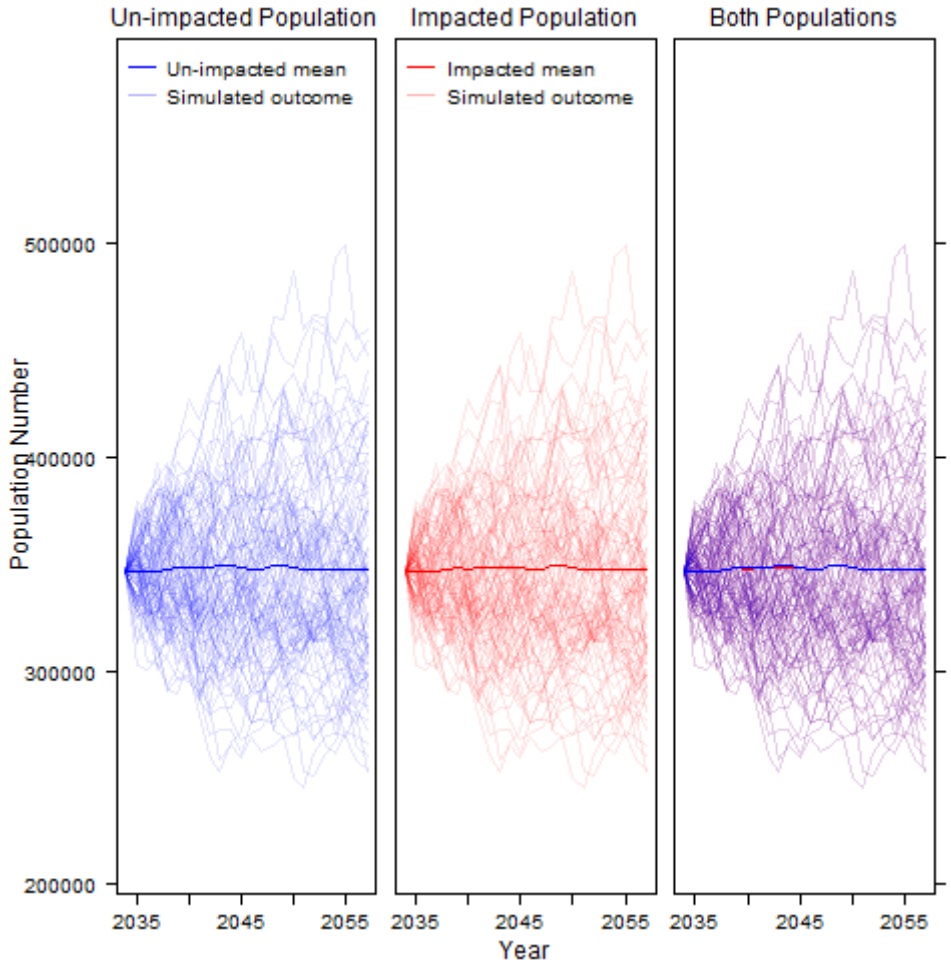

Figure 3.1: Simulated harbour porpoise population trajectories in an unimpacted versus impacted population for the maximum temporal scenario

Table 3.1: Modelled estimates for the unimpacted and impacted harbour porpoise population for the maximum temporal scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	346,602	346,602	346,602	346,602	346,602	346,602	1.0000	1.0000
2	2035	318,538	346,831	371,644	318,538	346,831	371,644	1.0000	1.0000
3	2036	309,416	346,846	380,497	309,400	346,733	380,496	0.9999	0.9997
4	2037	304,534	346,885	386,492	304,277	346,748	386,413	0.9999	0.9996
7	2040	294,827	348,129	402,336	294,673	348,033	402,330	0.9999	0.9997
13	2046	277,354	347,638	428,242	277,354	347,535	428,226	0.9999	0.9997
26	2059	250,594	346,586	467,795	250,436	346,482	467,766	0.9999	0.9997

3.1.2 HP-02 Maximum Spatial Scenario

3.1.2.1 The results for the maximum spatial scenario are presented in Figure 3.2. These indicate a very small difference in the growth trajectory of harbour porpoise between the unimpacted population and impacted population. At all time points, there was little difference in the mean size of the impacted and unimpacted populations, with a maximum difference of 46 individuals (approximately 0.013% of the North Sea MU reference population) at time point 4 (

3.1.2.2

3.1.2.3 Table 3.2).

3.1.2.4 At time point 3 (the year after piling finishes), there was a difference of 33 animals between the impacted and unimpacted populations (approximately 0.010% of the North Sea MU reference population). At time point 7, which corresponds to the six-year reporting period previously required under the Habitats Directive, the impacted population was modelled to be 31 animals smaller than the unimpacted one (approximately 0.00% of the North Sea MU reference population).

3.1.2.5 At time point 13 (corresponding to ten years after piling completion) the impacted population was modelled to be 34 animals smaller than the unimpacted one (approximately 0.010% of the North Sea MU reference population) (

3.1.2.6

3.1.2.7 Table 3.2).

3.1.2.8 At time point 26 (the end of the model run) the impacted population was modelled to be 33 animals smaller than the unimpacted one (approximately 0.010% of the North Sea MU reference population) (

3.1.2.9

3.1.2.10 Table 3.2). This suggests that long-term disturbance of the harbour porpoise population within the North Sea MU would not occur due to piling at Morven South.

3.1.2.11 The median counterfactual remained as one through the 26-year model, while the mean fluctuated between 1 and 0.9999 (

3.1.2.12

3.1.2.13 Table 3.2). Therefore, given that the differences in impacted and unimpacted populations approaches a ratio of 1, there is not considered to be a potential for a long-term effect from this piling scenario upon the harbour porpoise population within the North Sea MU.

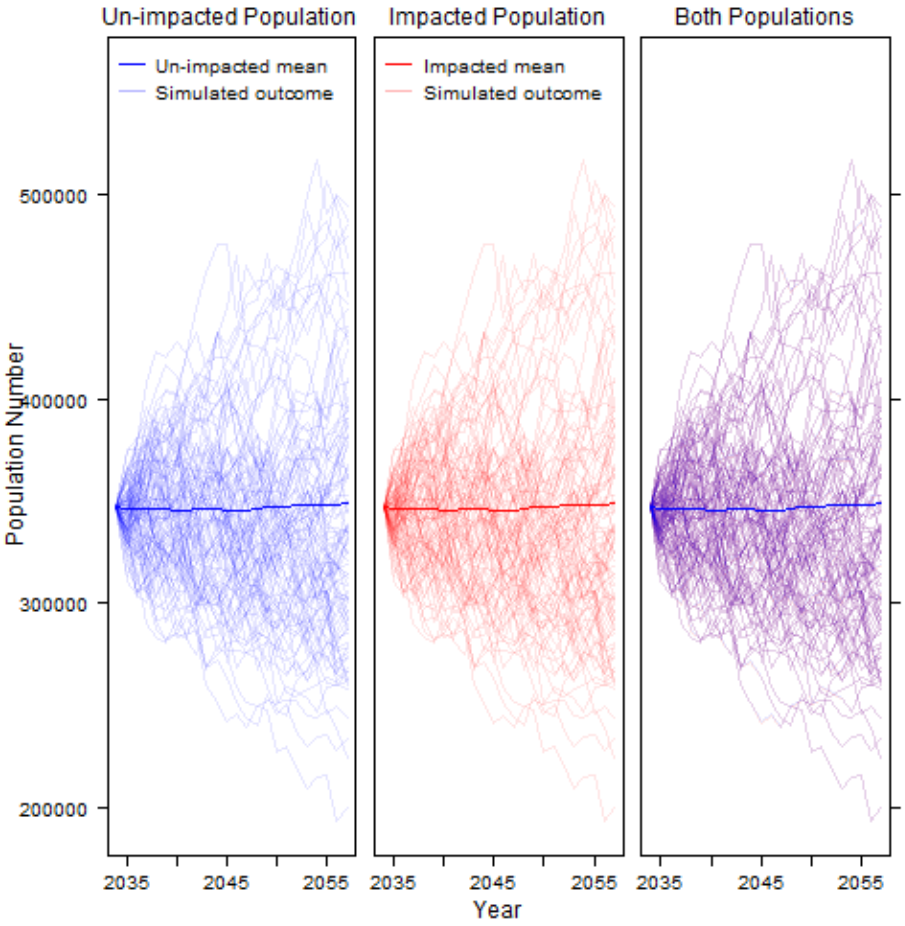

Figure 3.2: Simulated harbour porpoise population trajectories in an unimpacted versus impacted population for the maximum spatial scenario

Table 3.2: Modelled estimates for the unimpacted and impacted harbour porpoise population for the maximum spatial scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	346,602	346,602	346,602	346,602	346,602	346,602	1.0000	1.0000
2	2035	315,408	346,143	371,960	315,408	346,143	371,960	1.0000	1.0000
3	2036	307,026	346,078	380,158	307,022	346,045	380,158	1.0000	0.9999
4	2037	301,375	345,739	387,760	301,230	345,693	387,577	1.0000	0.9999
7	2040	290,599	345,411	401,838	290,428	345,380	401,838	1.0000	0.9999
13	2046	271,781	345,357	430,798	271,781	345,323	430,706	1.0000	0.9999
26	2059	247,948	347,479	467,047	247,948	347,446	467,039	1.0000	0.9999

3.1.3 HP-03 Cumulative Scenario

3.1.3.1 For the HP-03 cumulative modelling scenario, a total of 2,613 piling days were modelled (including 262 days for Morven South, see Table 2.9). These results indicated considerable difference in the simulated trajectories of harbour porpoise between the unimpacted population and impacted population (Figure 3.3). This corresponded to an impacted population that was smaller than the unimpacted population by 9,037 individuals at time point 26 (Table 3.3), corresponding to 2.61% of the North Sea MU reference population.

3.1.3.2 The maximum difference between the impacted and unimpacted populations was in time point 11, wherein the impacted population was predicted to be smaller than the unimpacted population by 9,547 animals (2.75% of the North Sea MU reference population; Table 3.3). This time point corresponded to the final year of piling for Ossian, and the end of the cumulative piling schedule. Ten years after this, at time point 22 (2049), there was a difference of 9,035 animals (2.61% of the North Sea MU population). This is considerably greater than the maximum difference of 137 animals modelled for Morven South alone (see Section 3.1.1).

3.1.3.3 The median counterfactual of population size for cumulative scenario HP-03 was 0.9829 at the end of the 26-year simulation, while the mean counterfactual was 0.9740 (Table 3.3).

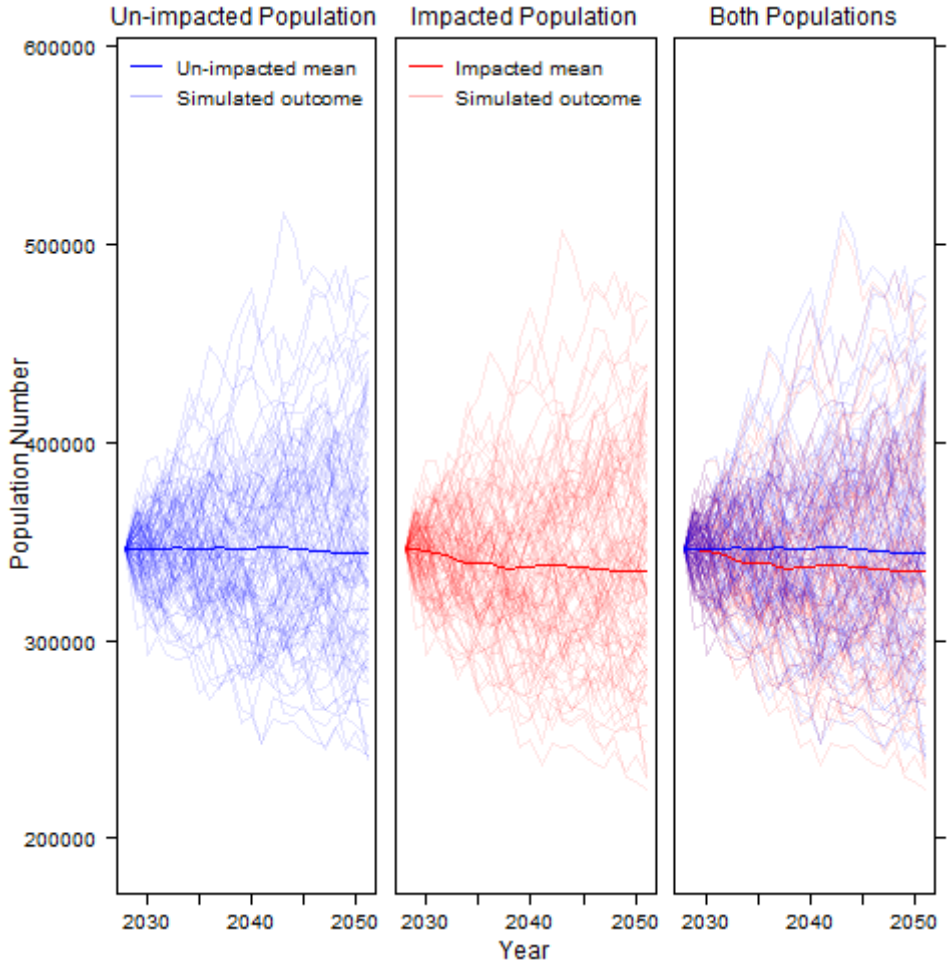

Figure 3.3: Simulated harbour porpoise population trajectories in an unimpacted versus impacted population for the cumulative scenario HP-03

Table 3.3: Modelled estimates for the unimpacted and impacted harbour porpoise population for the cumulative scenario HP-03

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2028	346,602	346,602	346,602	346,602	346,602	346,602	1.0000	1.0000
2	2029	317,983	346,715	370,785	317,983	346,715	370,785	1.0000	1.0000
3	2030	307,994	345,946	379,529	307,912	345,639	379,528	0.9999	0.9991
4	2031	302,175	345,934	388,494	301,488	344,531	387,098	0.9980	0.9960
5	2032	297,107	346,520	392,629	294,419	342,714	390,062	0.9928	0.9891
6	2033	292,483	347,027	399,519	286,055	340,166	395,387	0.9851	0.9803
7	2034	289,236	346,542	404,477	282,414	339,211	397,424	0.9847	0.9789
8	2035	284,112	346,624	407,240	278,515	339,422	400,078	0.9860	0.9794
9	2036	283,151	346,574	412,587	277,026	338,700	403,244	0.9851	0.9775
11	2038	278,531	345,976	424,109	270,893	336,429	412,938	0.9820	0.9726
12	2039	276,496	346,428	426,552	268,391	337,184	416,311	0.9826	0.9736
22	2049	250,594	344,220	455,553	244,246	335,185	445,824	0.9829	0.9741
26	2053	244,778	344,621	464,691	239,973	335,584	453,927	0.9829	0.9740

3.1.3.4 Over the model run, the difference between the mean unimpacted and impacted population sizes increased throughout the cumulative piling schedule for the different projects with the final year of piling in time point 11 (2038; as illustrated by the orange bar in Figure 3.4). After this point, the difference between the population sizes levelled off, suggesting that there would be no further effect beyond this point (Figure 3.4). Also, it should be noted that the iPCoD model does not facilitate as assessment of density-dependent population recovery and therefore the differences between the unimpacted and impacted population do not reflect the true population after ceases, which recovery would be anticipated (see paragraphs 1.2.1.5 and 1.2.1.6).

3.1.3.5 As illustrated in Figure 3.4, the steepest decline between the mean unimpacted population and impacted population sizes occurred between time points 4 (2031) and 6 (2033). The year 2031 corresponded to the timepoint when the majority of projects would be piling although this is two years prior to the start of piling at Morven South (see Table 2.9). Another notable difference between the mean unimpacted and impacted populations was observed between time points 8 (2035) and 11 (2038), which corresponded to the period of piling at Morven South and Morven North, and the completion of piling at Ossian (Figure 3.4 and Table 2.9). It is highlighted, however, that in the context of the North Sea MU these differences in population did not elicit a substantial drop in the counterfactual mean or median from a ratio of 1, which equates to no population-level impact

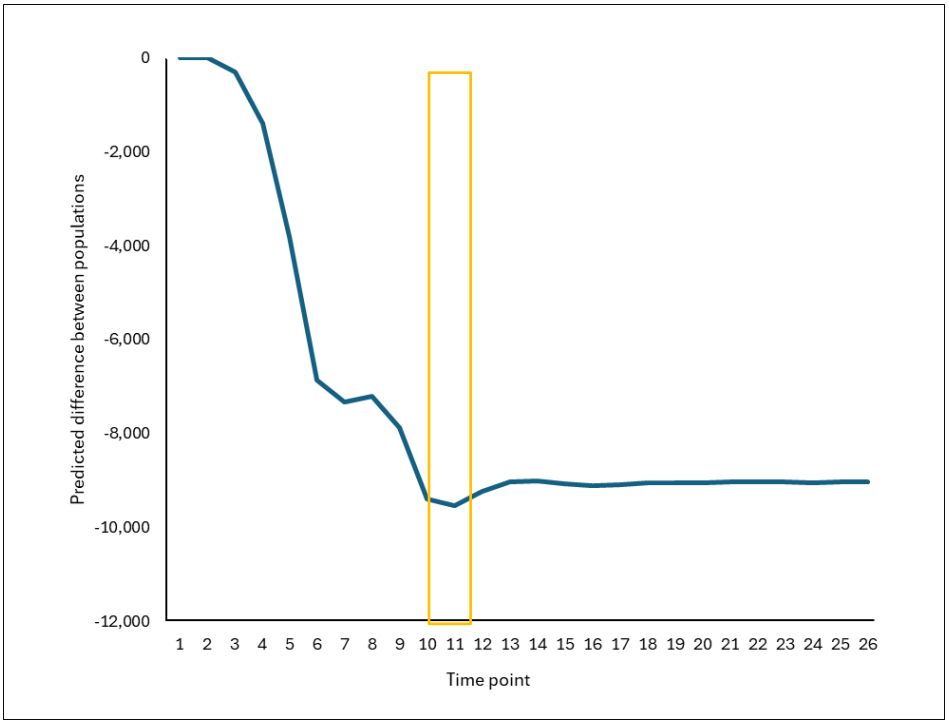

Figure 3.4: Difference in the mean number of harbour porpoise between the impacted and unimpacted populations across all time points for the cumulative scenario HP-03

3.2 Bottlenose Dolphin

3.2.1 BND-01 Maximum Temporal Scenario

3.2.1.1 The results for the maximum temporal scenario are presented in Figure 3.5. These indicate a very small difference in the growth trajectory of bottlenose dolphin between the unimpacted population and impacted population. Across all time points there was a maximum difference of three individuals (approximately 1.16% of the Greater North Sea MU reference population) at time points 3, 4, 6, 9, 15, and 17 to 22 (Table 3.4).

3.2.1.2 At time point 7, which corresponds to the six-year reporting period previously required under the Habitats Directive, there was a difference of two animals between the impacted and unimpacted populations (approximately 0.11% of the Greater North Sea MU reference population population).

3.2.1.3 At time point 26 (the end of the model run), there was also a difference of two individuals between the impacted and unimpacted populations (approximately 0.11% of the Greater North Sea MU reference population) (Table 3.4).

3.2.1.4 The median counterfactual remained as 1 through the 26-year model, while the mean fluctuated between 1 and 0.9983 (Table 3.4). Therefore, given that the differences in impacted and unimpacted populations approaches a ratio of 1, there is not considered to be a potential for a long-term effect from this piling scenario upon the bottlenose dolphin population within the Greater North Sea MU.

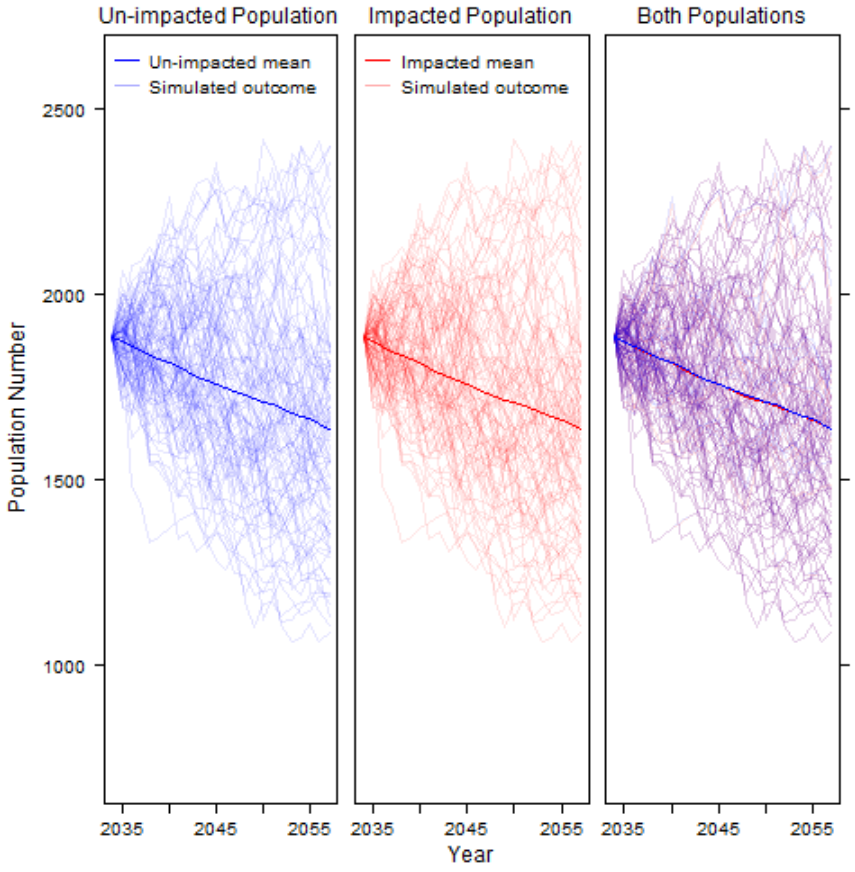

Figure 3.5: Simulated population trajectories in an unimpacted versus impacted population for the maximum temporal scenario for the Greater North Sea MU bottlenose dolphin population

Table 3.4: Modelled estimates for the unimpacted and impacted bottlenose dolphin population for the maximum temporal scenario for the Greater North Sea MU

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	1,886	1,886	1,886	1,886	1,886	1,886	1.0000	1.0000
2	2035	1,694	1,872	2,010	1,694	1,872	2,010	1.0000	1.0000
3	2036	1,628	1,861	2,028	1,628	1,858	2,022	1.0000	0.9985
4	2037	1,600	1,850	2,054	1,594	1,847	2,054	1.0000	0.9983
6	2039	1,512	1,827	2,098	1,512	1,824	2,096	1.0000	0.9985
7	2040	1,496	1,816	2,128	1,496	1,814	2,128	1.0000	0.9986
9	2042	1,416	1,791	2,138	1,410	1,788	2,138	1.0000	0.9988
13	2046	1,316	1,748	2,156	1,314	1,746	2,156	1.0000	0.9987
15	2048	1,288	1,727	2,194	1,286	1,724	2,194	1.0000	0.9986
17	2050	1,244	1,709	2,218	1,244	1,706	2,218	1.0000	0.9986
18	2051	1,226	1,702	2,212	1,226	1,699	2,212	1.0000	0.9987
19	2052	1,216	1,693	2,210	1,216	1,690	2,210	1.0000	0.9987

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
20	2053	1,196	1,681	2,240	1,196	1,678	2,240	1.0000	0.9987
21	2054	1,176	1,671	2,197	1,176	1,668	2,197	1.0000	0.9986
22	2055	1,160	1,663	2,236	1,160	1,660	2,236	1.0000	0.9986
26	2059	1,112	1,617	2,176	1,112	1,615	2,176	1.0000	0.9986

3.2.2 BND-02 Maximum Spatial Scenario

3.2.2.1 The results for the maximum spatial scenario are presented in Figure 3.6. These indicate a very small difference in the growth trajectory of bottlenose dolphin between the unimpacted population and impacted population. Across all time points there was a maximum difference of one individual (approximately 0.05% of the Greater North Sea MU reference population) time points 4, 5, 8, 12, 15, and 16. At all other time points, there was no difference between the impacted and unimpacted populations (Table 3.5).

3.2.2.2 The median counterfactual remained as 1 through the 26-year model, while the mean fluctuated between 1 and 0.9997 (Table 3.5). Therefore, given that the differences in impacted and unimpacted populations approaches a ratio of 1, there is not considered to be a potential for a long-term effect from this piling scenario upon the bottlenose dolphin population within the Greater North Sea MU.

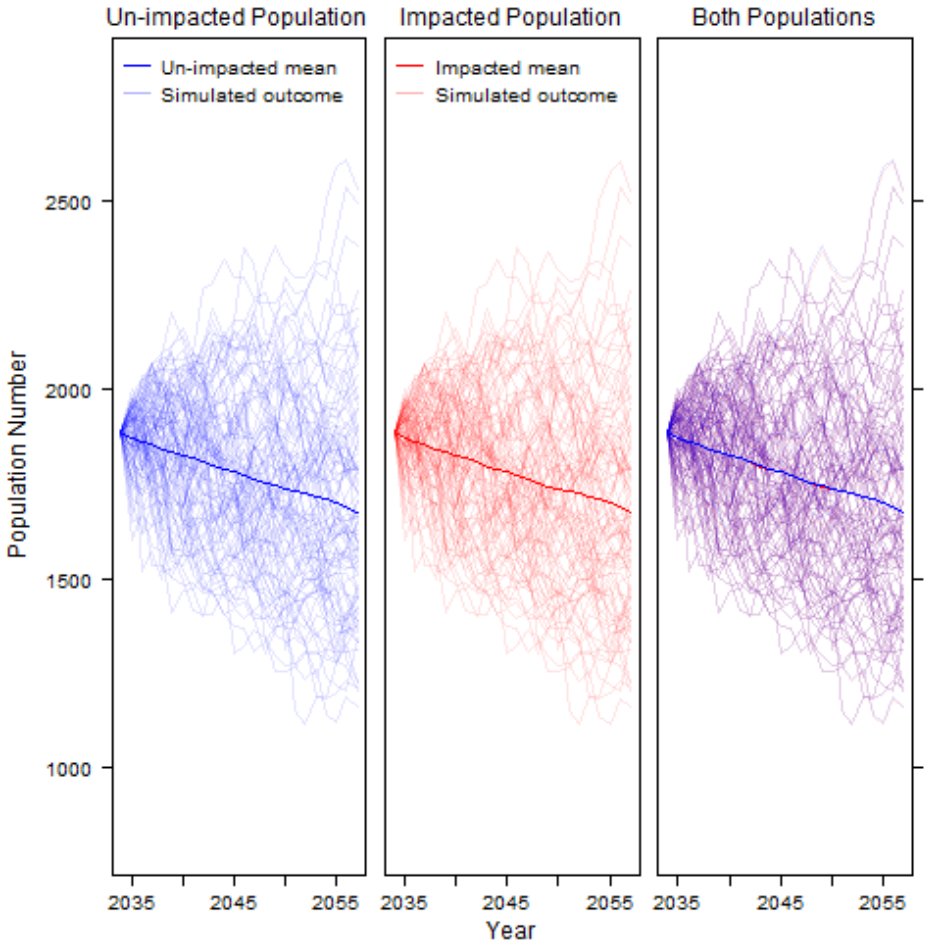

Figure 3.6: Simulated population trajectories in an unimpacted versus impacted population for the maximum spatial scenario for the Greater North Sea management unit bottlenose dolphin population

Table 3.5: Modelled estimates for the unimpacted and impacted bottlenose dolphin population for the maximum spatial scenario for the Greater North Sea MU

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	1,886	1,886	1,886	1,886	1,886	1,886	1.000	1.0000
2	2035	1,692	1,875	2,000	1,692	1,875	2,000	1.000	1.0000
3	2036	1,622	1,864	2,042	1,622	1,864	2,042	1.000	0.9997
4	2037	1,590	1,858	2,068	1,590	1,857	2,068	1.000	0.9997
5	2038	1,558	1,844	2,086	1,558	1,843	2,086	1.000	0.9997
7	2040	1,496	1,827	2,106	1,496	1,827	2,106	1.000	0.9998
8	2041	1,500	1,819	2,120	1,500	1,818	2,120	1.000	0.9998
12	2045	1,416	1,784	2,168	1,412	1,783	2,168	1.000	0.9998
13	2046	1,378	1,773	2,182	1,378	1,773	2,178	1.000	0.9998
15	2048	1,330	1,756	2,198	1,330	1,755	2,198	1.000	0.9998

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
16	2049	1,296	1,746	2,186	1,296	1,745	2,196	1.000	0.9998
26	2059	1,158	1,654	2,256	1,158	1,654	2,264	1.000	0.9998

3.2.3 BND-03 Cumulative Scenario (Greater North Sea MU only)

3.2.3.1 As detailed in Table 2.12, this cumulative scenario modelled the Greater North Sea MU population of bottlenose dolphin. Projects included in the model were those which also included this MU population within their iPCoD models. The Tier 1 projects were Caledonia and Muir Mhor alongside Morven South, and the Tier 2 projects were Ayre and Bowdun.

3.2.3.2 For the BND-03 cumulative modelling scenario, a total of 1,606 piling days were modelled (including 262 days for Morven South, see Table 2.9). These results indicated some difference in the simulated trajectories of the bottlenose dolphin population from the Greater North Sea MU between the unimpacted population and impacted population (Figure 3.7).

3.2.3.3 The maximum difference between the impacted and unimpacted populations was in time point 6 (2033), wherein the impacted population was smaller than the unimpacted population by 61 individuals (3.24% of the Greater North Sea MU reference population; Table 3.6). This time point corresponded to the year after piling was completed at Caledonia and two years after piling completion at Muir Mhor, and one year prior to the commencement of piling at Morven South.

3.2.3.4 From time point 7 (2034, the year in which piling commences at Morven South) to 25 (2052), the difference in the mean impacted and unimpacted populations remained between 50 and 59 individuals (2.65% to 3.13% of the Greater North Sea MU reference population). By the end of the model (time point 26), this had reduced to a difference of 51 animals in the impacted population, compared to the un-impacted population (Table 3.6) corresponding to 2.71% of the Greater North Sea MU reference population. This could suggest that the population had stabilised.

3.2.3.5 The median counterfactual of population size for cumulative scenario BND-03 remained at 1 throughout, while the mean counterfactual was 0.9700 at the end of the 26-year simulation (Table 3.6).

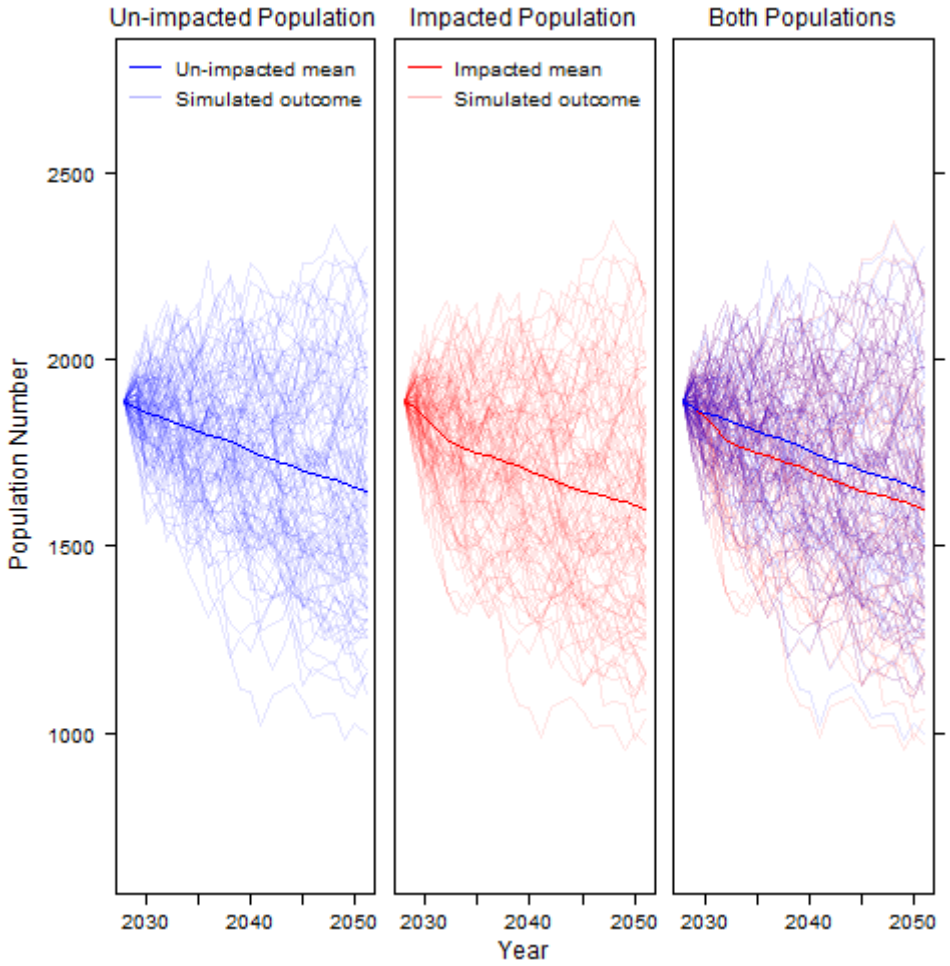

Figure 3.7: Simulated Greater North Sea management unit bottlenose dolphin population trajectories in an unimpacted versus impacted population for the cumulative scenario BND-03

Table 3.6: Modelled estimates for the unimpacted and impacted Greater North Sea MU bottlenose dolphin population for the cumulative scenario BND-03

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2028	1,886	1,886	1,886	1,886	1,886	1,886	1.0000	1.0000
2	2029	1,672	1,873	2,012	1,672	1,873	2,012	1.0000	1.0000
3	2030	1,602	1,858	2,048	1,586	1,848	2,040	1.0000	0.9944
4	2031	1,576	1,850	2,062	1,508	1,818	2,046	1.0000	0.9829
5	2032	1,516	1,838	2,086	1,430	1,788	2,076	1.0000	0.9726
6	2033	1,494	1,830	2,108	1,364	1,769	2,090	1.0000	0.9668
7	2034	1,484	1,817	2,104	1,330	1,758	2,100	1.0000	0.9673
8	2035	1,454	1,807	2,128	1,338	1,749	2,116	1.0000	0.9679
9	2036	1,444	1,798	2,132	1,326	1,742	2,114	1.0000	0.9687
10	2037	1,408	1,791	2,156	1,296	1,734	2,140	1.0000	0.9682

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
20	2047	1,192	1,687	2,244	1,116	1,634	2,220	1.0000	0.9688
26	2053	1,124	1,631	2,202	1,030	1,580	2,202	1.0000	0.9688

3.2.3.6 Over the model run, the difference between the mean unimpacted and impacted population sizes increased throughout the cumulative piling schedule for the different projects with the final year of piling in time point 9 (as illustrated by the orange bar in Figure 3.8). As illustrated in Figure 3.8, the steepest decline occurred between time points 2 (2029) and 6 (2033); the year 2031 is the point at which most cumulative projects are piling, although this is two years prior to the start of Morven South. After the commencement of piling at Morven South (time point 7: 2034) and Morven North (time point 8: 2035), the difference between the mean unimpacted and impacted populations began to level off, suggesting that these two projects contribute very little to cumulative effects (Figure 3.8). It should be noted that the iPCoD model does not facilitate as assessment of density-dependent population recovery and therefore the differences between the unimpacted and impacted population do not reflect the true population after ceases, when recovery would be anticipated (see paragraphs 1.2.1.5 and 1.2.1.6).

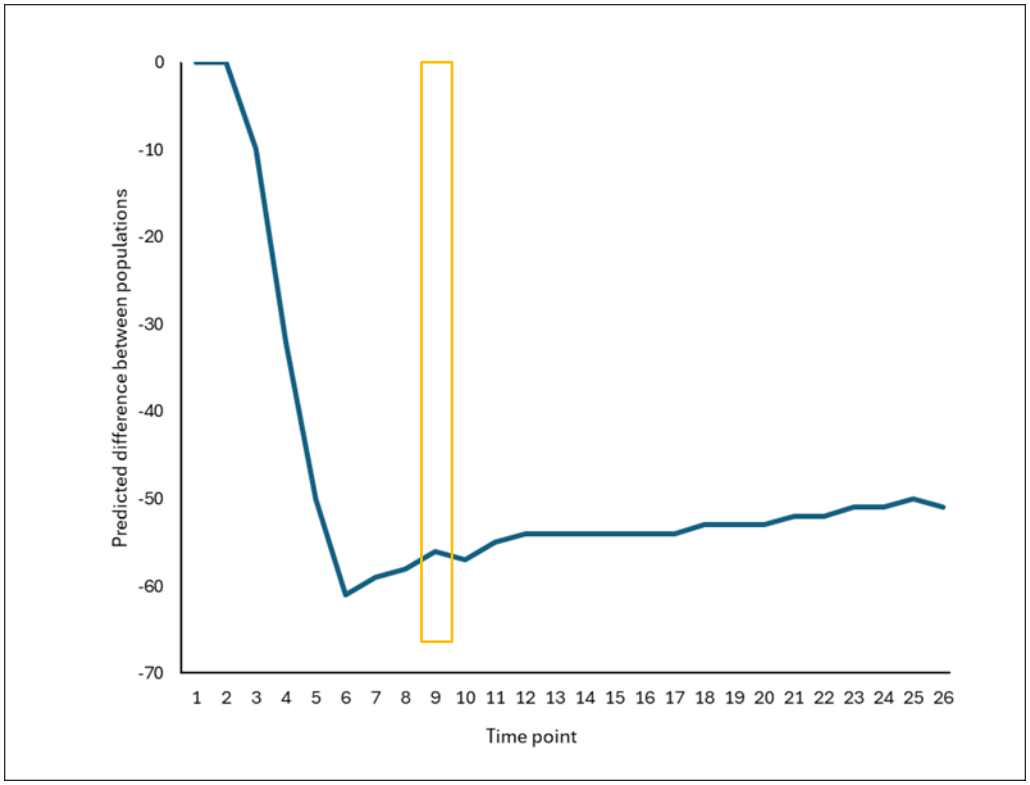

Figure 3.8: Difference in the mean number of bottlenose dolphin from the Greater North Sea management unit between the impacted and unimpacted populations across all time points for the cumulative scenario BND-03

3.2.4 BND-04 Cumulative Scenario (Coastal East Scotland and Greater North Sea management units: Coastal East Scotland management units vital rates)

3.2.4.1 As detailed in Table 2.12, this cumulative scenario assessed the combined bottlenose dolphin populations of the Greater North Sea MU and Coastal East Scotland MU and used the vital rates for the Coastal East Scotland MU (see Table 2.4). Cenos was excluded from this model as although bottlenose dolphin was included as a key species in the assessment, this project did not include bottlenose dolphin from either MU in its iPCoD modelling, and therefore no estimates of animals potentially disturbed were available (see Table 2.10).

3.2.4.2 For Berwick Bank and Ossian, which only included the Coastal East Scotland MU, the number of animals disturbed was included in the model (see Table 2.10). Finally, for the projects which assessed both MU populations, the total numbers of animals disturbed were combined (see Table 2.10).

3.2.4.3 For the BND-04 cumulative modelling scenario, a total of 2,111 piling days were modelled (including 262 days for Morven South, see Table 2.9). These results indicated a difference in the simulated trajectories of the unimpacted combined MU population and the impacted combined MU population (Figure 3.9). The maximum difference between the impacted and unimpacted populations was in time point 26 (2053), wherein the impacted population was smaller than the unimpacted population by 271 individuals (12.84% of the combined Greater North Sea MU and Coastal East Scotland MU reference population; Table 3.7).

3.2.4.4 At time point 12 (which corresponds to the first year after all cumulative piling ended), there was a difference of 158 animals between the unimpacted and impacted populations (7.48% of the combined Greater North Sea MU and Coastal East Scotland MU reference population). At time point 22, which corresponded to ten years after the completion of all cumulative piling, there was a difference of 234 animals between the impacted and unimpacted populations (11.08% of the combined Greater North Sea MU and Coastal East Scotland MU reference population; Table 3.7).

3.2.4.5 The median and mean counterfactuals of population size for cumulative scenario BND-04 were 0.9988 and 0.9523, respectively at the end of the 26-year simulation (Table 3.7).

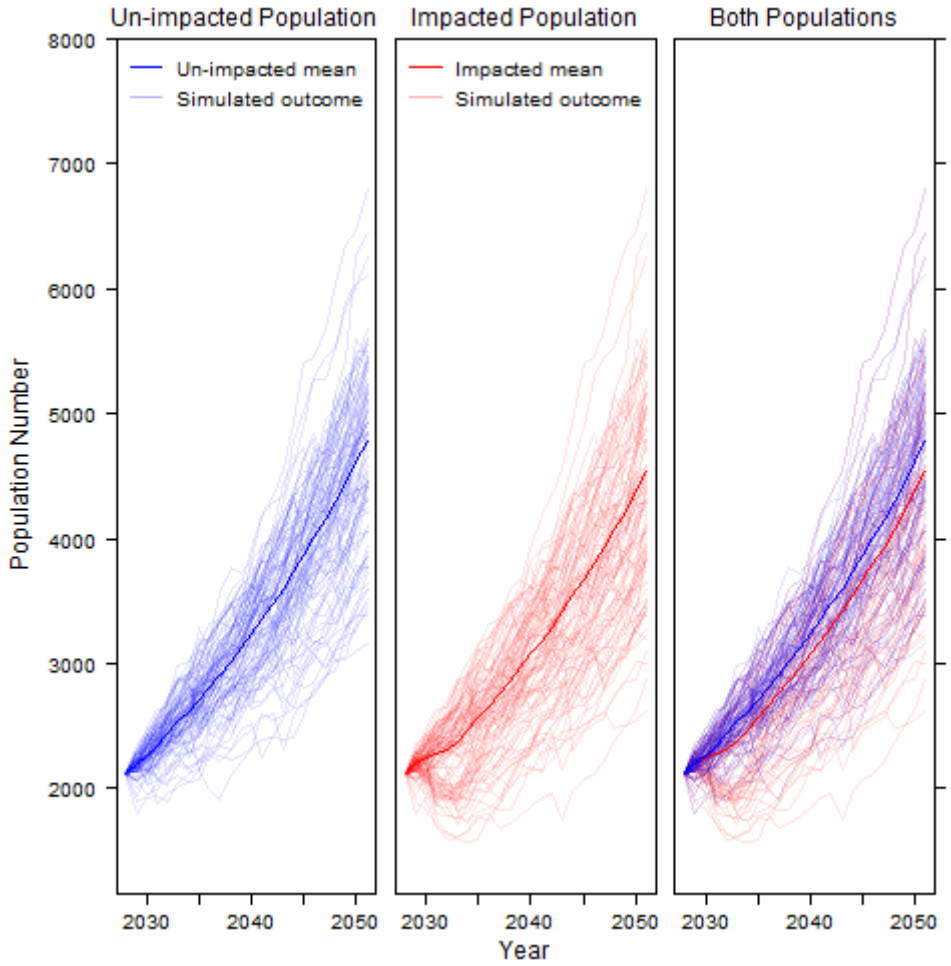

Figure 3.9: Simulated bottlenose dolphin population trajectories for the combined Greater North Sea and Coastal East Scotland management units in an unimpacted versus impacted population for the cumulative scenario BND-04

Table 3.7: Modelled estimates for the unimpacted and impacted bottlenose dolphin populations (Greater North Sea management unit and Coastal East Scotland management unit combined) for the cumulative scenario BND-04

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2028	2,110	2,110	2,110	2,110	2,110	2,110	1.0000	1.0000
2	2029	2,006	2,190	2,330	2,006	2,190	2,330	1.0000	1.0000
3	2030	2,012	2,269	2,466	1,928	2,239	2,452	1.0000	0.9867
4	2031	2,042	2,350	2,590	1,802	2,272	2,574	1.0000	0.9669
5	2032	2,072	2,436	2,718	1,738	2,315	2,692	0.9975	0.9504
6	2033	2,106	2,527	2,856	1,722	2,377	2,822	0.9969	0.9407
7	2034	2,166	2,616	2,988	1,764	2,467	2,944	0.9971	0.9434
8	2035	2,236	2,708	3,138	1,848	2,562	3,098	0.9974	0.9461
9	2036	2,296	2,801	3,256	1,894	2,655	3,208	0.9977	0.9480
11	2038	2,406	3,011	3,596	2,006	2,854	3,530	0.9978	0.9480

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
12	2039	2,474	3,120	3,718	2,088	2,962	3,674	0.9977	0.9493
22	2049	3,260	4,444	5,716	2,826	4,210	5,588	0.9978	0.9480
26	2053	3,724	5,141	6,724	3,234	4,870	6,546	0.9975	0.9481

3.2.4.6 Over the model run, the difference between the mean unimpacted and impacted population sizes increased throughout the cumulative piling schedule for the different projects with the final year of piling in time point 11 (2038; as illustrated by the orange bar in Figure 3.10). After this point, the difference continued to increase, however not so sharply (Figure 3.10). As illustrated in Figure 3.10, the steepest decline occurred between time points 2 (2029) and 6 (2033); the year 2031 is the point at which most cumulative projects are piling, although this is two years prior to the start of Morven South After the commencement of piling at Morven South (time point 7: 2034) and Morven North (time point 8: 2035), the difference between the mean unimpacted and impacted populations was lower (Figure 3.10), suggesting that these two projects contribute very little to cumulative effects. However, it should be noted that the iPCoD model does not facilitate as assessment of density-dependent population recovery and therefore the differences between the unimpacted and impacted population do not reflect the true population after ceases, when recovery would be anticipated (see paragraphs 1.2.1.5 and 1.2.1.6).

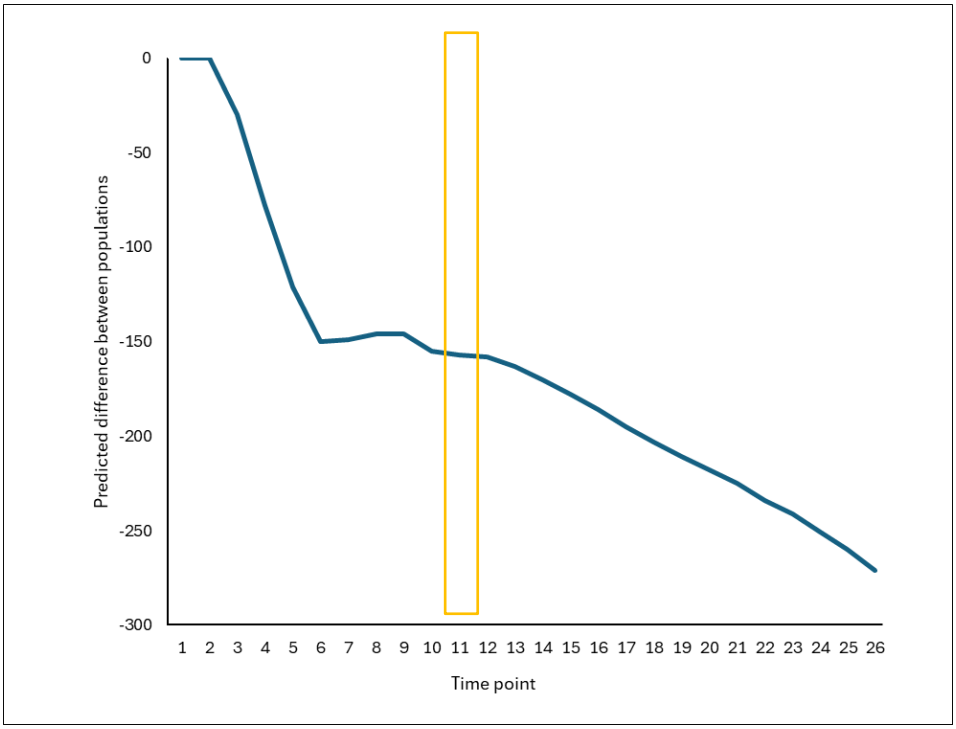

Figure 3.10: Difference in the mean number of bottlenose dolphins (Greater North Sea and Coastal East Scotland management units combined) between the impacted and unimpacted populations across all time points for the cumulative scenario BND-04

3.2.5 BND-05 Cumulative Scenario (Coastal East Scotland and Greater North Sea management units: Greater North Sea management unit vital rates)

3.2.5.1 As detailed in Table 2.12, this cumulative scenario assessed the combined bottlenose dolphin populations of the Greater North Sea MU and Coastal East Scotland MU and used the vital rates for the Greater North Sea MU (see Table 2.4). Cenos was excluded from this model as this project did not include bottlenose dolphin from either MU in its iPCoD models, and therefore no estimates of animals potentially disturbed were available (see Table 2.10).

3.2.5.2 For Berwick Bank and Ossian, which only included the Coastal East Scotland MU, the number of animals disturbed was included in the model (see Table 2.10). Finally, for the projects which assessed both MU populations, the total numbers of animals disturbed were combined (see Table 2.10).

3.2.5.3 For the BND-05 cumulative modelling scenario, a total of 2,111 piling days were modelled (including 262 days for Morven South, see Table 2.9). These results indicated a difference in the simulated trajectories of the unimpacted combined MU population and the impacted combined MU population (Figure 3.9). The maximum difference between the impacted and unimpacted populations was in time point 6 (2033), wherein the impacted population was smaller than the unimpacted population by 88 individuals (4.17% of the combined Greater North Sea MU and Coastal East Scotland MU reference population; Table 3.8).

3.2.5.4 At time point 12 (which corresponds to the first year after all cumulative piling ended), there was a difference of 73 animals between the unimpacted and impacted populations (3.46% of the combined Greater North Sea MU and Coastal East Scotland MU reference population). At time point 22, which corresponded to ten years after the completion of all cumulative piling, there was a difference of 71 animals between the impacted and unimpacted populations (3.41% of the combined Greater North Sea MU and Coastal East Scotland MU reference population; Table 3.8).

3.2.5.5 The median and mean counterfactuals of population size for cumulative scenario BND-05 were 0.9989 and 0.919, respectively, at the end of the 26-year simulation (Table 3.8).

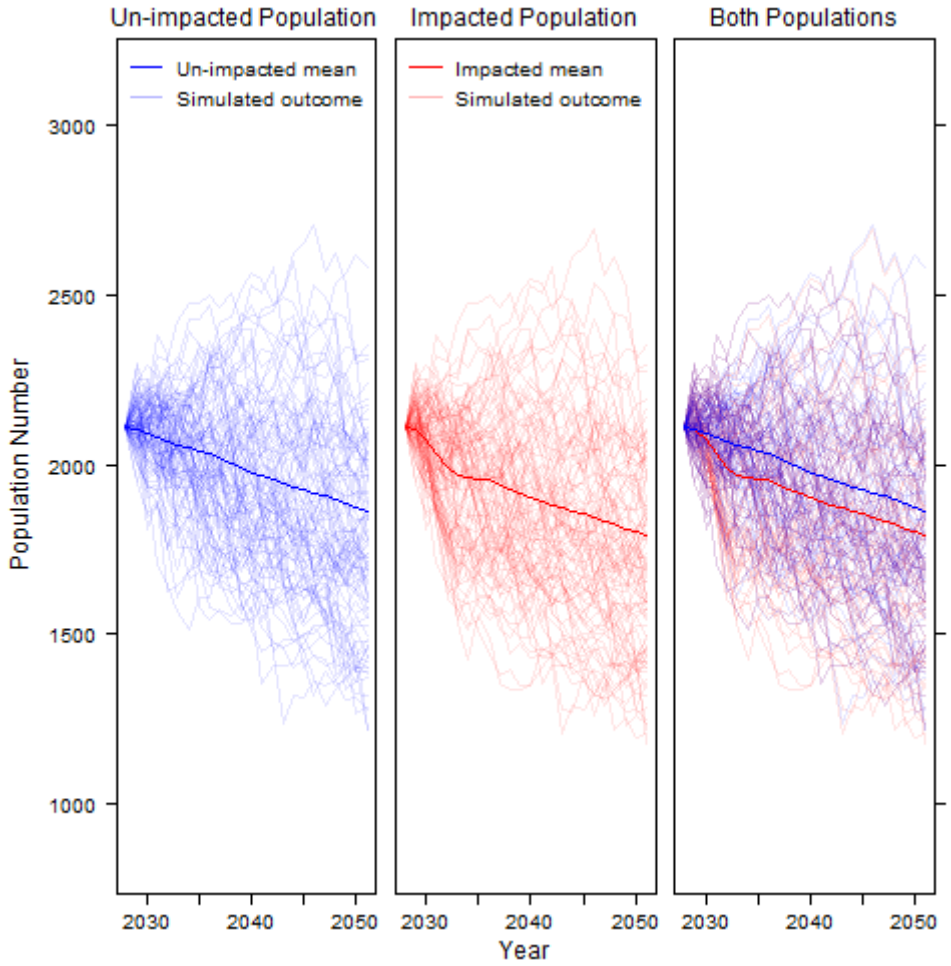

Figure 3.11: Simulated bottlenose dolphin population trajectories for the combined Greater North Sea and Coastal East Scotland MUs in an unimpacted versus impacted population for the cumulative scenario BND-05

Table 3.8: Modelled estimates for the unimpacted and impacted bottlenose dolphin populations (Greater North Sea management unit and Coastal East Scotland management unit combined) for the cumulative scenario BND-05

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2028	2,112	2,112	2,112	2,112	2,112	2,112	1.0000	1.0000
2	2029	1,912	2,104	2,242	1,912	2,104	2,242	1.0000	1.0000
3	2030	1,838	2,093	2,284	1,822	2,076	2,278	1.0000	0.9921
4	2031	1,796	2,077	2,292	1,722	2,033	2,280	1.0000	0.9789
5	2032	1,748	2,066	2,308	1,620	1,994	2,286	0.9981	0.9655
6	2033	1,726	2,057	2,324	1,536	1,969	2,298	0.9980	0.9574
7	2034	1,682	2,048	2,340	1,512	1,965	2,326	0.9981	0.9594
8	2035	1,674	2,039	2,358	1,522	1,959	2,340	0.9982	0.9607
9	2036	1,642	2,032	2,398	1,486	1,953	2,366	0.9983	0.9617
11	2038	1,600	2,003	2,426	1,440	1,926	2,392	0.9989	0.9624

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
12	2039	1,560	1,990	2,420	1,426	1,917	2,400	0.9989	0.9635
22	2049	1,344	1,883	2,500	1,246	1,811	2,464	0.9988	0.9618
26	2053	1,256	1,840	2,464	1,204	1,770	2,448	0.9989	0.9619

3.2.5.6 Over the model run, the difference between the mean unimpacted and impacted population sizes increased sharply throughout the cumulative piling schedule for the different projects with the final year of piling in time point 11 (as illustrated by the orange bar in Figure 3.12). As illustrated in Figure 3.12, the steepest decline occurred between time points 2 (2029) and 6 (2033); the year 2031 is the point at which most cumulative projects are piling, although this is two years prior to the start of Morven South. After the commencement of piling at Morven South (time point 7: 2034) and Morven North (time point 8: 2035), the difference between the mean unimpacted and impacted populations began to level off, suggesting that these two projects contribute very little to cumulative effects(Figure 3.12). It should be noted that the iPCoD model does not facilitate as assessment of density-dependent population recovery and therefore the differences between the unimpacted and impacted population do not reflect the true population after ceases, when recovery would be anticipated (see paragraphs 1.2.1.5 and 1.2.1.6).

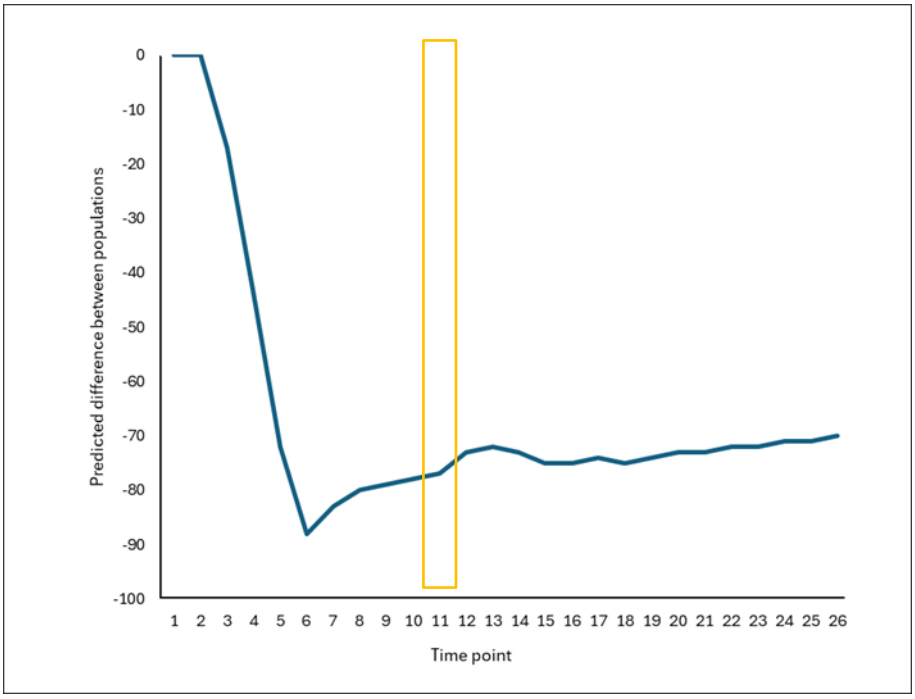

Figure 3.12: Difference in the mean number of bottlenose dolphins (Greater North Sea and Coastal East Scotland management units combined) between the impacted and unimpacted populations across all time points for the cumulative scenario BND-05

3.3 Minke Whale

3.3.1 MW-01 Maximum Temporal Scenario

3.3.1.1 The results for the maximum temporal scenario are presented in Figure 3.13. These indicate a very small difference in the growth trajectory of minke whale between the unimpacted population and impacted population. At all time points, there was little difference in the mean size of the impacted and unimpacted populations, with a maximum difference of 1 individual (approximately 0.005% of the Celtic and Greater North Seas MU reference population) at time point 14. At all other time points, there was no difference between the impacted and unimpacted populations (Table 3.9). This suggests that long-term disturbance of the minke whale population within the Celtic and Greater North Seas MU would not occur due to piling at Morven South.

3.3.1.2 The median counterfactual remained as 1 through the 26-year model, while the mean fluctuated between 1 and 0.9999 (Table 3.9). Therefore, given that the differences in impacted and unimpacted populations approaches a ratio of 1, there is not considered to be a potential for a long-term effect from this piling scenario upon the minke whale population within the Celtic and Greater North Seas MU.

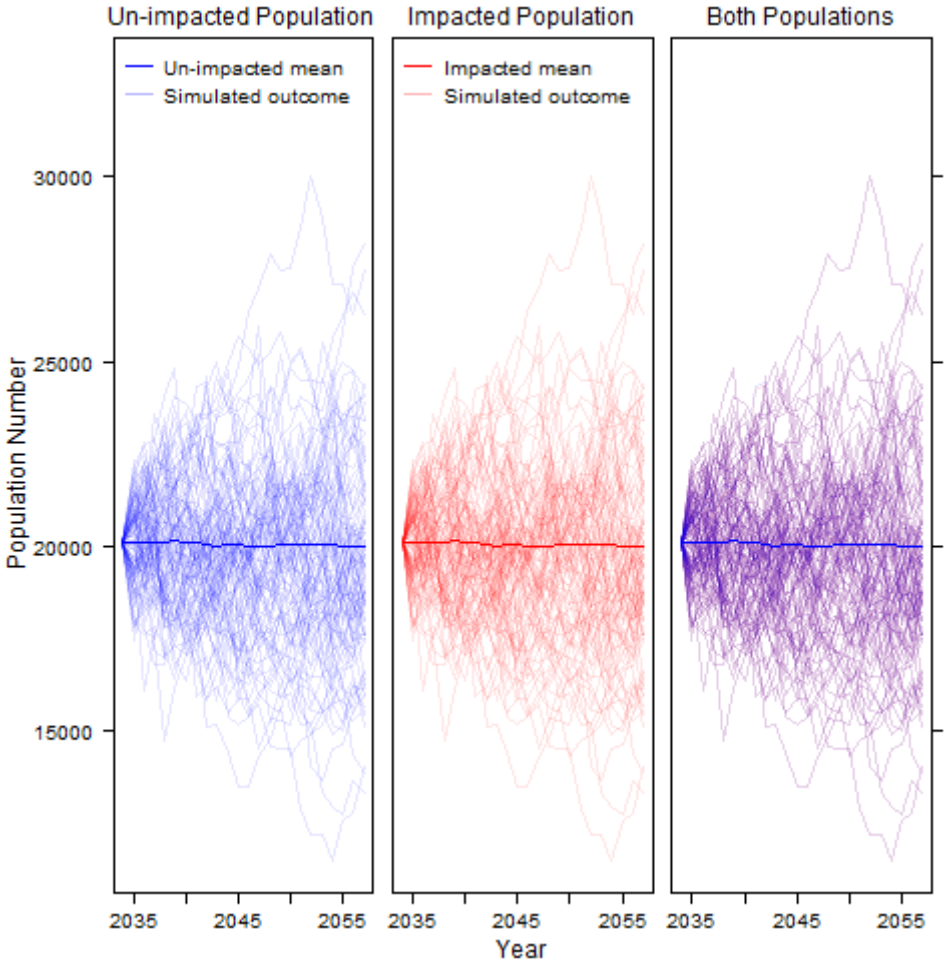

Figure 3.13: Simulated minke whale population trajectories in an unimpacted versus impacted population for the maximum temporal scenario

Table 3.9: Modelled estimates for the unimpacted and impacted minke whale population for the maximum temporal scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	20,120	20,120	20,120	20,120	20,120	20,120	1.0000	1.0000
2	2035	17,831	20,074	21,908	17,831	20,074	21,908	1.0000	1.0000
3	2036	17,589	20,085	22,620	17,589	20,085	22,620	1.0000	0.9999
7	2040	16,928	20,113	23,495	16,928	20,113	23,495	1.0000	0.9999
13	2046	15,797	19,973	25,236	15,797	19,973	25,236	1.0000	0.9999
14	2047	15,870	19,992	25,062	15,870	19,991	25,062	1.0000	0.9999
26	2059	14,337	19,935	26,805	14,337	19,935	26,805	1.0000	0.9999

3.3.2 MW-02 Maximum Spatial Scenario

3.3.2.1 The results for the maximum spatial scenario are presented in Figure 3.14. These indicate a very small difference in the growth trajectory of minke whale between the unimpacted population and impacted population. At all time points, there was little difference in the mean size of the impacted and unimpacted populations, with a maximum difference of 38 individuals (approximately 0.19% of the Celtic and Greater North Seas MU reference population) at time point 20 (

3.3.2.2

3.3.2.3 Table 3.10).

3.3.2.4 At time point 3 (the year after piling finishes), there was a difference of 6 animals between the impacted and unimpacted populations (approximately 0.03% of the Celtic and Greater North Seas MU reference population). At time point 7, which corresponds to the six-year reporting period previously required under the Habitats Directive, the impacted population was modelled to be 22 animals smaller than the unimpacted population (approximately 0.11% of the North Sea MU reference population) At time point 13 (corresponding to ten years after piling completion) the impacted population was modelled to be 34 animals smaller than the unimpacted population (approximately 0.17% of the Celtic and Greater North Seas MU reference population) (

3.3.2.5

3.3.2.6 Table 3.10).

3.3.2.7 At time point 26 (the end of the model run), the impacted population was modelled to be 36 animals smaller than the unimpacted population (approximately 0.18% of the Celtic and Greater North Seas MU reference population) (

3.3.2.8

3.3.2.9 Table 3.10). This suggests that long-term disturbance of the minke whale population within the Celtic and Greater North Seas MU would not occur due to piling at Morven South.

3.3.2.10 The median counterfactual fluctuated between 1 and 0.9986 through the 26-year model and the mean fluctuated between 1 and 0.9981 (

3.3.2.11

3.3.2.12 Table 3.10). Therefore, given that the differences in impacted and unimpacted populations approaches a ratio of 1, there is not considered to be a potential for a long-term effect from this piling scenario upon the minke whale population within the Celtic and Greater North Seas MU.

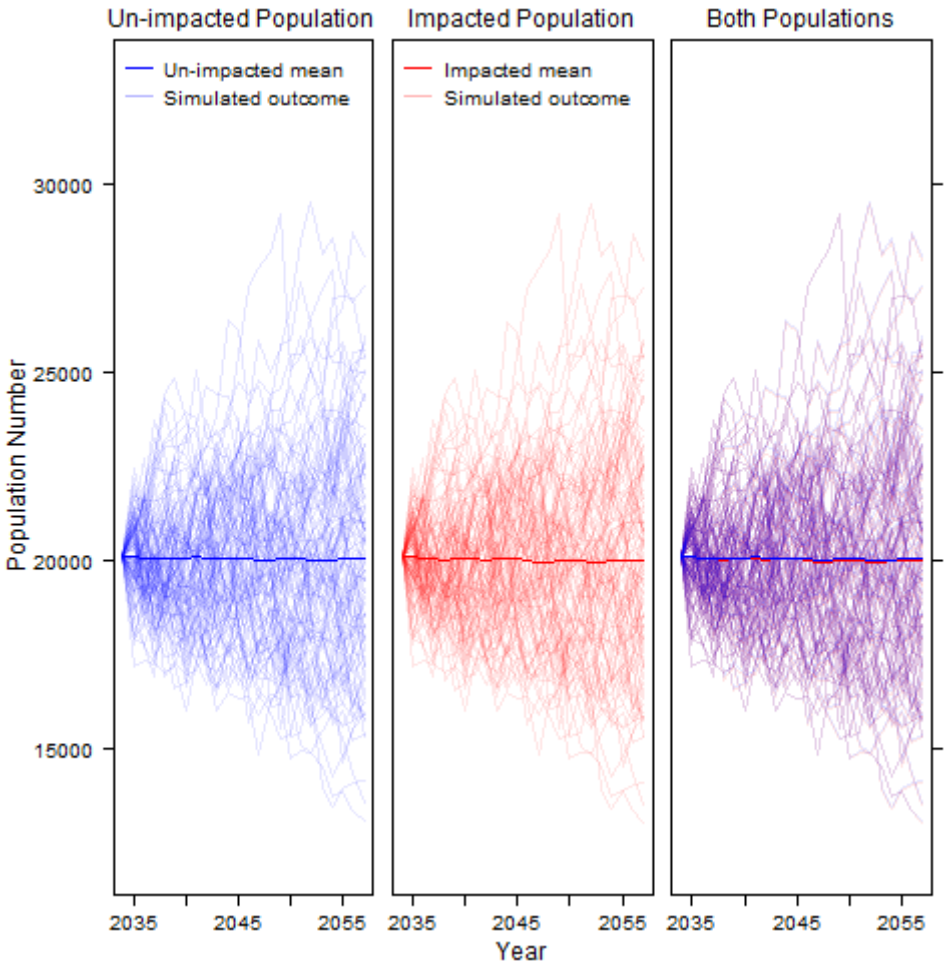

Figure 3.14: Simulated minke whale population trajectories in an unimpacted versus impacted population for the maximum spatial scenario

Table 3.10: Modelled estimates for the unimpacted and impacted minke whale population for the maximum spatial scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	20,120	20,120	20,120	20,120	20,120	20,120	1.000	1.000
2	2035	17,798	20,119	21,860	17,798	20,119	21,860	1.000	1.000
3	2036	17,369	20,066	22,498	17,365	20,060	22,492	0.9999	0.9997
7	2040	16,757	20,046	23,608	16,730	20,024	23,596	0.9993	0.9989
13	2046	16,024	20,030	24,951	16,019	19,996	24,908	0.9988	0.9983
20	2053	15,032	19,974	26,556	15,027	19,936	26,460	0.9986	0.9981

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
26	2059	14,448	19,958	27,663	14,429	19,922	27,640	0.9987	0.9982

3.3.3 MW-03 Cumulative Scenario

3.3.3.1 For the MW-03 cumulative modelling scenario, a total of 2,181 piling days were modelled (including 48 days for Morven South, see Table 2.9). These results indicated some difference in the simulated trajectories of minke whale between the unimpacted population and impacted population (Figure 3.15). This corresponded to an impacted population that was smaller than the unimpacted population by 94 individuals at time point 26 (Table 3.11), corresponding to 0.47% of the Celtic and Greater North Seas MU reference population. This was also the maximum difference between the impacted and un-impacted populations (Table 3.11).

3.3.3.2 At time point 22, which corresponded to ten years after the completion of all cumulative piling, there was a difference of 90 animals between the impacted and unimpacted populations (0.45% of the Greater North Seas MU reference population). This is more than double the difference of 34 animals at time point 13 for the modelling of Morven South alone (corresponding to ten years after piling completion of Morven South) (see Section 3.3.2).

3.3.3.3 The median counterfactual of population size for cumulative scenario MW-03 was 0.9965 at the end of the 26-year simulation, while the mean counterfactual was 0.9954 (Table 3.11). The counterfactual remained close to 1 throughout the cumulative piling period, suggesting that even though there were some declines in the population during cumulative piling, this was relatively small in relation to the Greater North Sea MU geographic frame of reference.

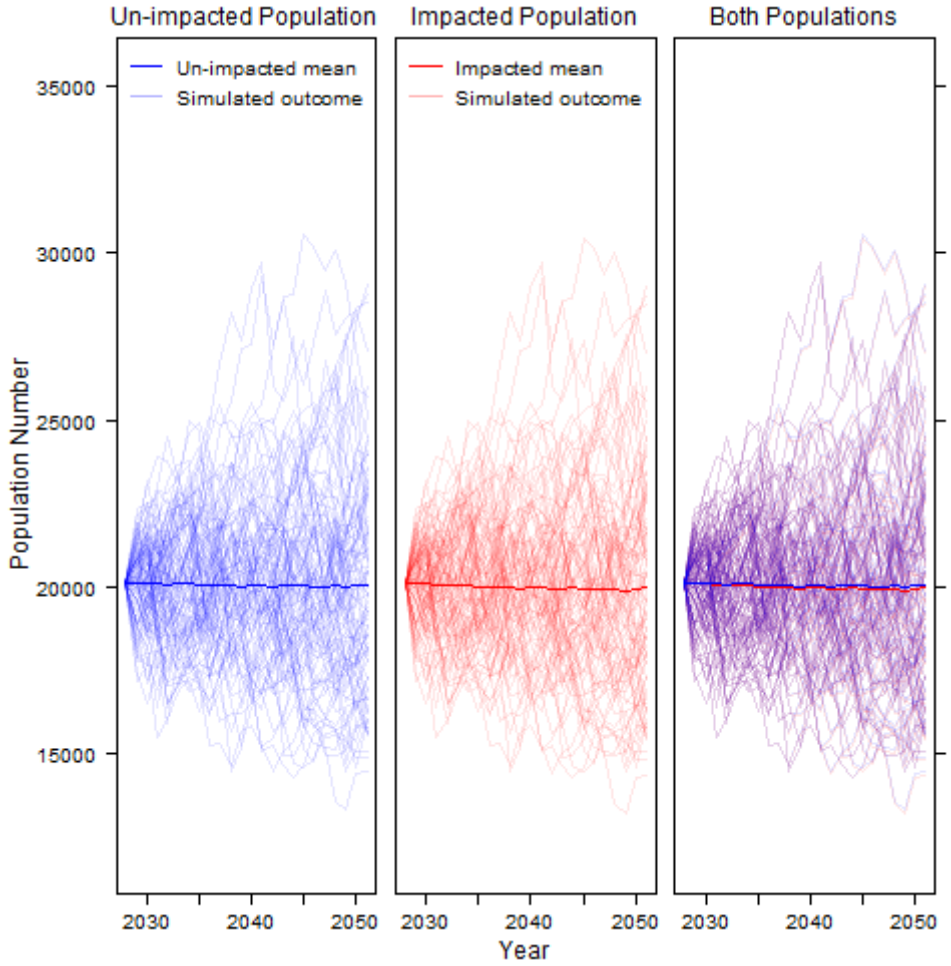

Figure 3.15: Simulated minke whale population trajectories in an unimpacted versus impacted population for the cumulative scenario MW-03

Table 3.11: Modelled estimates for the unimpacted and impacted minke whale population for the cumulative scenario MW-03

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2028	20,120	20,120	20,120	20,120	20,120	20,120	1.0000	1.0000
2	2029	17,817	20,147	21,934	17,817	20,147	21,934	1.0000	1.0000
3	2030	17,560	20,149	22,512	17,560	20,148	22,498	1.0000	0.9999
4	2031	17,446	20,104	22,879	17,446	20,095	22,868	1.0000	0.9996
5	2032	17,056	20,089	23,220	16,944	20,052	23,210	1.0000	0.9982
6	2033	17,060	20,121	23,568	16,818	20,060	23,499	1.0000	0.9970
7	2034	16,744	20,105	23,882	16,712	20,055	23,839	1.0000	0.9976
8	2035	16,537	20,073	24,225	16,452	20,032	24,176	1.0000	0.9981
9	2036	16,482	20,066	24,431	16,458	20,030	24,396	0.9998	0.9982
11	2038	16,301	20,039	24,614	16,243	19,991	24,598	0.9989	0.9977

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
22	2049	14,873	19,995	27,260	14,794	19,905	27,060	0.9967	0.9955
26	2053	20,120	20,120	20,120	20,120	20,120	20,120	1.0000	1.0000

3.3.3.4 Over the model run, the difference between the mean unimpacted and impacted population sizes increased sharply until time point 6 (2033), decreased until time point 9 (2036), and then increased steadily until the end of the model run (Figure 3.16). As illustrated in Figure 3.16, the steepest decline occurred between time points 4 (2031) and 6 (2033); the year 2031 is the point at which most cumulative projects are piling, although this is two years prior to the start of piling at Morven South (see Table 2.9). The difference between the mean unimpacted and impacted populations decreased from time point 7 (corresponding to the commencement of piling at Morven South) to time point 9 (end of piling at Morven North), however increased again steadily until the end of the model run (Figure 3.16). Furthermore, it should be noted that the iPCoD model does not facilitate as assessment of density-dependent population recovery and therefore the differences between the unimpacted and impacted population do not reflect the true population after piling ceases, when recovery would be anticipated (see paragraphs 1.2.1.5 and 1.2.1.6).

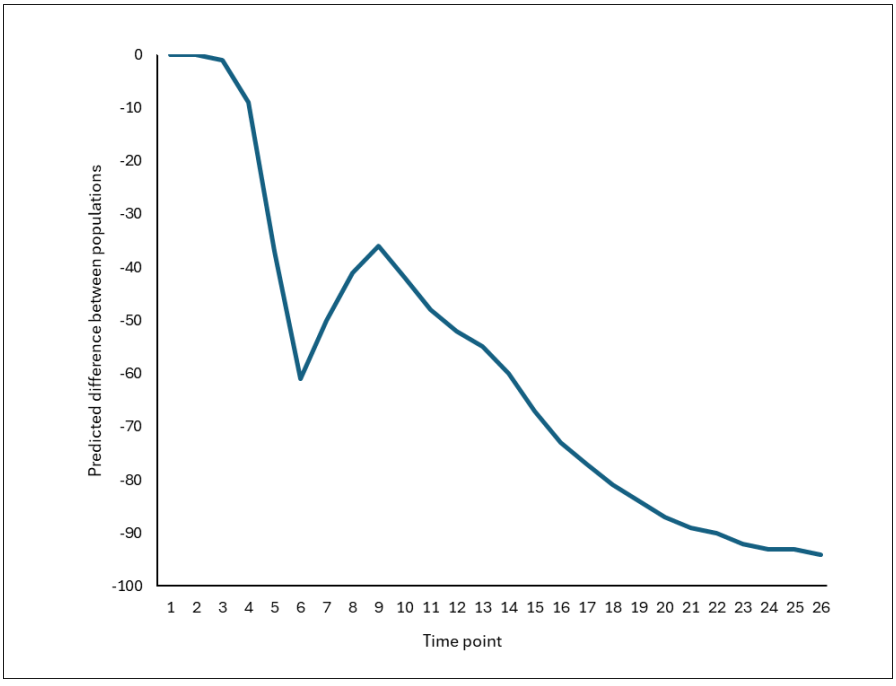

Figure 3.16: Difference in the mean number of minke whale between the impacted and unimpacted populations across all time points for the cumulative scenario MW-03

3.4 Grey Seal

3.4.1 GS-01 Maximum Temporal Scenario

3.4.1.1 The results for the maximum temporal scenario are presented in Figure 3.17. These results indicate that there will be no difference between the trajectories of the impacted and unimpacted grey seal

populations. There was no difference in the mean size of the impacted and unimpacted grey seal populations (Table 3.12).

3.4.1.2 The mean and median counterfactuals both remained at 1 throughout the 26 time points, indicating that there would be no discernible difference in the ratio of impacted to unimpacted populations (Table 3.12). This suggests that long-term disturbance of the grey seal population within the East Scotland and Northeast England seal MUs would not occur due to piling at Morven South.

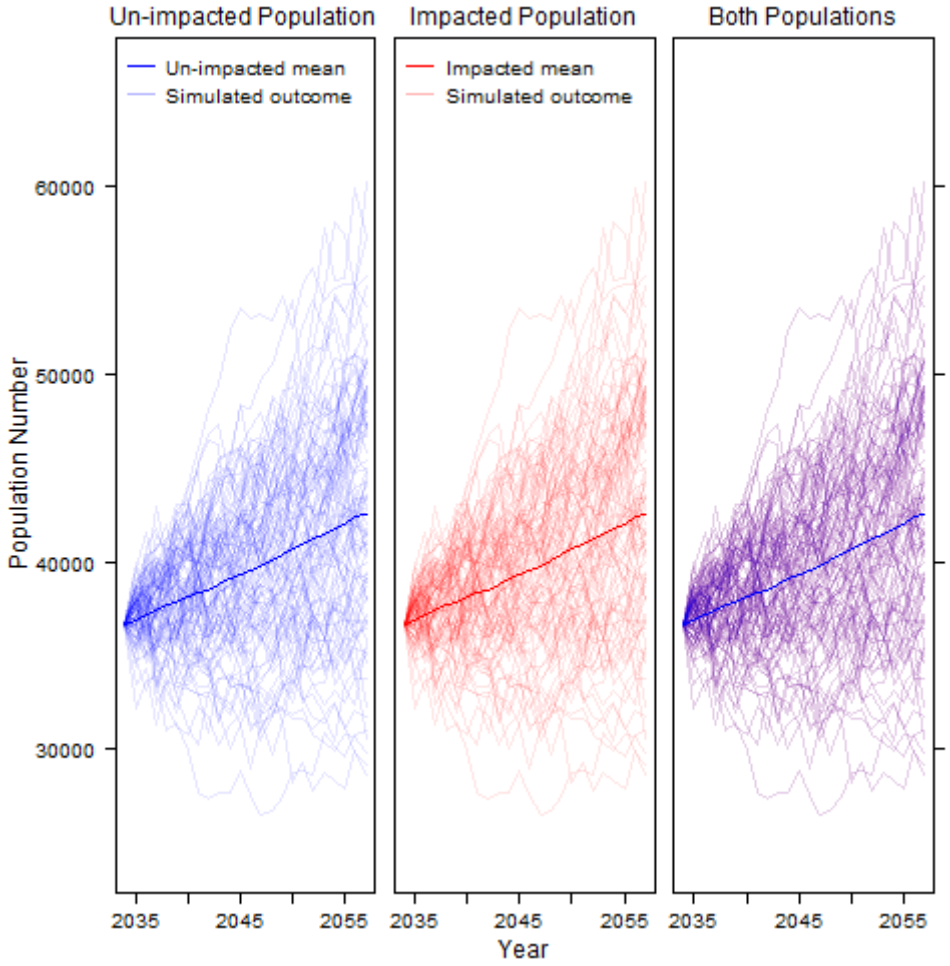

Figure 3.17: Simulated grey seal population trajectories in an unimpacted versus impacted population for the maximum temporal scenario

Table 3.12: Modelled estimates for the unimpacted and impacted grey seal population for the maximum temporal scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	36,696	36,696	36,696	36,696	36,696	36,696	1.0000	1.0000
2	2035	33,299	36,895	39,440	33,299	36,895	39,440	1.0000	1.0000
3	2036	32,879	37,200	40,550	32,879	37,200	40,550	1.0000	1.0000
7	2040	32,077	38,141	44,074	32,077	38,141	44,074	1.0000	1.0000

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
13	2046	31,016	39,553	48,548	31,016	39,553	48,548	1.0000	1.0000
26	2059	30,141	43,028	57,560	30,141	43,028	57,560	1.0000	1.0000

3.4.2 GS-02 Maximum Spatial Scenario

3.4.2.1 The results for the maximum spatial scenario are presented in Figure 3.18. These results indicate that there will be no difference between the trajectories of the impacted and unimpacted grey seal populations. There was no difference in the mean size of the impacted and unimpacted grey seal populations (Table 3.13).

3.4.2.2 The mean and median counterfactuals both remained at 1 throughout the 26 time points, indicating that there would be no discernible difference in the ratio of impacted to unimpacted populations (Table 3.13). This suggests that long-term disturbance of the grey seal population within the East Scotland and Northeast England seal MUs would not occur due to piling at Morven South.

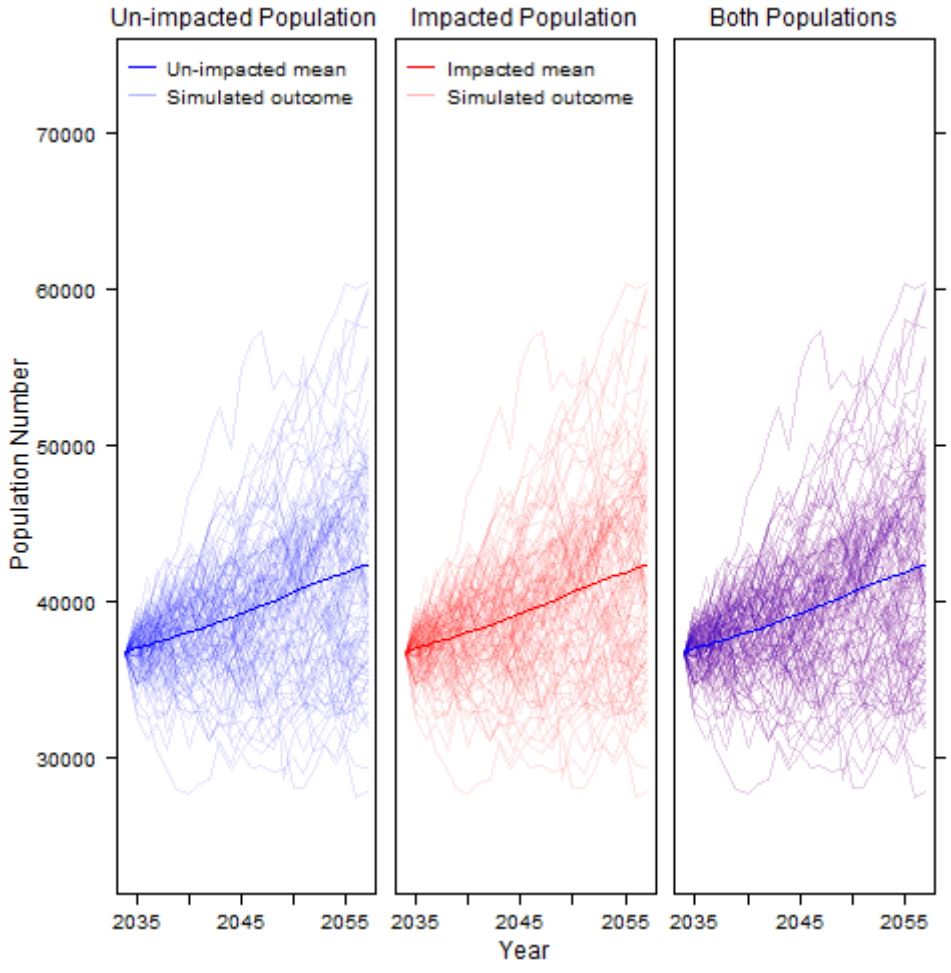

Figure 3.18: Simulated grey seal population trajectories in an unimpacted versus impacted population for the maximum spatial scenario

Table 3.13: Modelled estimates for the unimpacted and impacted grey seal population for the maximum spatial scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	36,696	36,696	36,696	36,696	36,696	36,696	1.0000	1.0000
2	2035	33,653	37,001	39,183	33,653	37,001	39,183	1.0000	1.0000
3	2036	33,085	37,196	40,426	33,085	37,196	40,426	1.0000	1.0000
7	2040	31,827	38,037	43,612	31,827	38,037	43,612	1.0000	1.0000
13	2046	30,738	39,521	48,928	30,738	39,521	48,928	1.0000	1.0000
26	2059	31,055	42,848	58,355	31,055	42,848	58,355	1.0000	1.0000

3.4.3 GS-03 Cumulative Scenario

3.4.3.1 For the GS-03 cumulative modelling scenario, a total of 2,613 piling days were modelled (including 262 days for Morven South, see Table 2.9). These results indicated some difference in the simulated trajectories of grey seal between the unimpacted population and impacted population (Figure 3.19). This corresponded to an impacted population that was smaller than the unimpacted population by 234 individuals at time point 26 (Table 3.14), corresponding to 0.64% of the combined reference populations of the East Scotland and Northeast England seal MUs. This was also the maximum difference between the impacted and unimpacted populations (Table 3.14).

3.4.3.2 The median counterfactual of population size for cumulative scenario GS-03 remained at 1 throughout, while the mean counterfactual was 0.9947 at the end of the 26-year simulation (Table 3.14). The counterfactual remained close to 1 throughout the cumulative piling period, suggesting that even though there were some declines in the population during cumulative piling, this was relatively small in relation to the East Scotland and Northeast England seal MUs geographic frame of reference.

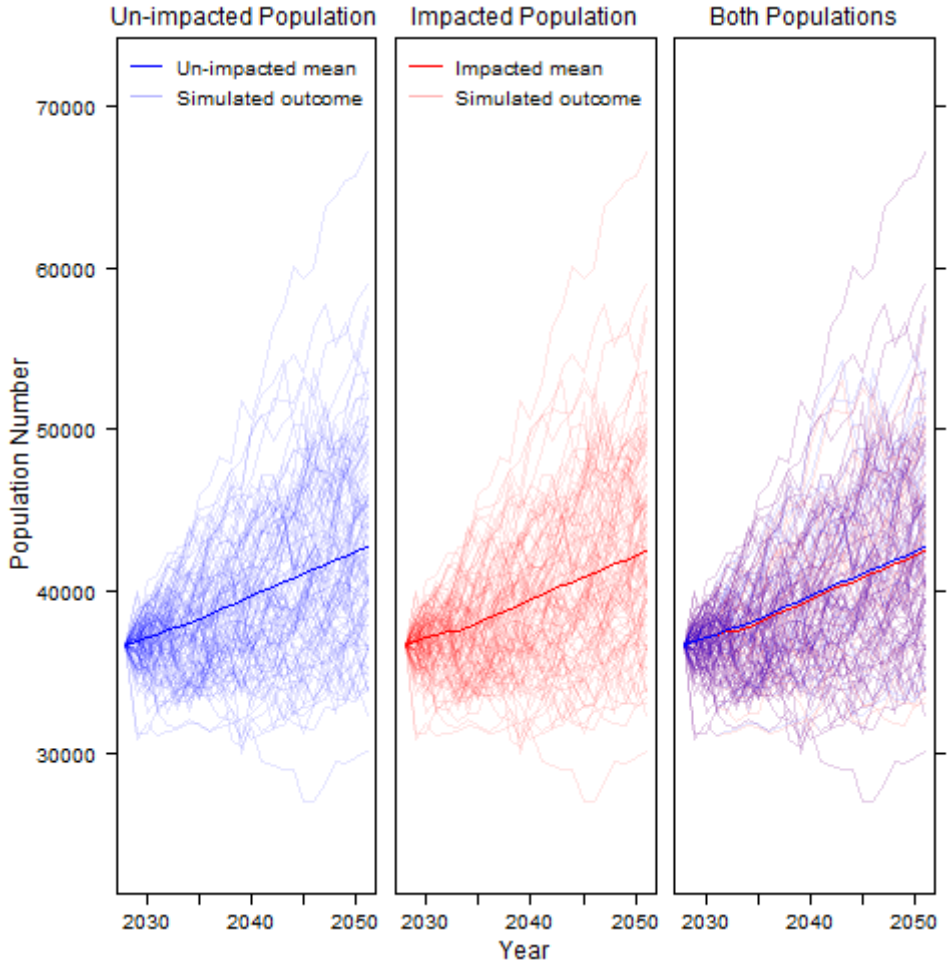

Figure 3.19: Simulated grey seal population trajectories in an unimpacted versus impacted population for the cumulative scenario GS-03

Table 3.14: Modelled estimates for the unimpacted and impacted grey seal population for the cumulative scenario GS-03

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2028	36,696	36,696	36,696	36,696	36,696	36,696	1.0000	1.0000
2	2029	33,454	36,932	39,217	33,454	36,932	39,217	1.0000	1.0000
3	2030	33,148	37,133	40,475	33,148	37,133	40,475	1.0000	1.0000
4	2031	32,636	37,322	41,177	32,636	37,302	41,155	1.0000	0.9995
5	2032	32,353	37,606	42,271	32,188	37,477	42,132	1.0000	0.9966
6	2033	31,668	37,745	42,541	31,626	37,543	42,395	1.0000	0.9947
7	2034	32,028	38,004	43,850	31,853	37,816	43,686	1.0000	0.9951
8	2035	31,803	38,254	44,607	31,689	38,075	44,606	1.0000	0.9954
9	2036	31,559	38,554	45,329	31,422	38,382	45,062	1.0000	0.9956
11	2038	31,302	39,152	47,163	31,205	38,932	46,990	1.0000	0.9945

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
22	2049	30,650	42,132	55,742	30,649	41,904	55,662	1.0000	0.9947
26	2053	33,454	36,932	39,217	33,454	36,932	39,217	1.0000	1.0000

3.4.3.3 Over the model run, the difference between the mean unimpacted and impacted population sizes increased throughout the cumulative piling schedule for the different projects with the final year of piling in time point 11 (2038; as illustrated by the orange bar in Figure 3.20). As illustrated in Figure 3.20, , steepest decline occurred between time points 4 (2031) and 6 (2033); the year 2031 is the point at which most cumulative projects are piling, although this is two years prior to the start of piling at Morven South (see Table 2.9). After the commencement of piling at Morven South (time point 7: 2034) until the end of the cumulative piling at Ossian in time point 11 (2038), the difference in mean unimpacted and impacted population sizes was lower. After this time point, the difference between the population sizes levelled off (Figure 3.20). Furthermore, it should be noted that the iPCoD model does not facilitate as assessment of density-dependent population recovery and therefore the differences between the unimpacted and impacted population do not reflect the true population after piling ceases, when recovery would be anticipated (see paragraphs 1.2.1.5 and 1.2.1.6).

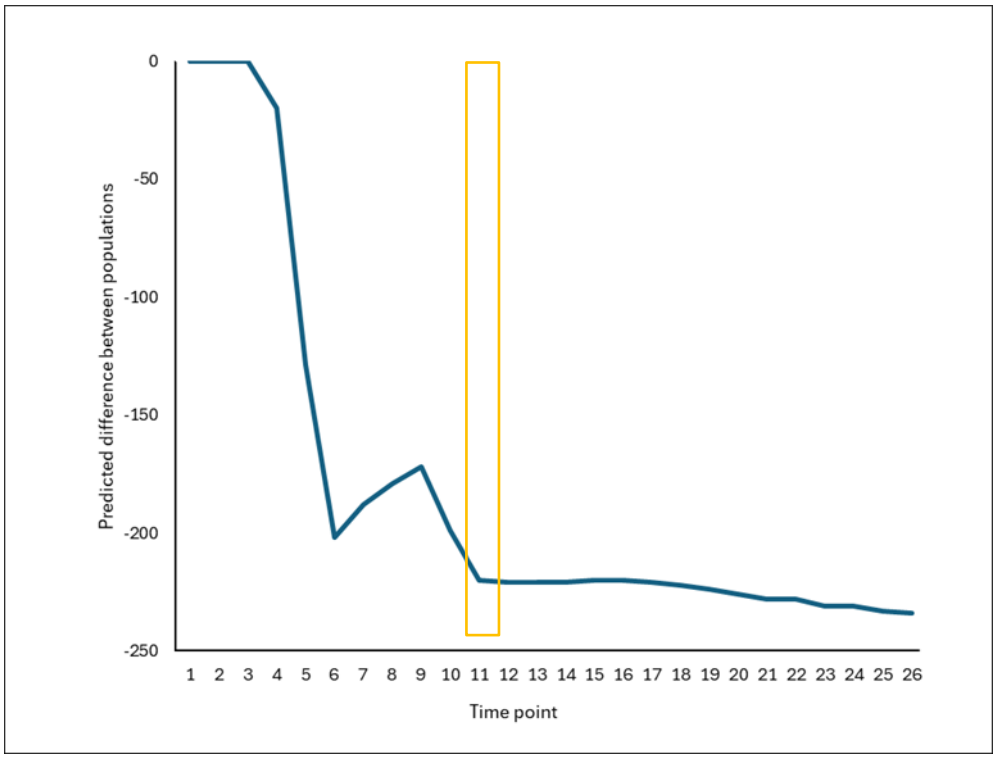

Figure 3.20: Difference in the mean number of grey seal between the impacted and unimpacted populations across all time points for the cumulative scenario GS-03

3.5 Harbour Seal

3.5.1.1 As detailed in Section 2.2.3, the Sinclair *et al.* (2020) vital rates for the East Scotland seal MU were used throughout the modelling, as they were the most precautionary.

3.5.2 HS-01 Maximum Temporal Scenario

3.5.2.1 The results for the maximum temporal scenario are presented in Figure 3.21. These results indicate that there will be no difference between the trajectories of the impacted and unimpacted harbour seal populations. There was no difference in the mean size of the impacted and unimpacted harbour seal populations (Table 3.15). The mean and median counterfactuals both remained at 1 throughout the 26 time points, indicating that there would be no discernible difference in the ratio of impacted to unimpacted populations (Table 3.15). This suggests that long-term disturbance of the harbour seal population within the East Scotland and Northeast England seal MUs would not occur due to piling at Morven South.

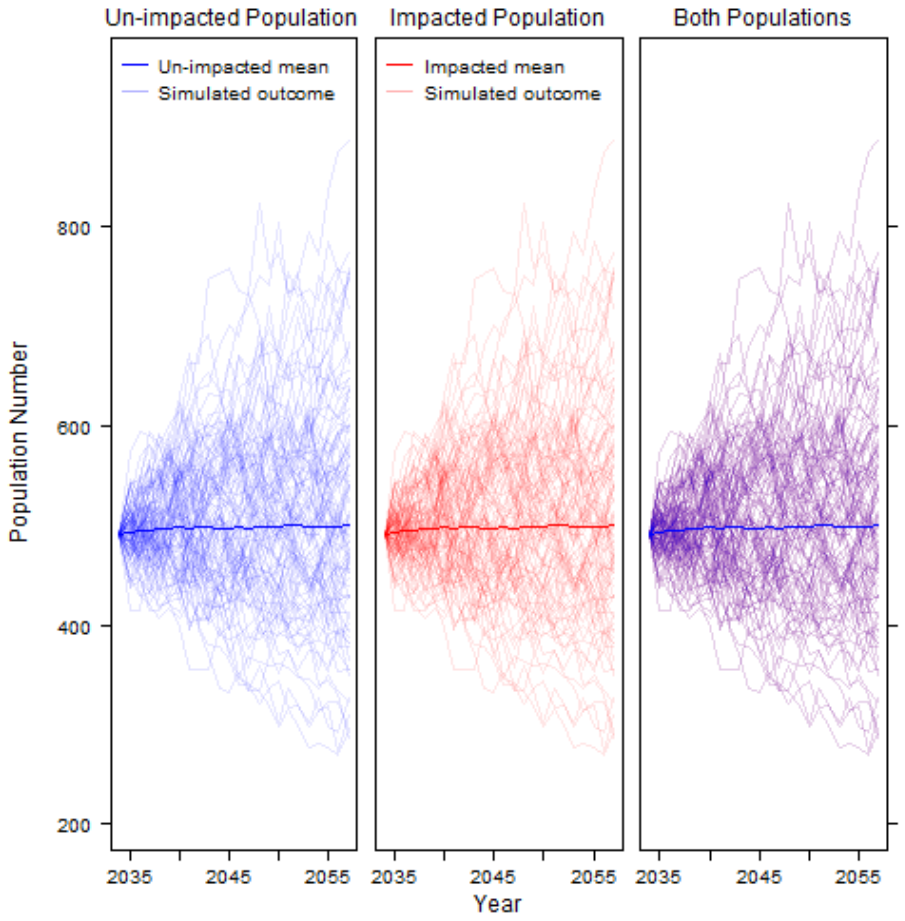

Figure 3.21: Simulated harbour seal population trajectories in an unimpacted versus impacted population for the maximum temporal scenario

Table 3.15: Modelled estimates for the unimpacted and impacted harbour seal population for the maximum temporal scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	492	492	492	492	492	492	1.0000	1.0000
2	2035	444	494	542	444	494	542	1.0000	1.0000
3	2036	430	495	556	430	495	556	1.0000	1.0000
7	2040	400	498	600	400	498	600	1.0000	1.0000
13	2046	370	498	656	370	498	656	1.0000	1.0000
26	2059	320	502	738	320	502	738	1.0000	1.0000

3.5.3 HS-02 Maximum Spatial Scenario

3.5.3.1 The results for the maximum spatial scenario are presented in Figure 3.22. These results indicate that there will be no difference between the trajectories of the impacted and unimpacted harbour seal populations. There was no difference in the mean size of the impacted and unimpacted harbour seal populations (Table 3.16).

3.5.3.2 The mean and median counterfactuals both remained at 1 throughout the 26 time points, indicating that there would be no discernible difference in the ratio of impacted to unimpacted populations (Table 3.16). This suggests that long-term disturbance of the harbour seal population within the East Scotland and Northeast England seal MUs would not occur due to piling at Morven South.

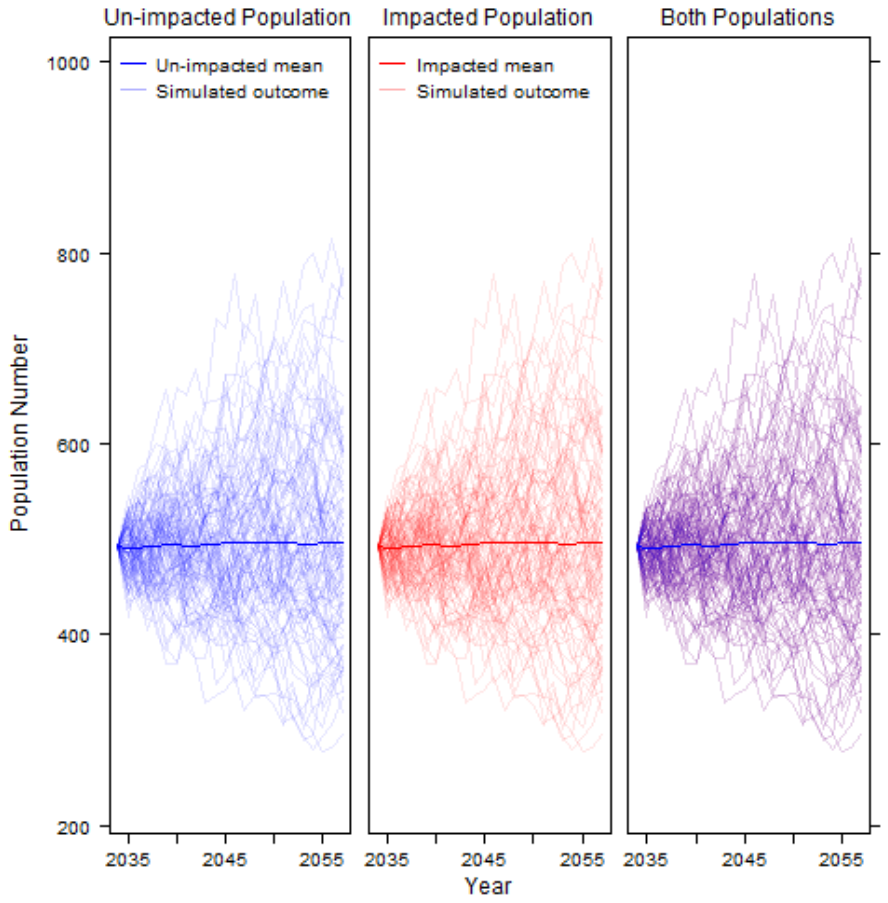

Figure 3.22: Simulated harbour seal population trajectories in an unimpacted versus impacted population for the maximum spatial scenario

Table 3.16: Modelled estimates for the unimpacted and impacted harbour seal population for the maximum spatial scenario

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2034	492	492	492	492	492	492	1.0000	1.0000
2	2035	440	491	540	440	491	540	1.0000	1.0000
3	2036	432	491	552	432	491	552	1.0000	1.0000
7	2040	400	495	600	400	495	600	1.0000	1.0000
13	2046	358	496	656	358	496	656	1.0000	1.0000
26	2059	314	498	728	314	498	728	1.0000	1.0000

3.5.4 HS-03 Cumulative Scenario

3.5.4.1 For the HS-03 cumulative modelling scenario, a total of 895 piling days were modelled (including 262 days for Morven South, see Table 2.9). These results indicated no difference in the simulated trajectories of harbour seal between the unimpacted population and impacted population across all time points (Figure 3.23 and key time points presented in Table 3.17). The median and mean counterfactual of population size for cumulative scenario HS-03 remained at 1 throughout, suggesting no population-level effects during any stage of the cumulative piling at offshore wind projects (Table 3.17).

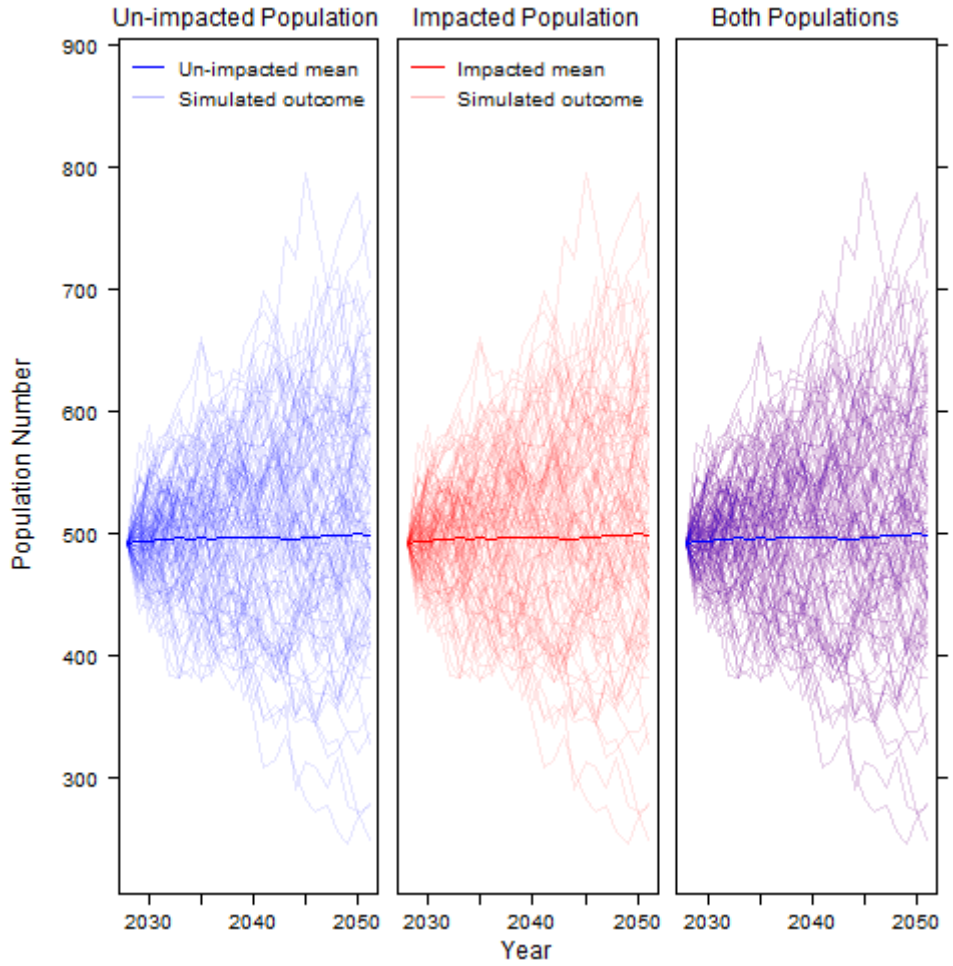

Figure 3.23: Simulated harbour seal population trajectories in an unimpacted versus impacted population for the cumulative scenario HS-03

Table 3.17: Modelled estimates for the unimpacted and impacted harbour seal population for the cumulative scenario HS-03

Time point	Year	Unimpacted population (number of animals)			Impacted population (number of animals)			Counterfactual	
		Lower 2.5%	Mean	Upper 97.5%	Lower 2.5%	Mean	Upper 97.5%	Median	Mean
1	2028	492	492	492	492	492	492	1.0000	1.0000
2	2029	448	494	544	448	494	544	1.0000	1.0000
3	2030	430	493	558	430	493	558	1.0000	1.0000
4	2031	418	494	570	418	494	570	1.0000	1.0000
5	2032	414	495	578	414	495	578	1.0000	1.0000
6	2033	406	496	588	406	496	588	1.0000	1.0000
7	2034	400	495	592	400	495	592	1.0000	1.0000
8	2035	398	496	596	398	496	596	1.0000	1.0000
9	2036	396	495	608	396	495	608	1.0000	1.0000
10	2037	392	497	614	392	497	614	1.0000	1.0000
12	2039	372	496	624	372	496	624	1.0000	1.0000
20	2047	346	498	692	346	498	692	1.0000	1.0000
26	2053	322	498	720	322	498	720	1.0000	1.0000

4 Summary

4.1.1.1 This report presents the results of the iPCoD modelling for harbour porpoise, bottlenose dolphin, minke whale, grey seal and harbour seal as a result of Morven South alone and cumulatively with other projects. The numbers of animals with the potential to experience disturbance were based on the maximum temporal and maximum spatial scenarios as detailed in Section 2.1.

4.1.1.2 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 Morven South alone for all species.

4.1.1.3 There is considered potential for a population-level effects from the cumulative modelling upon harbour porpoise within the North Sea MU and bottlenose dolphin within the Greater North Sea and Coastal East Scotland MUs in the medium term (i.e. during the period when multiple projects are piling). For bottlenose dolphin the greatest effects were seen when the Coastal East Scotland MU was included in the population modelling as this incorporated a larger number of animals disturbed against only a small increase in the reference population (i.e. the combined Coastal East Scotland and Greater North Seas MUs). Morven South, however, does not overlap the Coastal East Scotland MU and therefore this modelling was undertaken for illustrative purposes only.

4.1.1.4 Both harbour porpoise and bottlenose dolphin populations were shown stabilise in the long-term, after piling has ceased, although the lack of density dependence in the model means that recovery was not illustrated graphically. This modelling study concluded that the Morven South project is likely to have only a small relative contribution to this cumulative effect, since much of the population effects were seen in the years preceding piling at Morven South (i.e. 2031) when there was a high level of piling activity expected from multiple projects.

4.1.1.5 It is highlighted that, whilst updates to the Caledonia and Muir Mhor bottlenose dolphin assessment have subsequently been published[2], the piling phases of these two projects did not directly overlap with the piling phase of Morven South. Furthermore, as stated above, Morven South (and North) contributed only a very small (and not significant) change to the bottlenose dolphin population and therefore the conclusions of the cumulative assessment are considered unlikely to change in light of any updated assessment to these two projects.

4.1.1.6 A precautionary approach was applied 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.

4.1.1.7 It is possible that variation in demographic rates between years could occur as a result of changes in environmental conditions, due to random processes or chance events which impact vital rates, or other sources of heterogeneity. For example, two identical populations experiencing exactly the same sequence of environmental conditions could follow slightly different trajectories over time due to demographic stochasticity.

4.1.1.8 While iPCoD is a relatively simple population model (simulating the link between days of disturbance and changes in individual vital rates), sources of uncertainty are considered to have been adequately captured in the development of the modelling framework. In addition, the precautionary approach applied throughout the marine mammal assessment helps to buffer the uncertainties around how animals respond to repeated piling over time.

5 References

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