Environmental Impact Assessment Report
Volume 3, Appendix 11.2: Population Distribution Modelling

MarramWind Offshore Wind Farm

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MarramWind

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1. Introduction

1.1.1.1 This Appendix of the Environmental Impact Assessment (EIA) Report presents the interim Population Consequences of Disturbance (iPCoD) modelling of the proposed MarramWind Offshore Wind Farm (hereafter referred to as 'the Project'). This Appendix should be read in conjunction with **Volume 1, Chapter 11: Marine Mammals** and the project description provided in **Volume 1, Chapter 4: Project Description**.

1.1.1.2 NatureScot has requested that the Project undertakes iPCoD modelling as part of the quantitative impact assessment to evaluate the long-term impact (over 25 years[1]) of the predicted disturbance of impact piling. The Project has conducted iPCoD modelling to assess the impact of the construction of both the Project alone and cumulatively with the construction of other nearby offshore wind farm projects. The modelling was conducted for the following marine mammal populations (identified in **Volume 1, Chapter 11: Marine Mammals** as having the potential to be present in the Project area and that are being evaluated as part of the cumulative effects assessment):

- harbour porpoise (*Phocoena phocoena*) in the North Sea (NS) management unit (MU);
- bottlenose dolphins (*Tursiops truncatus*) in the Greater North Sea (GNS) MU and the Coastal East Scotland (CES) MU;
- minke whales (*Balaenoptera acutorostrata*) in the Celtic and Greater North Seas (CGNS) MU;
- harbour seals (*Phoca vitulina*) in the East Scotland (ES) and North Coast and Orkney (NC&O) Seal Management Areas (SMAs); and
- grey seals (*Halichoerus grypus*) in the ES and NC&O SMAs.

1.1.1.3 Note that iPCoD can only be run on the five species and, therefore, other marine mammal species presented in **Volume 1, Chapter 11: Marine Mammals** are not discussed in this document. This Appendix presents an overview of the iPCoD model, the methodology and results for the Project alone and cumulative iPCoD simulations.

[1] The 25-year timeframe represents the maximum period for which current iPCoD models are considered capable of producing reliable predictions of population trajectories. Predictions of the model become increasingly uncertain as the number of years increases and, therefore, modelling in excess of 25 years is not recommended.

2. Population Modelling

2.1 Population model background

2.1.1.1 The iPCoD framework (Harwood *et al.,* 2014, King *et al.,* 2015); version 5.2 was used to predict the potential population consequences of the predicted amount of Permanent Threshold Shift (PTS) and disturbance resulting from the piling.

2.1.1.2 The iPCoD uses a stage structured model of population dynamics for all marine mammal species with nine age classes and one stage class (adults ten years and older). The model is used to run a number of simulations of future population trajectory with and without the predicted level of impact from the activity causing disturbance, in this case percussive driven piling, to allow an understanding of the potential future population level consequences of predicted behavioural responses. Each iPCoD model simulation is run with matched pairs of populations: one un-impacted population and impacted population (1,000 simulations are recommended for each scenario of interest). These matched pairs experience exactly the same environmental and demographic stochasticity within one simulation of the model. The only variable element between the matched pair is that one marine mammal population is subjected to a stressor (impulsive noise such as percussive piling) and, therefore, demonstrates the potential effect of disturbance (this is considered to be the impacted population in the pair). The other population in the pair receives no exposure to a stressor and is considered the un-impacted population.

2.1.1.3 In iPCoD, all individuals within the impacted population (within a pair) are assumed to be equally likely to be disturbed by a particular piling operation (unless vulnerable sub-populations are specified, but there were no vulnerable sub-populations present in the MUs identified to use for iPCoD modelling for the Project). On each day of piling, iPCoD performs a binomial trial for each simulated individual using the probability of being disturbed[2] divided by the size of the total population (pmean) to determine whether or not that individual will be disturbed. This results in a calendar record of the days during the simulated year in which each individual is disturbed. The probability of each animal being disturbed on a given day is independent from the probability of this individual being disturbed previously.

2.1.1.4 The potential for a change in an individual's vital rates (survival and fertility), is determined by the number of repeated piling days that an individual experiences. The probability distributions that form the transfer functions in iPCoD provide the number of days of repeated disturbance that an animal is expected to experience before the disturbance can have any effect on its vital rates (and many individuals need to have their vital rates markedly impacted before any change in the population is observed).

2.1.1.5 The effects of disturbance on vital rates (survival and reproduction) are currently unknown. Therefore, expert elicitation was used to construct a probability distribution to represent the knowledge and beliefs of a group of experts regarding a specific quantity of interest. In this case, the quantity of interest is the effect of disturbance on the probability of survival and fertility in harbour porpoise, harbour seal and grey seals (Booth *et al.,* 2019). The elicitation assumed that the behaviour of the disturbed harbour porpoise would be altered for six hours on the day of disturbance, and that no feeding (or nursing) would occur during the six hours of disturbance. For harbour and grey seals, the experts assumed that on average, the behaviour of the disturbed seals would be impacted for much less than 24 hours but did not define an exact duration.

[2] Calculated as the total number of animals predicted to be disturbed by a particular piling operation (numDT), as specified by the user.

2.2 iPCoD model limitations

2.2.1 Overview

2.2.1.1 There is a lack of empirical data on the way in which changes in behaviour and hearing sensitivity may affect the ability of individual marine mammals to survive and reproduce. Therefore, in the absence of empirical data, the iPCoD framework uses the results of an expert elicitation process conducted according to the protocol described in Donovan *et al*. (2016) to predict the effects of disturbance and PTS on survival and reproductive rate (based on assumed behavioural responses and for specific levels of threshold shift). The process generates a set of statistical distributions for these effects and then simulations are conducted using values randomly selected from these distributions that represent the opinions of a 'virtual' expert. This process is repeated many hundreds of times to capture the uncertainty among experts.

2.2.1.2 There are several precautions built into the iPCoD model and the Project-specific scenario that mean that the results are considered to be highly precautionary and likely over-estimate the true population level effects. These include:

- the fact that the model assumes a minke whale will not forage for 24 hours after being disturbed;
- the lack of density dependence in the model (meaning the population will not respond to any reduction in population size);
- the level of environmental and demographic stochasticity in the model; and
- the estimates of the number of animals disturbed come from noise impact assessments with many levels of precaution in the way these numbers are calculated (for example, density, impact threshold).

2.2.2 Duration of disturbance: minke whales and bottlenose dolphins

2.2.2.1 The iPCoD model for minke whale and bottlenose dolphin disturbance was last updated following the expert elicitation in 2013 (Harwood *et al.,* 2014). When this expert elicitation was conducted, the experts provided responses on the assumption that a disturbed individual would not forage for 24 hours. However, the most recent expert elicitation in 2018 highlighted that this was an unrealistic assumption for harbour porpoises (which are generally considered to be more responsive than minke whales and bottlenose dolphins), and the 2018 elicitation was amended to assume that disturbance resulted in six hours of non-foraging time (Booth *et al.,* 2019). Unfortunately, neither minke whale nor bottlenose dolphins were included in the updated expert elicitation for disturbance, and thus the iPCoD model still assumes 24 hours of non-foraging time for both minke whales and bottlenose dolphins. This is unrealistic considering what is known and described in literature about marine mammal behavioural responses to pile driving. A recent study of a number of marine mammal species (including harbour porpoise and minke whales) estimated energetic costs associated with disturbance from sonar, where it was assumed that one hour of feeding cessation was classified as a mild response, two hours of feeding cessation was classified as a strong response and eight hours of feeding cessation was classified as an extreme response (Czapanskiy *et al.,* 2021). Assuming 24 hours of feeding cessation for both minke whales and bottlenose dolphins in the iPCoD model is significantly beyond that which is considered to be an extreme response and is, therefore, considered to be overly precautionary and will over-estimate the true disturbance levels expected from the Project.

2.2.2.2 In the absence of better data for these species, this precautionary approach is considered to be the most appropriate approach to determining population level effects of disturbance.

2.2.3 Lack of density dependence

2.2.3.1 Density dependence is described as "*the process whereby demographic rates change in response to changes in population density, resulting in an increase in the population growth rate when density decreases and a decrease in that growth rate when density increases*" (Harwood *et al*., 2014). The iPCoD models run for this assessment assume no density dependence for any of the species available in the model, since there is insufficient data to parameterise this relationship. Essentially, this means that there is no ability for the modelled, impacted population to increase in size and return to carrying capacity (the maximum number of individuals the environment can sustainably support) following disturbance. It is possible that populations with a positive growth rate (for instance, an increasing population) will continue to increase in the absence of disturbance.

2.2.3.2 At a recent expert elicitation conducted for the purpose of modelling population impacts of the Deepwater Horizon oil spill (Schwacke *et al*., 2022), experts agreed that there would likely be a concave density dependence on fertility. That means, for a population that is assumed to be stable (for instance, neither increasing nor decreasing), it would be expected that if the impacted population declines, it would later recover to carrying capacity, rather than continuing at a stable trajectory that is smaller than that of the un-impacted population. Note that in the iPCoD model, for stable populations, carrying capacity is assumed to be equal to the size of un-impacted population – for instance, it is assumed the un-impacted population is at carrying capacity.

2.2.4 Environmental and demographic stochasticity

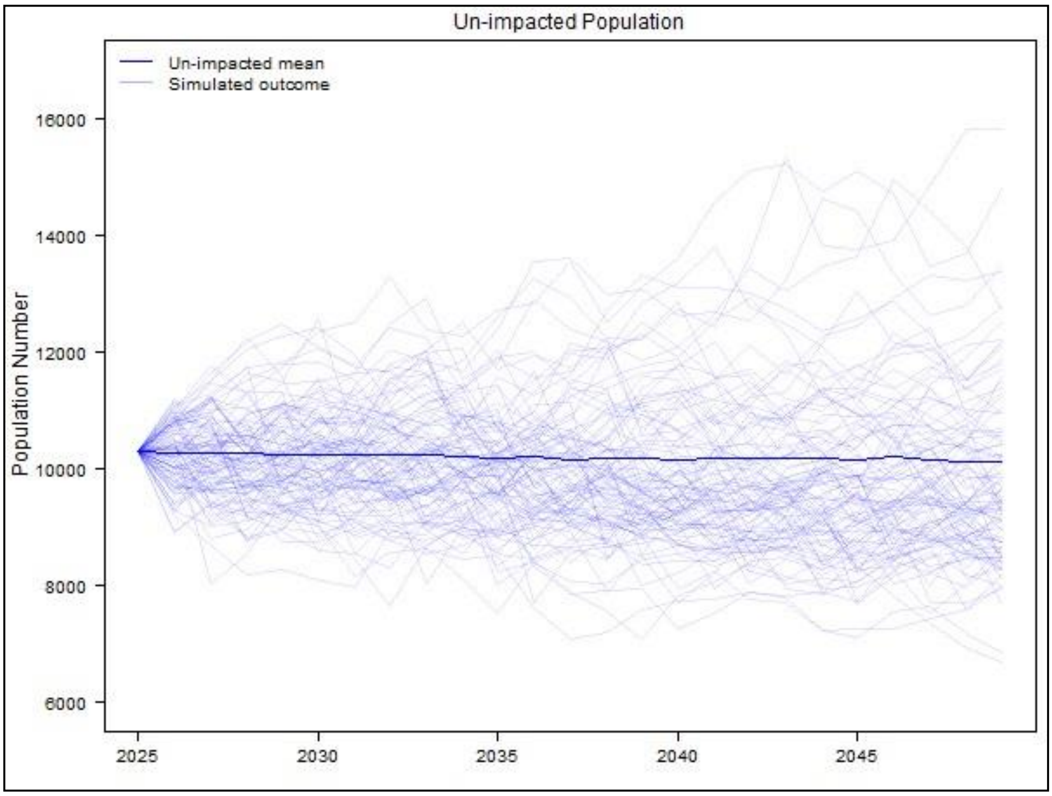
2.2.4.1 The iPCoD model attempts to model some of the sources of uncertainty inherent in the calculation of the potential effects of disturbance on marine mammal populations. This includes environmental variation and demographic stochasticity. Environmental variation is defined as "*the variation in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

2.2.4.2 The iPCoD protocol describes this in further detail:

"*Demographic stochasticity is caused by the fact that, even if survival and fertility rates are constant, the number of animals in a population that die and give birth will vary from year to year because of chance events. Demographic stochasticity has its greatest effect on the dynamics of relatively small populations, and we have incorporated it in models for all situations where the estimated population within an MU is less than 3,000 individuals. One consequence of demographic stochasticity is that two otherwise identical populations that experience exactly the same sequence of environmental conditions will follow slightly different trajectories over time. As a result, it is possible for a "lucky" population that experiences disturbance effects to increase, whereas an identical undisturbed but "unlucky" population may decrease*" (Harwood et al., 2014).

2.2.4.3 This is clearly evidenced in the outputs of iPCoD where the un-impacted (baseline) population size varies greatly between iterations, not as a result of disturbance but simply as a result of environmental and demographic stochasticity. In the example provided in **Plate 2.1**, after 25 years of simulation, the un-impacted population size varies between 6,692 (lower 2.5%) and 16,516 (upper 97.5%). Thus, the change in population size resulting from the impact of disturbance is significantly smaller than that driven by the environmental and demographic stochasticity in the model.

Plate 2.1 Simulated un-impacted (baseline) population size over the 25 years modelled



2.2.5 Seals in iPCoD

2.2.5.1 On each day of piling, iPCoD performs a binomial trial for each simulated individual using the probability of being disturbed (calculated as the total number of animals predicted to be disturbed by a particular piling operation, as specified by the user, divided by the size of the population) to determine whether or not that individual will be disturbed. This results in a calendar record of the days during the simulated year on which each individual is disturbed. The total number of disturbed days is then used to determine individual survival and birth rates using results from expert elicitation.

2.2.5.2 There are limitations to this approach given that seals are central place foragers that move between haul-outs and foraging areas at sea. Thus, the distribution surface contains grid cells that are used for transiting (where an individual is present only briefly) and grid cells that are used for foraging (where an individual can be present for several hours to days). Thus, the exposure of seals to disturbance within a cell differs by how they are using that cell. Additionally, while iPCoD assumes that the probability of repeated disturbance is spread across individuals in the population, this doesn't account for the movement pattern of seals, where certain individuals are far more likely to experience multiple days of repeated disturbance than others in the population. Ideally this should be modelled using a vulnerable sub population within a total population, but there is insufficient understanding of the residency and movement of seals at this time to define such a vulnerable sub population. It is recommended that future work is conduced to further analyse telemetry data to understand this residency and movement behaviour to better model how some individuals may be more exposed to disturbance than others in the population.

2.2.6 Summary

2.2.6.1 All of these precautions built into the iPCoD model mean that the results are considered to be highly conservative and provide a worst case scenario of the effects of disturbance on a population level. Despite these limitations and uncertainties, this assessment has been carried out according to current best practice and using the best available scientific information at this time. The information provided is, therefore, considered to be sufficient to carry out an adequate assessment, though a level of precaution around the results should be taken into account when drawing conclusions.

3. Project Model Inputs

3.1 Project piling parameters

3.1.1.1 The Project construction stage is expected to occur over 12 years, commencing in 2030. Although the piling schedule is unknown at the time of writing this Appendix, a worst-case scenario for population effects has been estimated and assumed based on the parameters presented in **Volume 1, Chapter 4: Project Description**. For the modelling, piling is assumed to occur across four years in three phases: 2033 (phase 1); 2036 (phase 2); and 2038 and 2039 (phase 3). Piling is assumed to occur during all months of the year in 2033 and 2036, with more piling days occurring between February and November, and in 2038 and 2039 it is expected to occur between March and October (**Table 3.1**).

3.1.1.2 The piling schedule represents the worst-case scenario (for example more piles in shorter time period) and may vary in practice. This is a precautionary approach, as the Project is expected to encounter weather-related delays and natural pauses in piling activities. The piling parameters conservatively assume that the following offshore infrastructure will require piling, offshore substations, Reactive Compensation Platform (RCPs) and anchors. However, in practice the offshore substations and RCP jacket foundation may include an alternative less impactful option to noise (for example suction caisson); and the Wind Turbine Generator (WTG) anchors may include a less impactful option (for examples drag embedment or suction anchor (see **Volume 1, Chapter 4: Project Description**).

3.1.1.3 Piling will be used to install:

- up to 225 WTG floating units, using eight moorings with one driven pile anchor per mooring, resulting in a total of 1,800 driven pile anchors;
- up to four offshore substations, using 12 driven piles per offshore substation, resulting in a total of 48 driven piles; and
- up to two RCPs, using four driven piles per RCP, resulting in a total of eight driven piles.

3.1.1.4 This results in a total of 1,856 driven piles, which will be installed using a maximum hammer energy of 3,500 kilojoules. Whilst it is likely that two piles could be installed per day, which would result in 928 piling days, as a precautionary approach, it has been assumed that either one of two piles will be installed per day as the Project will likely experience downtime due to poor weather conditions or natural breaks in piling. Therefore, MarramWind Limited (hereafter, referred to as 'the Applicant') advised to model the effects of piling using a conservative estimate of 1,082 piling days over the three phases of piling. The indicative piling schedule created for use in the iPCoD modelling is based on the parameters presented above and in **Volume 1, Chapter 4: Project Description**.

Table 3.1 Distribution of piling days for the Project construction stage

Month	Number of piling days in each year of Project construction											
	2030	**2031**	**2032**	**2033**	**2034**	**2035**	**2036**	**2037**	**2038**	**2039**	**2040**	**2041**
January	0	0	0	3	0	0	3	0	0	0	0	0
February	0	0	0	28	0	0	28	0	0	0	0	0
March	0	0	0	31	0	0	31	0	22	22	0	0
April	0	0	0	30	0	0	30	0	30	30	0	0
May	0	0	0	31	0	0	31	0	31	31	0	0
June	0	0	0	30	0	0	30	0	30	30	0	0
July	0	0	0	31	0	0	31	0	31	31	0	0
August	0	0	0	31	0	0	31	0	31	31	0	0
September	0	0	0	30	0	0	30	0	30	30	0	0
October	0	0	0	31	0	0	31	0	27	27	0	0
November	0	0	0	30	0	0	30	0	0	0	0	0
December	0	0	0	3	0	0	3	0	0	0	0	0

3.2 Marine mammal demographic parameters

3.2.1.1 **Table 3.2** presents the MUs and SMAs included in this assessment and their respective population sizes, which reflects those presented in **Volume 1, Chapter 11: Marine Mammals**. Demographic parameters for these MUs were obtained primarily from Sinclair *et al.* (2020). The exception was for the calf / pup survival rate for bottlenose dolphins in the GNS MU, which was obtained from Harwood and King (2017) to reflect the stable status of the population. Note that for harbour seals, the ES and NC&O SMAs are presented separately as the two MUs have different population trajectories and recommended demographic parameters (**Table 3.2**). For grey seals, both SMAs are assessed together as Sinclair *et al.* (2020) recommends the use of the same demographic parameters for all grey seals around the UK.

Table 3.2 Demographic parameters used in iPCoD modelling

Parameters	Harbour porpoise	Bottlenose dolphin		Minke whale	Harbour seal		Grey seal
MU / SMA	NS	CES	GNS	CGNS	ES	NC&O	ES and NC&O
Population size	346,601	226	2,022	20,118	383	1,915	40,564
Trajectory	Stable	Increasing	Stable	Stable	Stable	Decreasing	Increasing
Calf / pup survival	0.8455	0.925	0.86	0.7	0.4	0.24	0.222
Juvenile survival	0.85	0.962	0.94	0.77	0.78	0.86	0.94
Adult survival	0.925	0.98	0.94	0.96	0.92	0.80	0.94
Fertility	0.34	0.24	0.25	0.91	0.85	0.90	0.84
Age at independence	1	3	2	1	1	1	1
Age at first birth	5	9	9	9	4	4	6

3.3 Marine mammal disturbance numbers

3.3.1.1 The number of animals predicted to be disturbed per piling day is presented in **Table 3.3**. The disturbance values calculated using the offshore substation North scenario presented in **Volume 1, Chapter 11: Marine Mammals**. Note that for bottlenose dolphins in the CES and GNS MU and for harbour and grey seals, a greater number of animals were predicted to be disturbed from the modelled RCP location. However, as these values were only applicable to two piling days, using these values would result in an unrealistic impact to the population if they were used for modelling. Given that the number of piling days being used in the model is already highly conservative (using 100+ more days than the maximum design scenario), using the offshore substation disturbance values represents the most likely worst case disturbance value and so this was applied to all piling days. These disturbance values also reflect those being presented in the cumulative effects assessment presented in **Volume 1, Chapter 33: Cumulative Effects Assessment**.

3.3.1.2 The methodology used to calculate these values are presented in **Volume 1, Chapter 11: Marine Mammals**. Note that modelling using United Kingdom (UK) MU populations was only conducted for the Project alone iPCoD.

Table 3.3 Disturbance values used in iPCoD modelling

Parameters	Harbour porpoise		Bottlenose dolphin			Minke whale		Harbour seal		Grey seal
MU / SMA	NS	NS UK MU	CES	GNS	GNS UK MU	CGNS	CGNS UK MU	ES	NC&O	ES and NC&O
Number of animals disturbed per piling day	14,787	14,376	31	20	20	984	956	1	1	183
MU / SMA disturbed per piling day (%)	4.27	9.01	13.72	0.99	1.06	4.89	9.29	1.08	0.34	0.09

3.4 Cumulative effects assessment

3.4.1.1 Within the cumulative effects assessment, marine mammal disturbance numbers have been taken from published EIA Reports; however, where values are not available, Effective Deterrent Ranges (EDR) have been used following Joint Nature Conservation Committee (JNCC) (2020) guidance (further detail on EDRs is included in **Appendix 33.3: Marine Mammals CEA**) to estimate disturbance numbers. These EDRs have since been updated in the JNCC (2025) guidance where the EDR for monopile installation without noise abatement has decreased from 26 kilometres (km) (included in this assessment) to 20km, based on evidence from passive acoustic monitoring studies (for example, Brandt *et al*., 2018; Geelhoed *et al*., 2018; Thompson *et al.,* 2025). However, the EDR for pin pile installation without noise abatement has increased in the latest guidance from 15km (included in this assessment) to 20km. Brown *et al.* (2025) note that there remains uncertainty in the evidence of disturbance from pile driving and estimated the impact to be between 15km to 20km. The JNCC (2025) guidance took the higher end of this range as a precautionary measure. These piling EDRs are also considered precautionary due to some studies, such as Graham *et al*. (2019), which have reported a 50% probability of harbour porpoises responding within 7.5km from the location of the first pile driven within installation of offshore wind farm foundations in the Moray Firth, which decreased to 1.3km from the location of the last pile driven. This suggests individuals may, to some degree, habituate to piling activities over time

3.4.1.2 Other offshore wind farm developments with a construction period that overlaps temporarily with the Project may result in cumulative disturbance to marine mammals. Cumulative iPCoD modelling was conducted for the same species as modelled for the Project alone assessment (see **Table 3.2** for species and demographic parameters). A list of offshore wind farm developments within Scottish waters was identified by the Project for each of the MUs / SMAs to inform the cumulative effects assessment. Developments in the pre-planning phase without submission documents (scoping or EIA) available in the public domain did not have sufficient information available to be included in the model (for example, construction years, number and type of structures) and so were not included in the cumulative effects assessment short list. Additional screening was then applied based on the Project piling years (2033 to 2039), with only offshore wind farms expected to be piling during the Project piling period ± one year being screened into the final shortlist. Therefore, only offshore wind farm developments scheduled to be under construction between 2032 and 2040 inclusive were included in the assessment. The modelling included all piling years for each of the offshore wind farm development screened into the assessment outwith the screening period (not just piling in 2032 to 2040).

3.4.1.3 The offshore wind farm developments included in the final cumulative short list are presented in **Table 3.4,** alongside the parameters used for each development, with the timelines presented in **Table 3.5**. For each marine mammal species, only the offshore wind farms located within their respective Mus / SMAs were screened into the cumulative iPCoD assessment (**Figure 1**).

3.4.1.4 For offshore wind farms where an EIA Report was available at the time of the assessment, piling parameters were obtained from the project-specific EIA Reports (where available). If multiple piling parameters were presented in an EIA Report, those resulting in the greatest number of piling days were selected.

3.4.1.5 For offshore wind farms where only a scoping report was available at the time of the assessment, fewer details regarding piling parameters were available. In these instances, the number of piling days were assumed, given the following:

- one day per monopile;
- two days per jacket structure; and
- three days per floating structure.

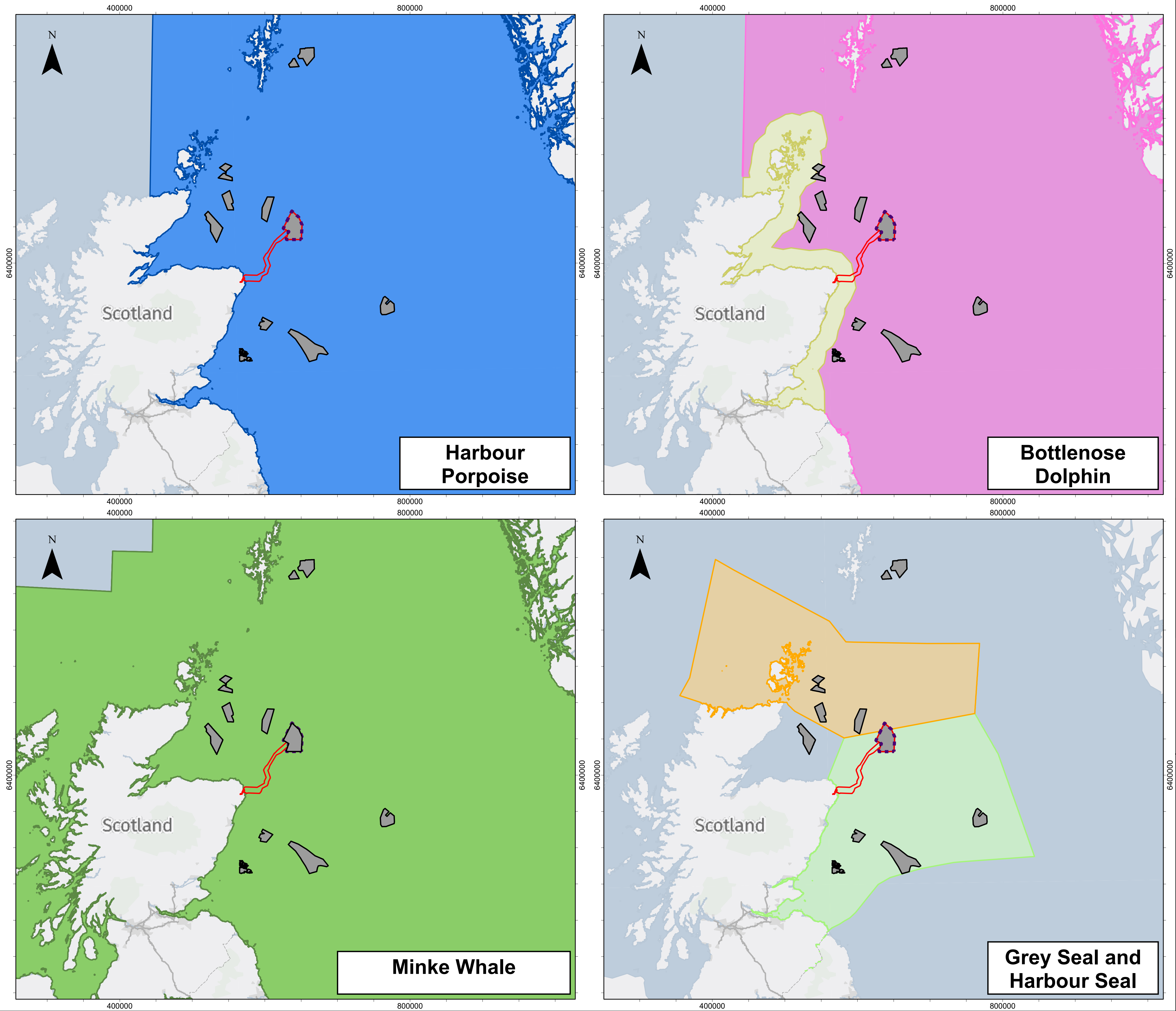
3.4.1.6 For each species, the cumulative iPCoD modelling commenced at the start of the first year of construction of any offshore wind farm development screened into the species assessment and ran for 25 years. The earliest piling start year for offshore wind farms in the final cumulative short list was Caledonia, expected to being piling in 2028 (**Table 3.5**). This was located within the MU / SMA for all species except for harbour seals in the NC&O SMA. Therefore, for the majority of species the cumulative iPCoD model was run from the start of 2028 until the end of 2052. The earliest offshore wind farms piling within the NC&O SMA for harbour seals are Buchan and Stromar offshore wind farms, both expected to start in 2029. Therefore, the cumulative iPCoD model for harbour seals in the NC&O SMA ran from the start of 2029 until the end of 2053.

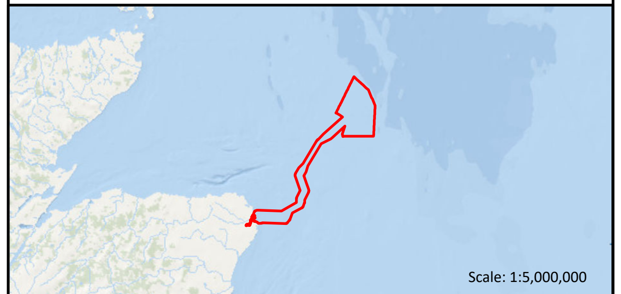
Table 3.4 Offshore wind farm -specific information input into the cumulative iPCoD model

Offshore wind farm	Source	Pile type	Number of structures	Piling days
Marram	EIA Report.	Driven pile.	225 WTG, four offshore substations, two RCPs.	1,082
Arven offshore substation	Scoping	Pin pile.	Ten offshore substations (16 piles / offshore substation).	20
Arven WTG	Scoping	Anchor	161 WTGs (nine piles / WTG).	483
Ayre offshore substation	Scoping	Pin pile.	Three offshore substations (four piles / offshore substation).	6
Ayre WTG	Scoping	Anchor	67 WTGs (nine piles / WTG).	201
Bowdun	Scoping	Pin pile.	67 WTGs (nine piles / WTG).	134
Buchan	Scoping	Anchor	70 WTGs (nine piles / WTG).	210
Caledonia WTG fixed	EIA Report.	Pin pile.	105 WTGs (four piles / WTG).	105
Caledonia WTG floating	EIA Report.	Anchor	39 WTGs (six piles / WTG).	410
Cenos WTG	EIA Report.	Anchor	95 WTGs (nine piles / WTG).	285
Cenos offshore substation	EIA Report.	Pin pile.	Two offshore substations (12 piles / offshore substation).	8
Ossian WTG	EIA Report.	Anchor	265 WTG (six piles / WTG).	530
Ossian offshore substation	EIA Report.	Pin pile.	15 offshore substations (12 or six piles / offshore substation).	72
Seagreen 1A	Scoping / Piling Strategy.	Pin pile.	36 WTGs (four piles / WTG).	72
Stromar WTG	Scoping	Anchor	71 WTGs (piles / WTG unknown).	213
Stromar offshore substation	Scoping	Pin pile.	Three offshore substations (four piles / offshore substation).	6

Table 3.5 Construction periods for offshore wind farms screened into the cumulative effects assessment. Green cells = offshore wind farm development is assumed to be piling

Offshore wind farm	Tier	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	2038	2039
Marram	-												
Arven	2												
Ayre	2												
Bowdun	2												
Buchan	2												
Caledonia	1												
Cenos	1												
Ossian	1												
Seagreen 1A	1												
Stromar	2												





REV	REV DATE	GIS CREATOR	GIS REVIEWER	TECHNICAL CHECKER	TECHNICAL APPROVER
3	04/11/2025	EH	LT	LG	NC
2	24/10/2025	EH	LT	LG	NC
1	02/10/2025	EH	LT	LG	NC

WSP DRAWING NUMBER	808368-WEIS-IA-E5-FG-M8-82494
MarramWind DRAWING NUMBER	MAR-GEN-ENV-MAP-WSP-000600

DATUM	ETRS 89	PROJECTION	UTM Zone 30N
SCALE	1:5,000,000	PAGE SIZE	A3

PROJECT TITLE

MarramWind Offshore Wind Farm

DRAWING TITLE

Figure 1 Offshore wind farms in the cumulative effects assessment located in each marine mammal MU SMA

Environmental Impact Assessment Report

Appendix 12.2

NOT TO BE USED FOR NAVIGATION

wsp MarramWind

4. Project Alone iPCoD Model Results

4.1 Harbour porpoise NS MU

4.1.1.1 The iPCoD modelling shows that the mean impacted population size of harbour porpoise in the NS MU is predicted to reduce to 98.25% of the size of the un-impacted population mean during piling and then remains at ~98.30% after piling ceases. The impacted population is then predicted to continue on a stable trajectory, the same as the un-impacted population, albeit at a very slightly lower population size (**Plate 4.1, Plate 4.2** and **Table 4.1**).

Plate 4.1 Predicted population trajectories (mean and 95% confidence intervals (CIs)) for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations for the NS MU. Piling is occurring between 2033 to 2039 inclusive

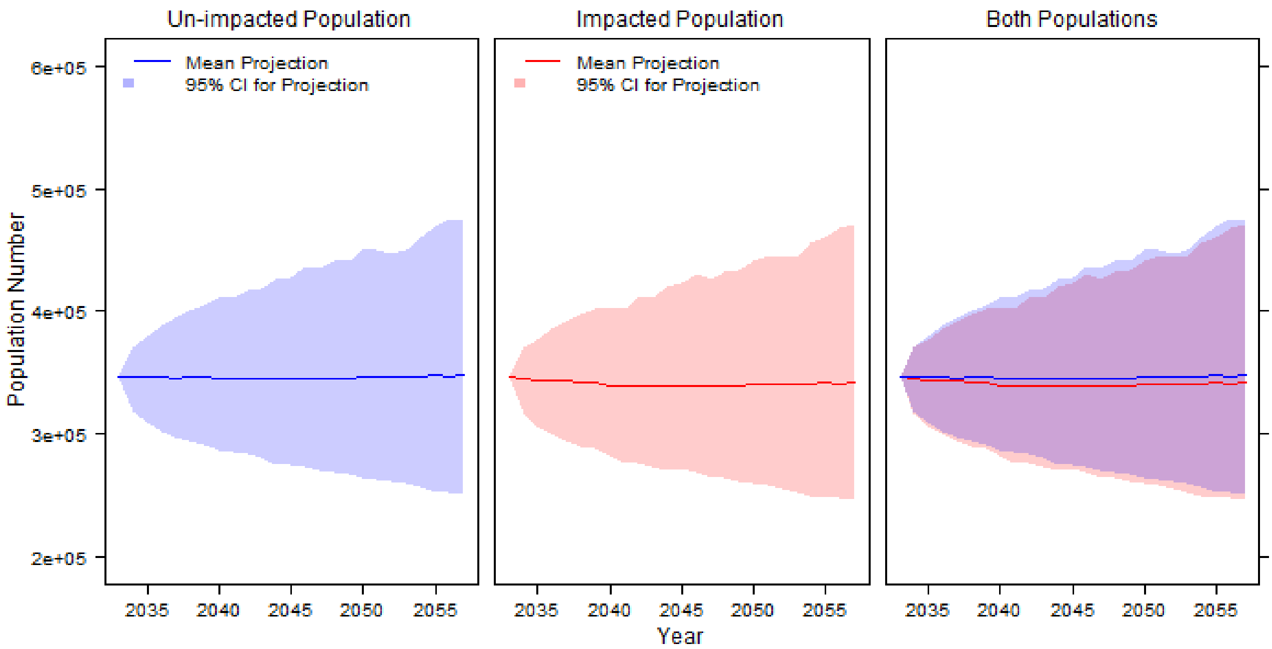


Plate 4.2 Predicted population trajectories for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations for the NS MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

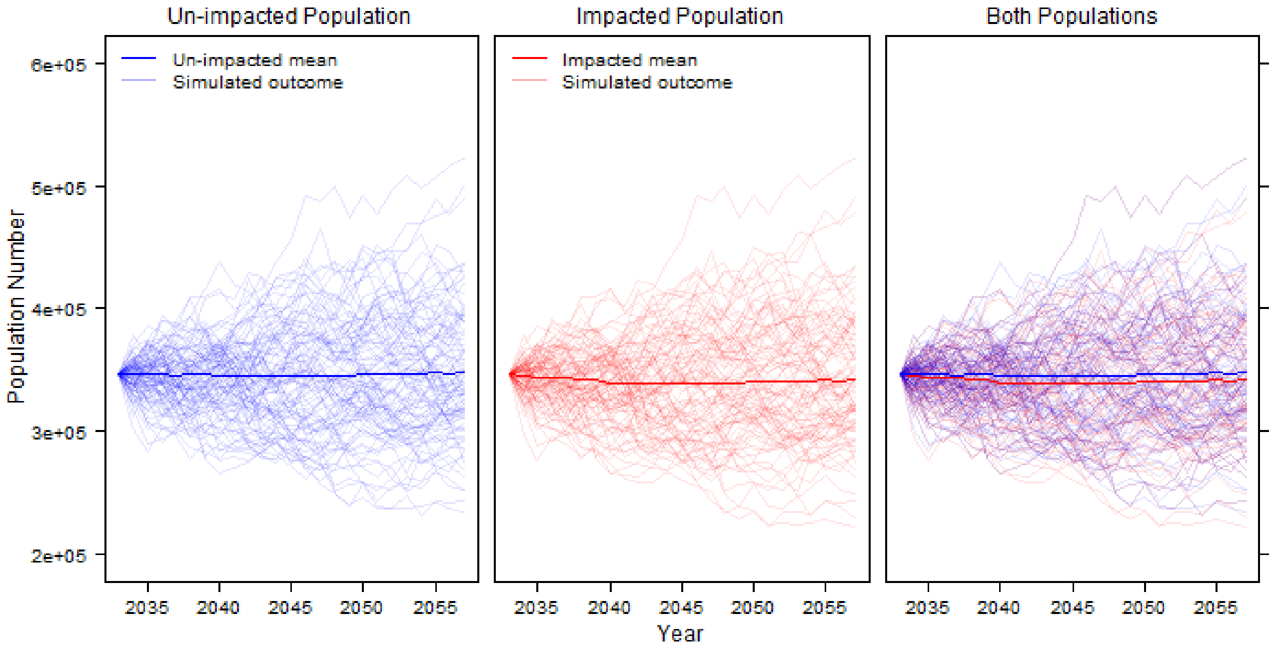


Table 4.1 Mean un-impacted and impacted population sizes for the NS MU for harbour porpoise

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	346,602	346,602	100.00%
End 2033 (end piling year 1)	346,344	345,396	99.73%
End 2036 (end piling year 2)	345,838	343,142	99.22%
End 2038 (end piling year 3)	346,318	342,091	98.78%
End 2039 (end piling year 4)	345,935	339,893	98.25%
End 2040 (one year after piling ends)	345,903	339,191	98.06%
End 2045 (six years after piling ends)	345,771	339,857	98.29%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	346,260	340,351	98.29%
End 2057 (18 years after piling ends)	347,526	341,602	98.30%

4.2 Harbour porpoise NS UK MU

4.2.1.1 The iPCoD modelling shows that the mean impacted population size of harbour porpoise in the NS UK MU is predicted to reduce to 95.59% of the size of the un-impacted population mean during piling and then remains at ~95.66% after piling ceases. The impacted population is then predicted to continue on a stable trajectory, the same as the un-impacted population, albeit at a very slightly lower population size (**Plate 4.3, Plate 4.4** and **Table 4.2**).

Plate 4.3 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations for the NS UK MU. Piling is occurring between 2033 to 2039 inclusive

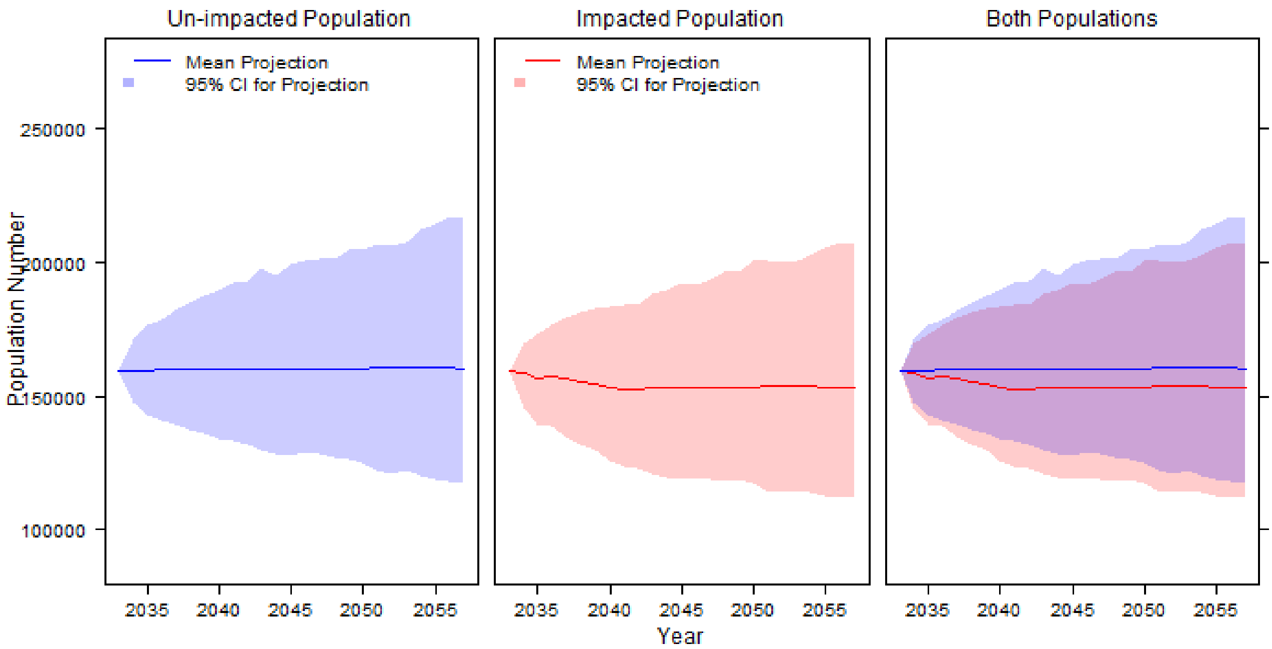


Plate 4.4 Predicted population trajectories for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations for the NS UK MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

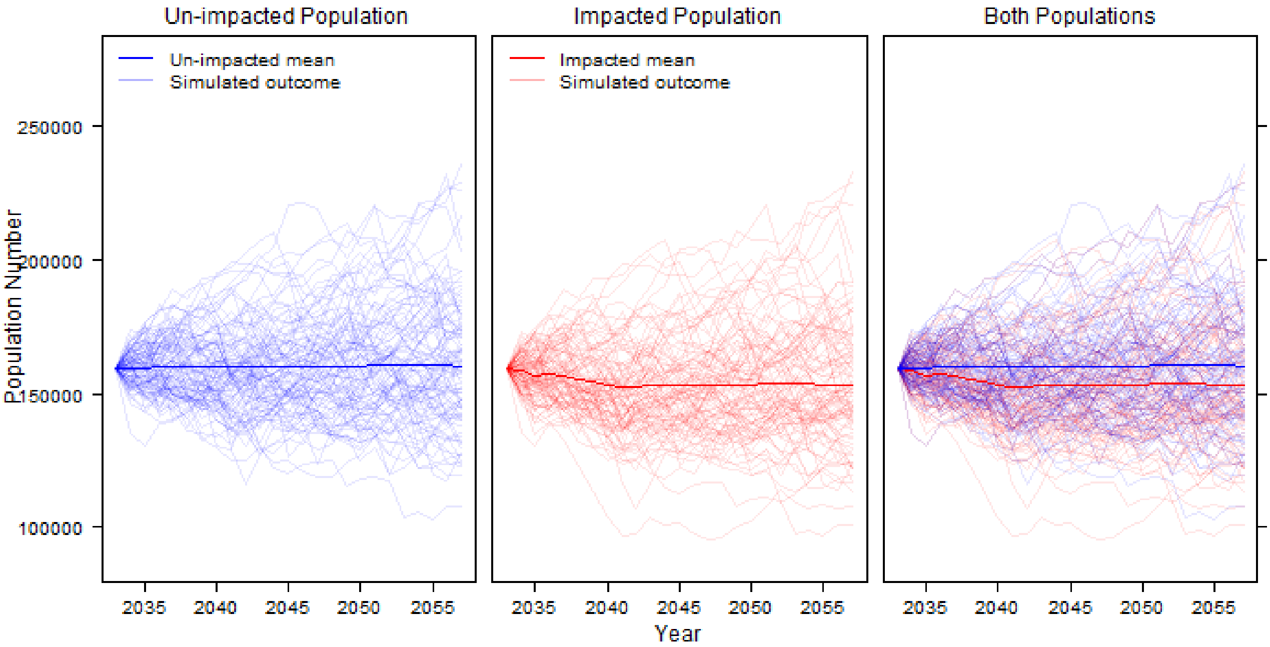


Table 4.2 Mean un-impacted and impacted population sizes for the NS UK MU for harbour porpoise

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	159,634	159,634	100.00%
End 2033 (end piling year 1)	159,682	158,536	99.28%
End 2036 (end piling year 2)	159,847	156,644	98.00%
End 2038 (end piling year 3)	159,834	154,822	96.86%
End 2039 (end piling year 4)	160,123	153,068	95.59%
End 2040 (1 year after piling ends)	160,370	153,425	95.67%
End 2045 (6 years after piling ends)	160,896	153,906	95.66%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	160,896	153,906	95.66%
End 2057 (18 years after piling ends)	160,134	153,177	95.66%

4.3 Bottlenose dolphin CES MU

4.3.1.1 The iPCoD modelling shows that the mean impacted population size of bottlenose dolphins in the CES MU is predicted to reduce to 90.48% of the size of the un-impacted population mean during piling and then remains at ~91.2% after piling ceases. The impacted population is then predicted to continue on an increasing trajectory, the same as the un-impacted population, albeit at a lower population size (**Plate 4.5, Plate 4.6** and **Table 4.3**).

Plate 4.5 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for the CES MU. Piling is occurring between 2033 to 2039 inclusive

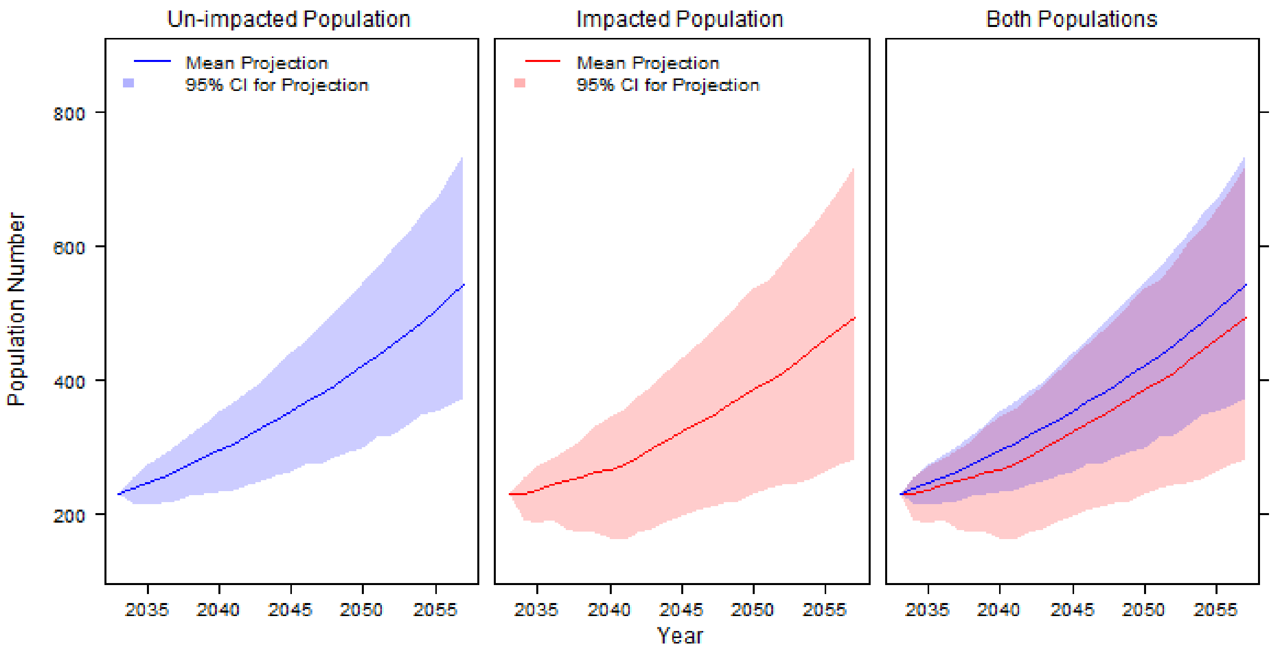


Plate 4.6 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for the CES MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

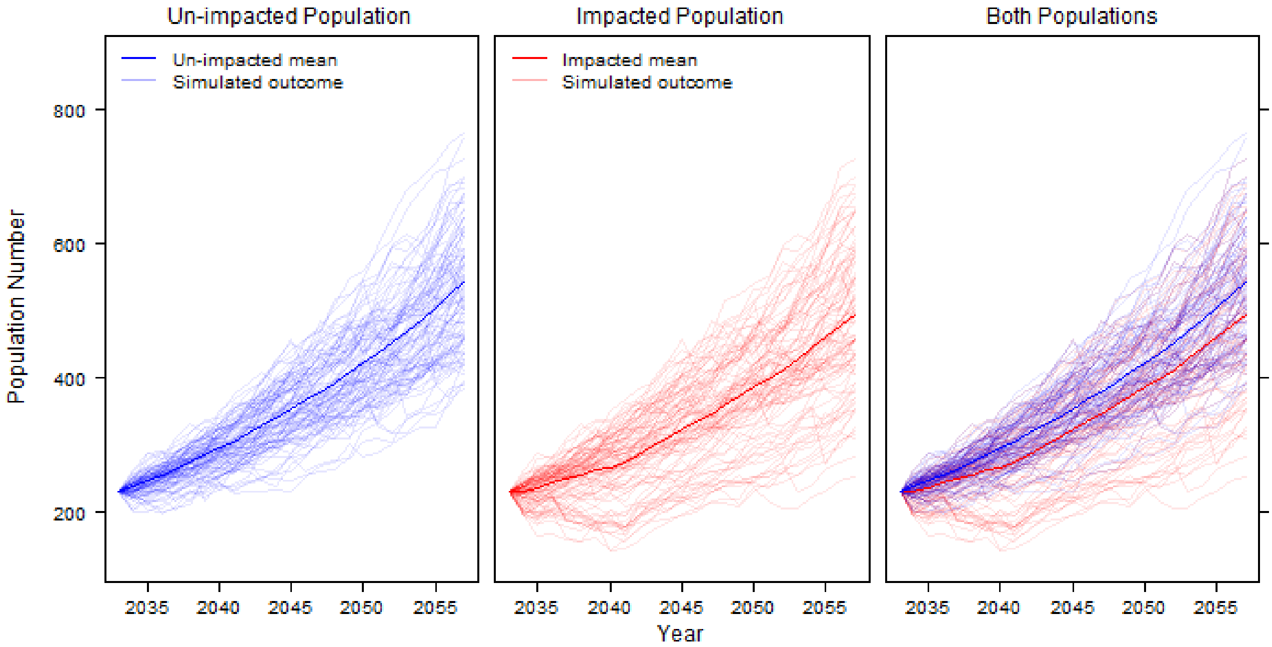


Table 4.3 Mean un-impacted and impacted population sizes for the CES MU for bottlenose dolphins

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	228	228	100.00%
End 2033 (end piling year 1)	236	229	97.03%
End 2036 (end piling year 2)	263	248	94.30%
End 2038 (end piling year 3)	283	262	92.58%
End 2039 (end piling year 4)	294	266	90.48%
End 2040 (1 year after piling ends)	305	273	89.51%
End 2045 (6 years after piling ends)	365	334	91.51%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	451	411	91.13%
End 2057 (18 years after piling ends)	560	511	91.25%

4.4 Bottlenose dolphin GNS MU

4.4.1.1 The iPCoD modelling shows that the mean impacted population size of bottlenose dolphins in the GNS MU is predicted to remain within 99% of the size of the un-impacted population mean. The impacted population is predicted to continue on a stable trajectory, the same as the un-impacted population (**Plate 4.7, Plate 4.8** and **Table 4.4**).

Plate 4.7 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for the GNS MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

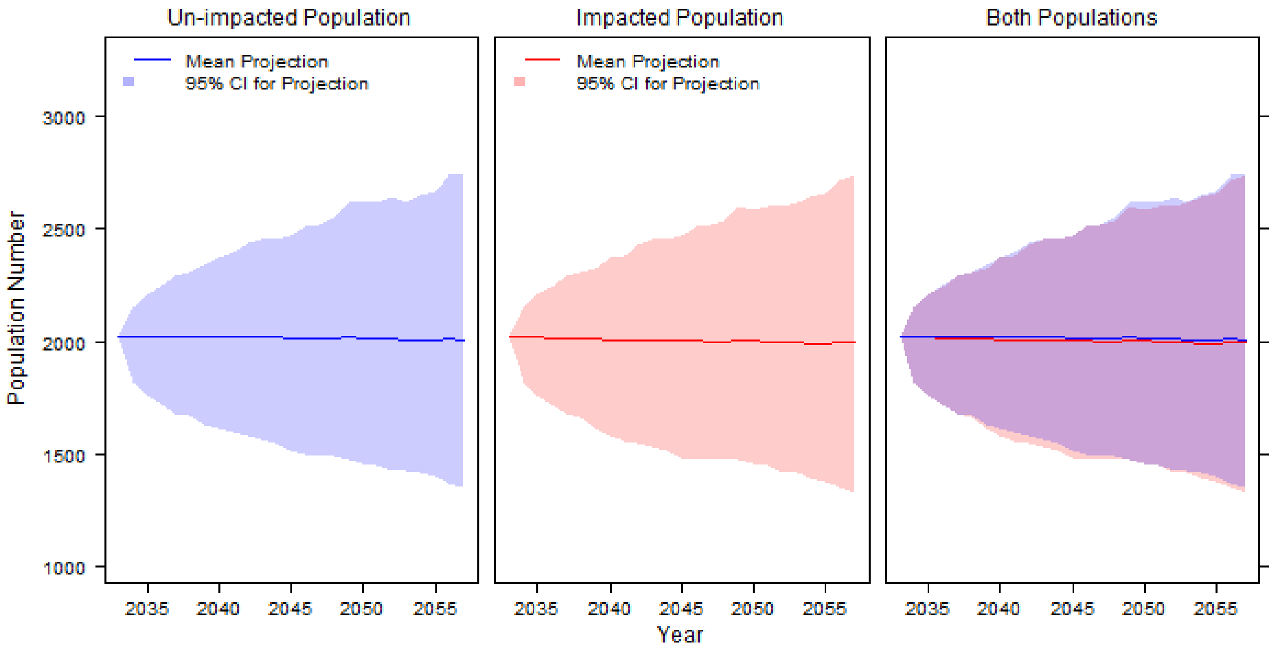


Plate 4.8 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for the GNS MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

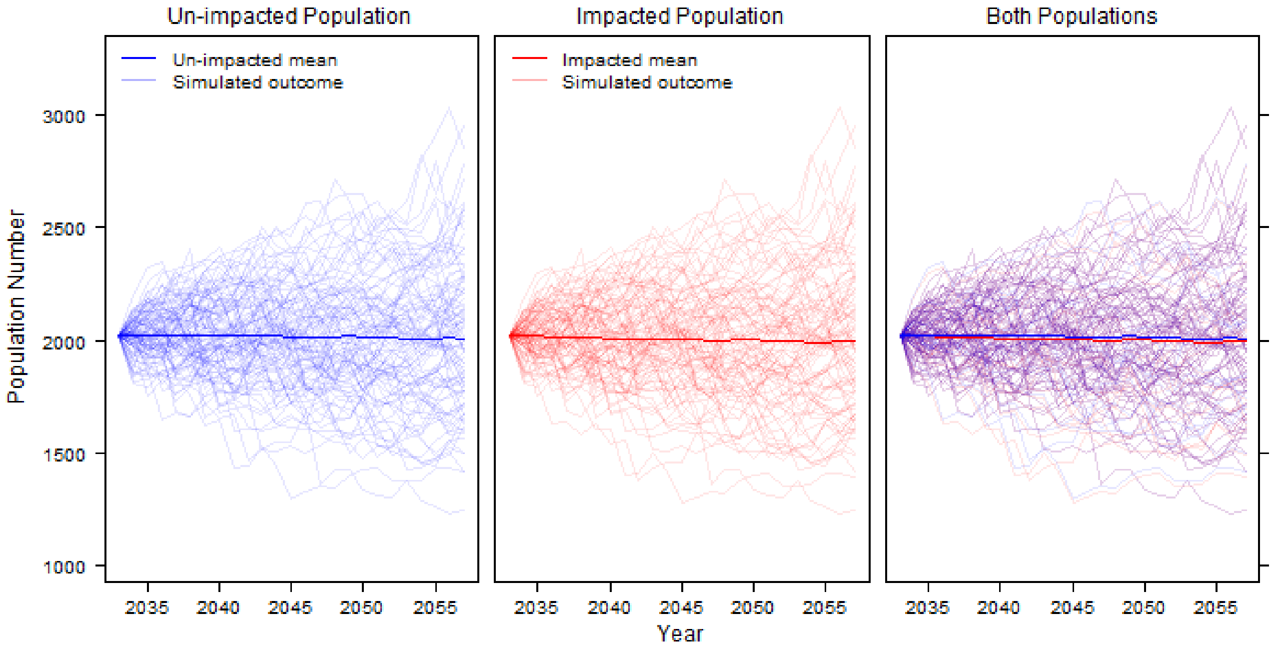


Table 4.4 Mean un-impacted and impacted population sizes for the GNS MU for bottlenose dolphins

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	2,024	2,024	100.00%
End 2033 (end piling year 1)	2,023	2,022	99.95%
End 2036 (end piling year 2)	2,021	2,015	99.70%
End 2038 (end piling year 3)	2,022	2,012	99.51%
End 2039 (end piling year 4)	2,023	2,009	99.31%
End 2040 (1 year after piling ends)	2,020	2,005	99.26%
End 2045 (6 years after piling ends)	2,017	2,003	99.31%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	2,014	2,000	99.30%
End 2057 (18 years after piling ends)	2,011	1,998	99.35%

4.5 Bottlenose dolphin GNS UK MU

4.5.1.1 The iPCoD modelling shows that the mean impacted population size of bottlenose dolphins in the GNS UK MU is predicted to remain within 99% of the size of the un-impacted population mean. The impacted population is predicted to continue on a stable trajectory, the same as the un-impacted population (**Plate 4.9, Plate 4.10** and **Table 4.5**).

Plate 4.9 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for the GNS UK MU. Piling is occurring between 2033 to 2039 inclusive

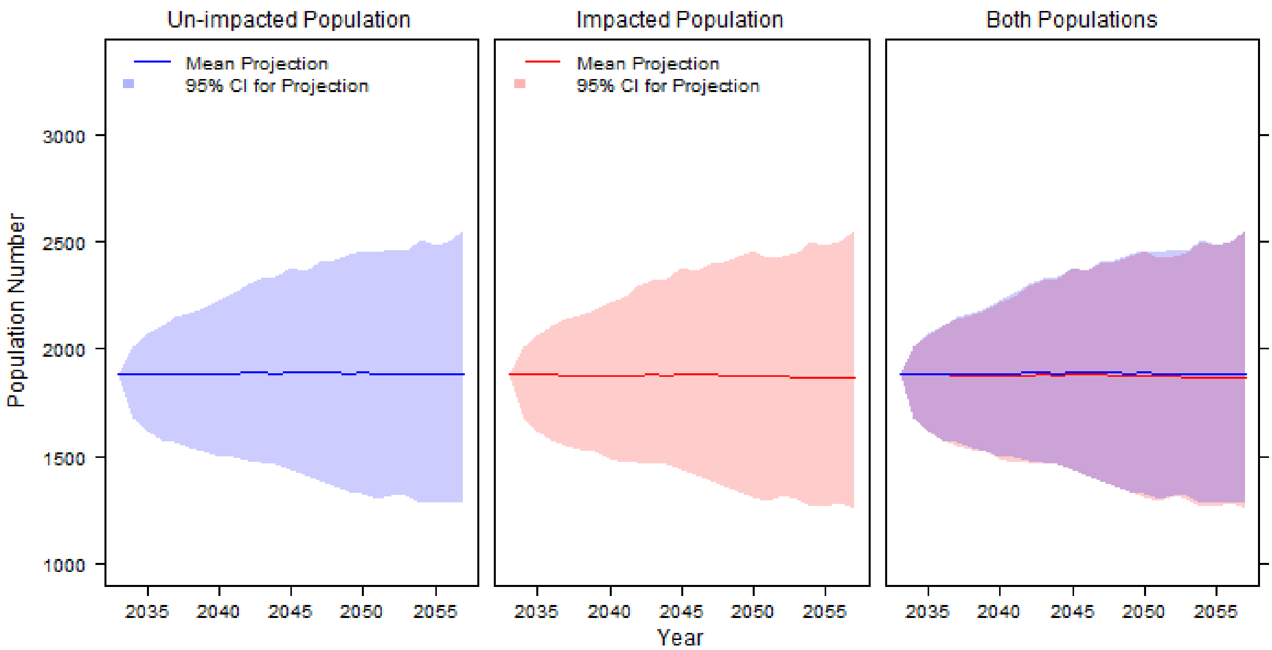


Plate 4.10 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for the GNS UK MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

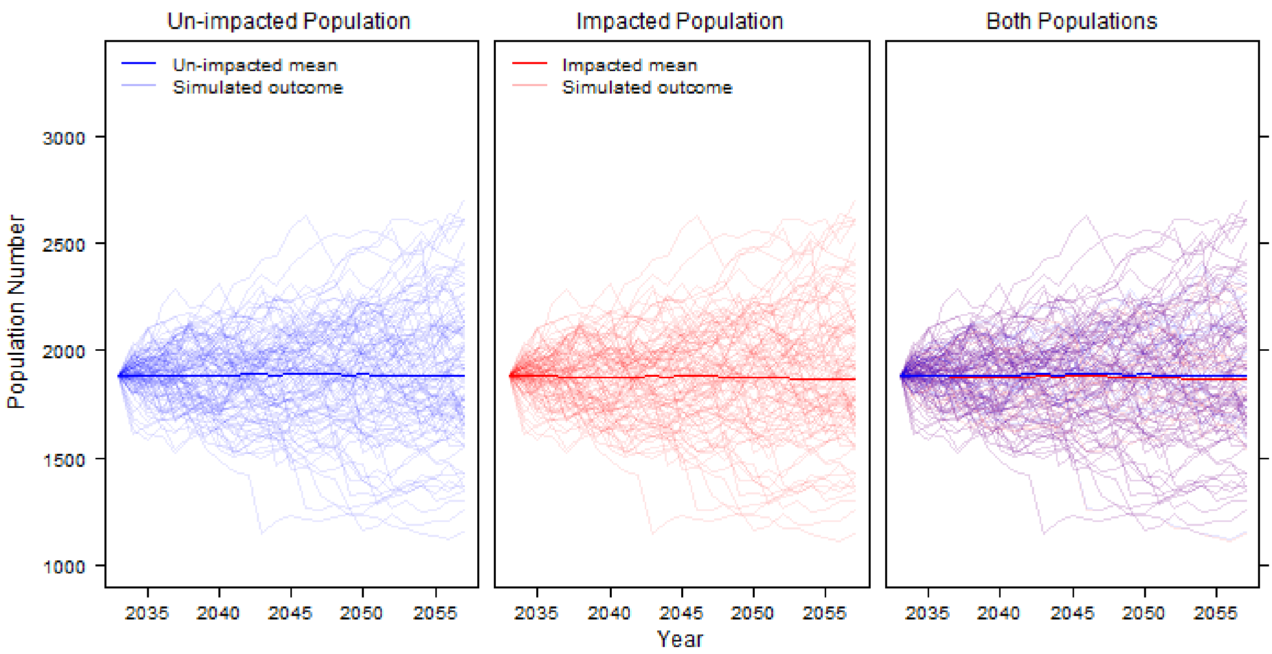


Table 4.5 Mean un-impacted and impacted population sizes for the GNS UK MU for bottlenose dolphins

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	1,882	1,882	100.00%
End 2033 (end piling year 1)	1,880	1,879	99.95%
End 2036 (end piling year 2)	1,879	1,874	99.73%
End 2038 (end piling year 3)	1,880	1,872	99.57%
End 2039 (end piling year 4)	1,881	1,870	99.42%
End 2040 (1 year after piling ends)	1,886	1,873	99.31%
End 2045 (6 years after piling ends)	1,889	1,878	99.42%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	1,882	1,870	99.36%
End 2057 (18 years after piling ends)	1,879	1,867	99.36%

4.6 Minke whale CGNS MU

4.6.1.1 The iPCoD modelling shows that the mean impacted population size of minke whales in the CGNS MU is predicted to remain within 99.9% of the size of the un-impacted population mean. The impacted population is predicted to continue on a stable trajectory, the same as the un-impacted population (**Plate 4.11, Plate 4.12** and **Table 4.6**).

Plate 4.11 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted minke whale iPCoD simulations for the CGNS MU. Piling is occurring between 2033 to 2039 inclusive

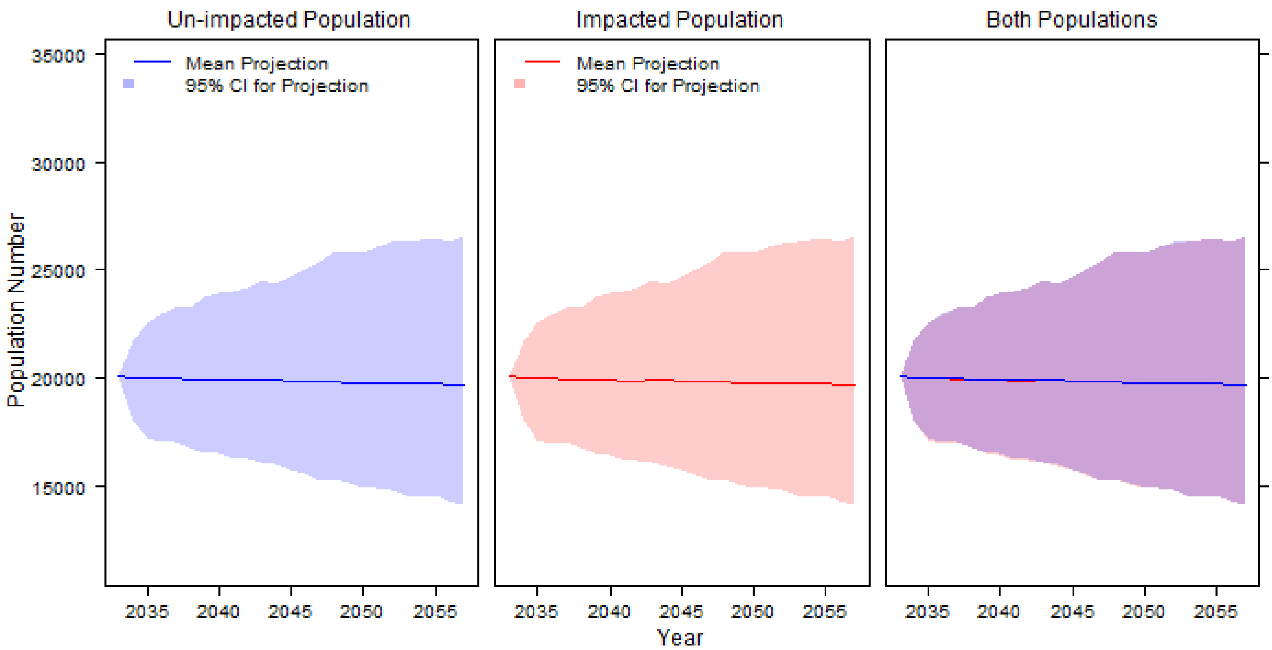


Plate 4.12 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted minke whale iPCoD simulations for the CGNS MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

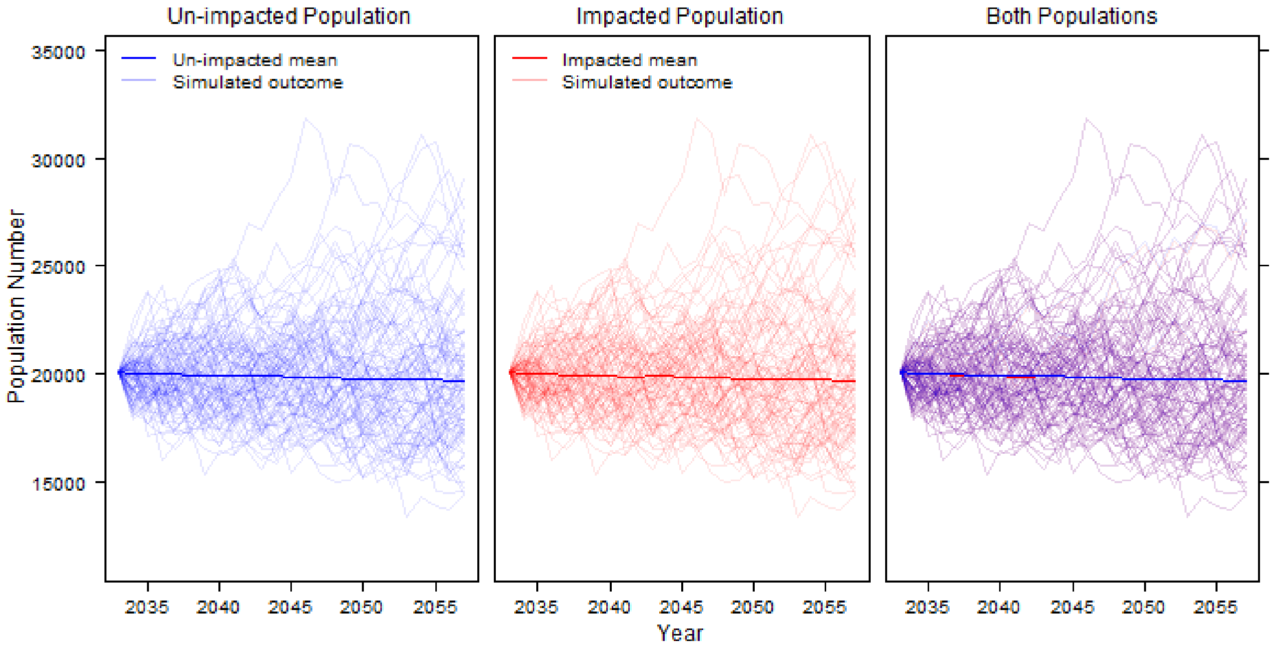


Table 4.6 Mean un-impacted and impacted population sizes for the CGNS MU for minke whales

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	20,120	20,120	100.00%
End 2033 (end piling year 1)	20,048	20,045	99.99%
End 2036 (end piling year 2)	19,996	19,989	99.96%
End 2038 (end piling year 3)	19,982	19,972	99.95%
End 2039 (end piling year 4)	19,981	19,964	99.91%
End 2040 (1 year after piling ends)	19,922	19,905	99.91%
End 2045 (6 years after piling ends)	19,891	19,886	99.97%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	19,757	19,751	99.97%
End 2057 (18 years after piling ends)	19,769	19,764	99.97%

4.7 Minke whale CGNS UK MU

4.7.1.1 The iPCoD modelling shows that the mean impacted population size of minke whales in the CGNS UK MU is predicted to remain within 99% of the size of the un-impacted population mean. The impacted population is predicted to continue on a stable trajectory, the same as the un-impacted population (**Plate 4.13, Plate 4.14** and **Table 4.7**).

Plate 4.13 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted minke whale iPCoD simulations for the CGNS UK MU. Piling is occurring between 2033 to 2039 inclusive

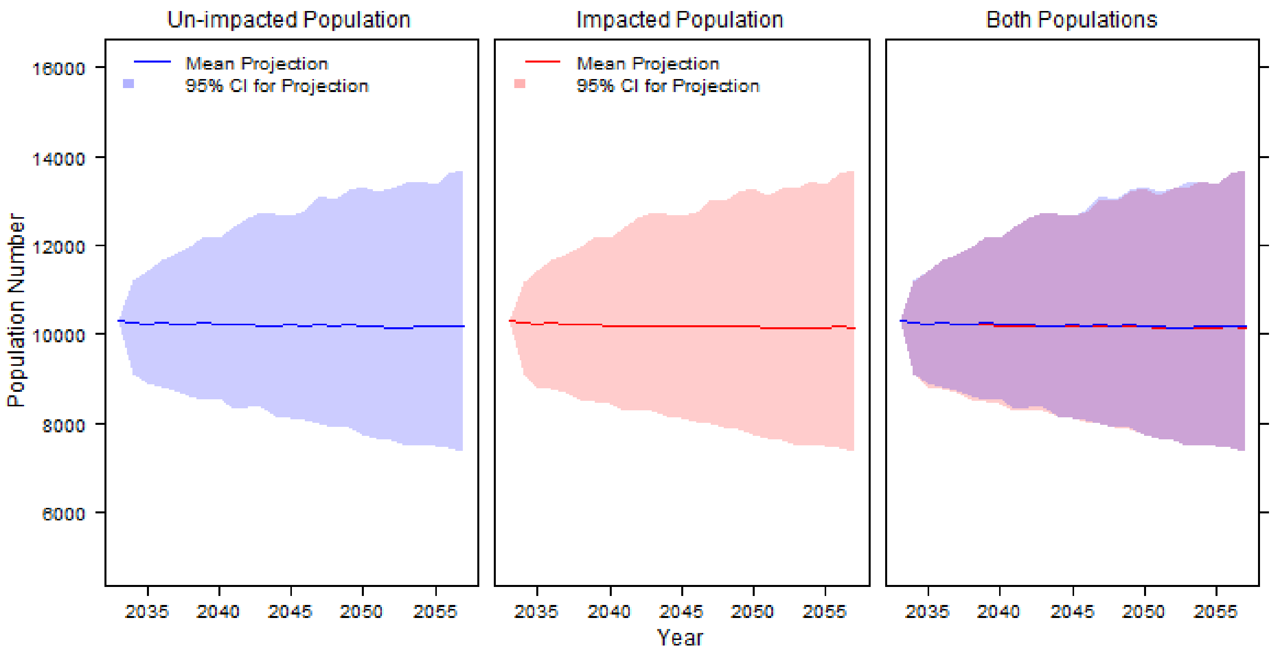


Plate 4.14 Predicted population trajectories for the un-impacted (baseline) and impacted minke whale iPCoD simulations for the CGNS UK MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

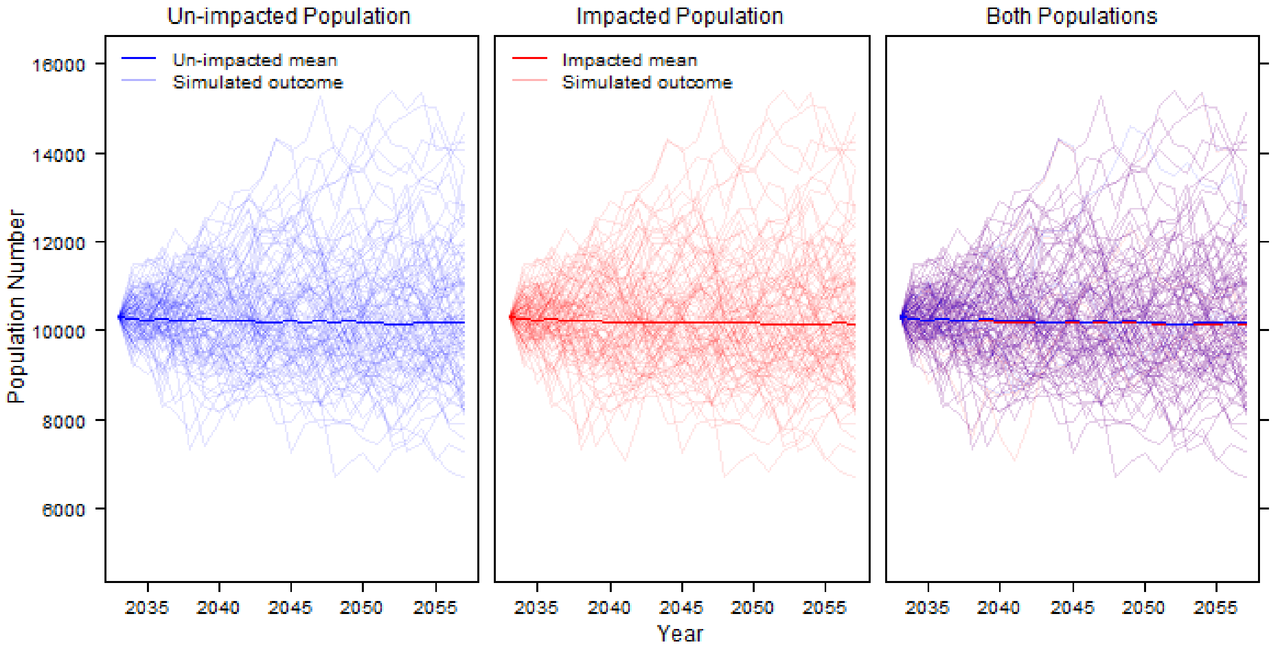


Table 4.7 Mean un-impacted and impacted population sizes for the CGNS UK MU for minke whales

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	10,288	10,288	100.00%
End 2033 (end piling year 1)	10,259	10,253	99.94%
End 2036 (end piling year 2)	10,238	10,222	99.84%
End 2038 (end piling year 3)	10,261	10,239	99.79%
End 2039 (end piling year 4)	10,236	10,193	99.58%
End 2040 (1 year after piling ends)	10,210	10,171	99.62%
End 2045 (6 years after piling ends)	10,196	10,182	99.86%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	10,152	10,138	99.86%
End 2057 (18 years after piling ends)	10,184	10,169	99.85%

4.8 Harbour seals ES SMA

4.8.1.1 The iPCoD modelling shows that the mean impacted population size of harbour seals in the ES SMA is predicted to remain at 100% of the size of the un-impacted population mean. The impacted population is predicted to continue on a stable trajectory, the same as the un-impacted population (**Plate 4.15, Plate 4.16** and **Table 4.8**).

Plate 4.15 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted harbour seals iPCoD simulations for the ES SMA. Piling is occurring between 2033 to 2039 inclusive

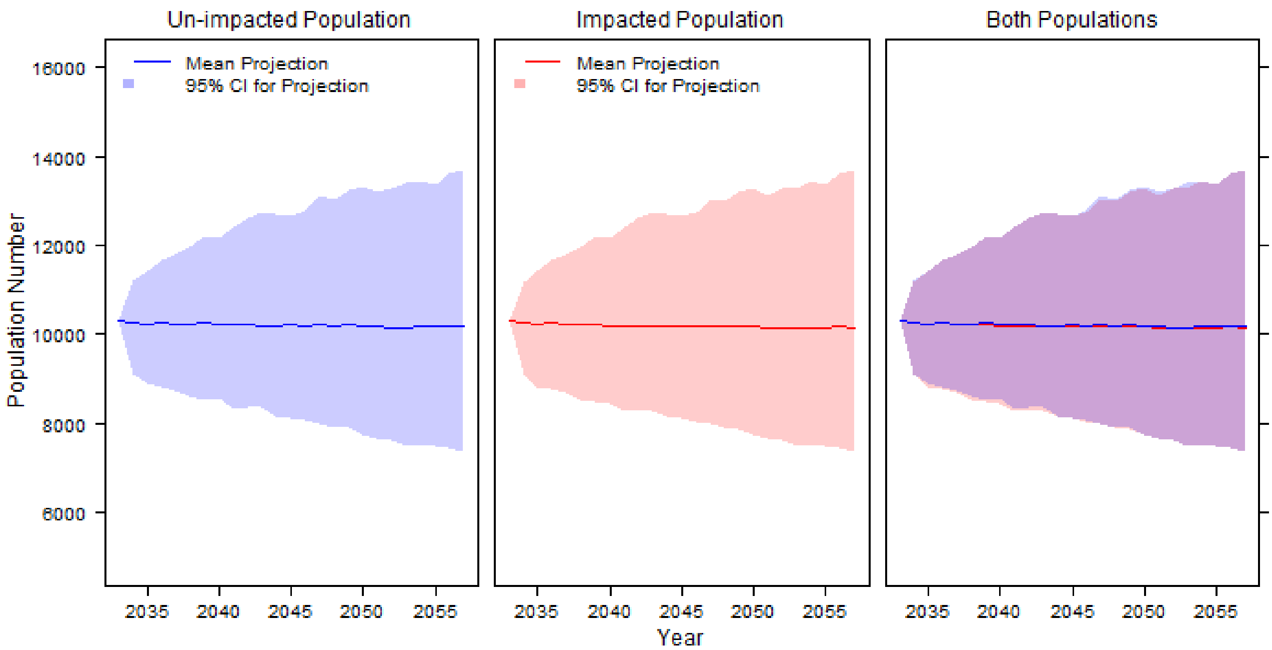


Plate 4.16 Predicted population trajectories for the un-impacted (baseline) and impacted harbour seals iPCoD simulations for the ES SMA. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

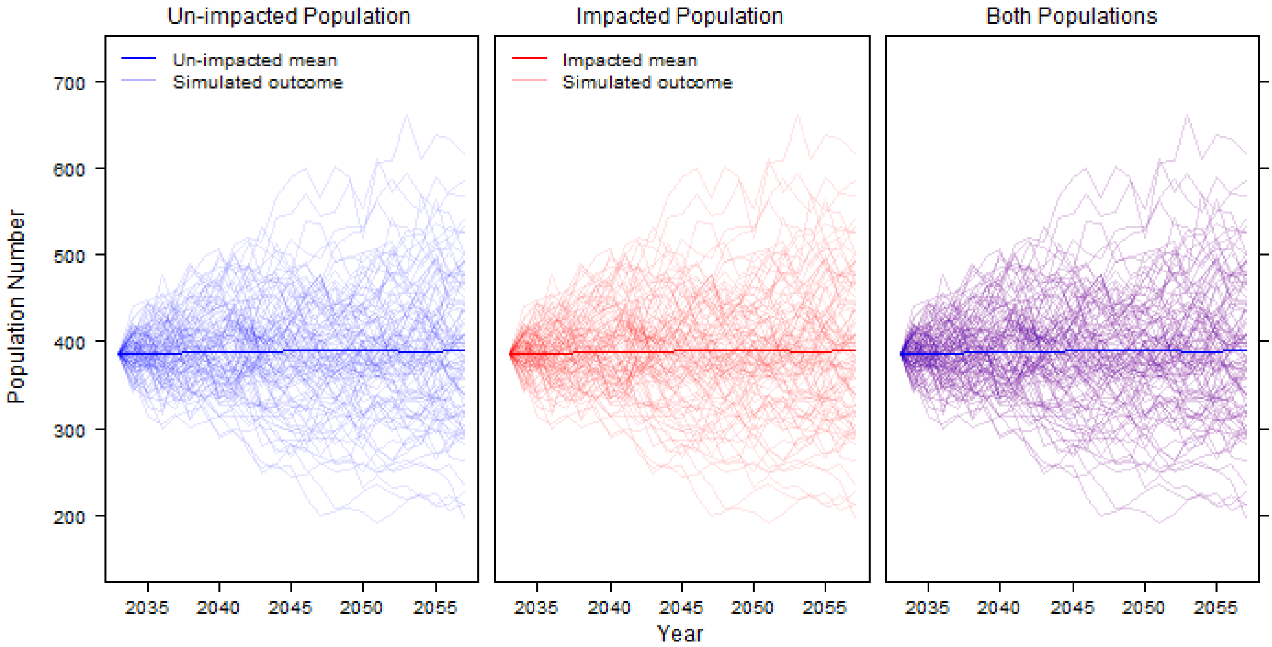


Table 4.8 Mean un-impacted and impacted population sizes for the ES SMA for harbour seals

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	386	386	100%
End 2033 (end piling year 1)	385	385	100%
End 2036 (end piling year 2)	386	386	100%
End 2038 (end piling year 3)	387	387	100%
End 2039 (end piling year 4)	388	388	100%
End 2040 (1 year after piling ends)	388	388	100%
End 2045 (6 years after piling ends)	390	390	100%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	389	389	100%
End 2057 (18 years after piling ends)	388	388	100%

4.9 Harbour seals NC&O SMA

4.9.1.1 The iPCoD modelling shows that the mean impacted population size of harbour seals in the NC&O SMA is predicted to remain at 100% of the size of the un-impacted population mean. The impacted population is predicted to continue on a declining trajectory, the same as the un-impacted population (**Plate 4.17, Plate 4.18** and **Table 4.9**).

Plate 4.17 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted harbour seals iPCoD simulations for the NC&O SMA. Piling is occurring between 2033 to 2039 inclusive

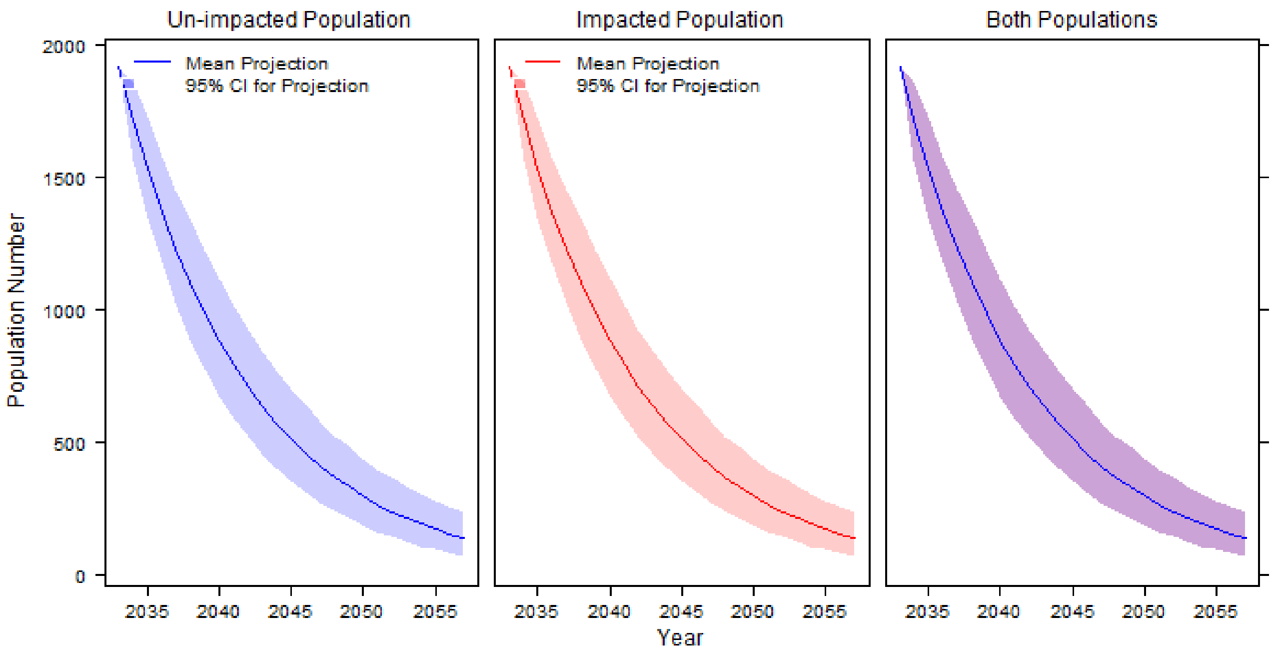


Plate 4.18 Predicted population trajectories for the un-impacted (baseline) and impacted harbour seals iPCoD simulations for the NC&O SMA. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

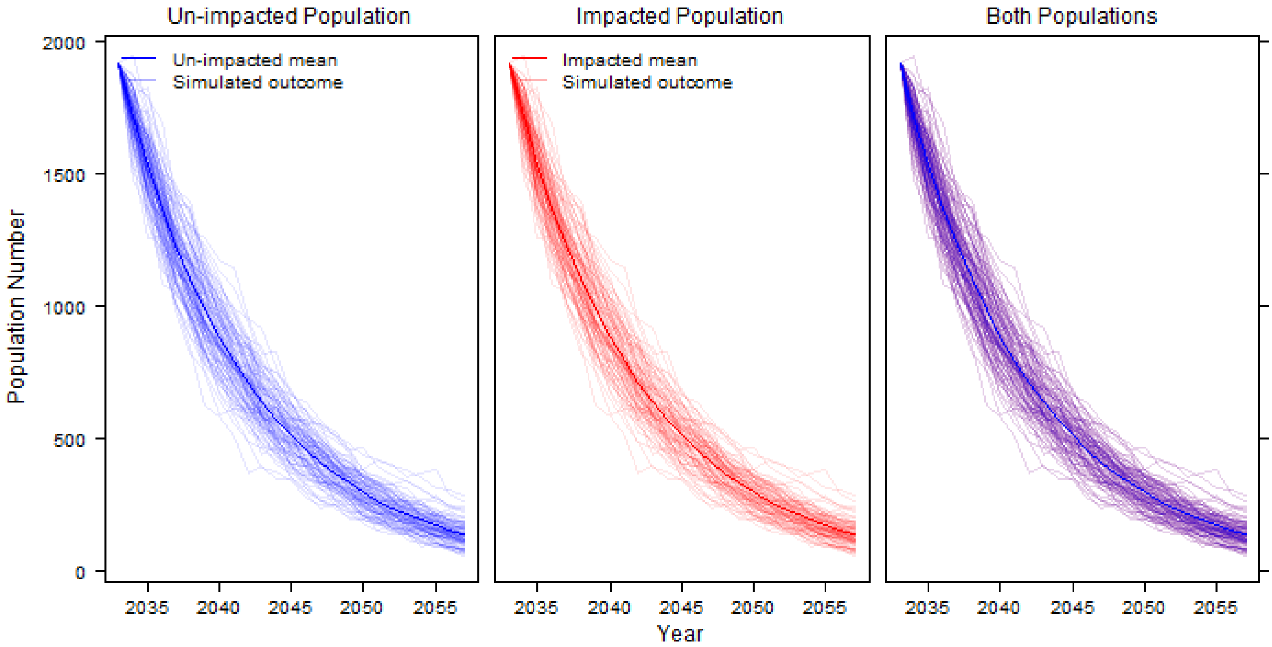


Table 4.9 Mean un-impacted and impacted population sizes for the NC&O SMA for harbour seals

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	1,916	1,916	100%
End 2033 (end piling year 1)	1,716	1,716	100%
End 2036 (end piling year 2)	1,227	1,227	100%
End 2038 (end piling year 3)	985	985	100%
End 2039 (end piling year 4)	882	882	100%
End 2040 (1 year after piling ends)	792	792	100%
End 2045 (6 years after piling ends)	460	460	100%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	236	236	100%
End 2057 (18 years after piling ends)	123	123	100%

4.10 Grey seals ES and NC&O SMA

4.10.1.1 The iPCoD modelling shows that the mean impacted population size of grey seals in the ES and NC&O SMAs is predicted to remain at 100% of the size of the un-impacted population mean. The impacted population is predicted to continue on an increasing trajectory, the same as the un-impacted population (**Plate 4.19, Plate 4.20** and **Table 4.10**).

Plate 4.19 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted grey seals iPCoD simulations for the ES and NC&O SMAs. Piling is occurring between 2033 to 2039 inclusiveThe

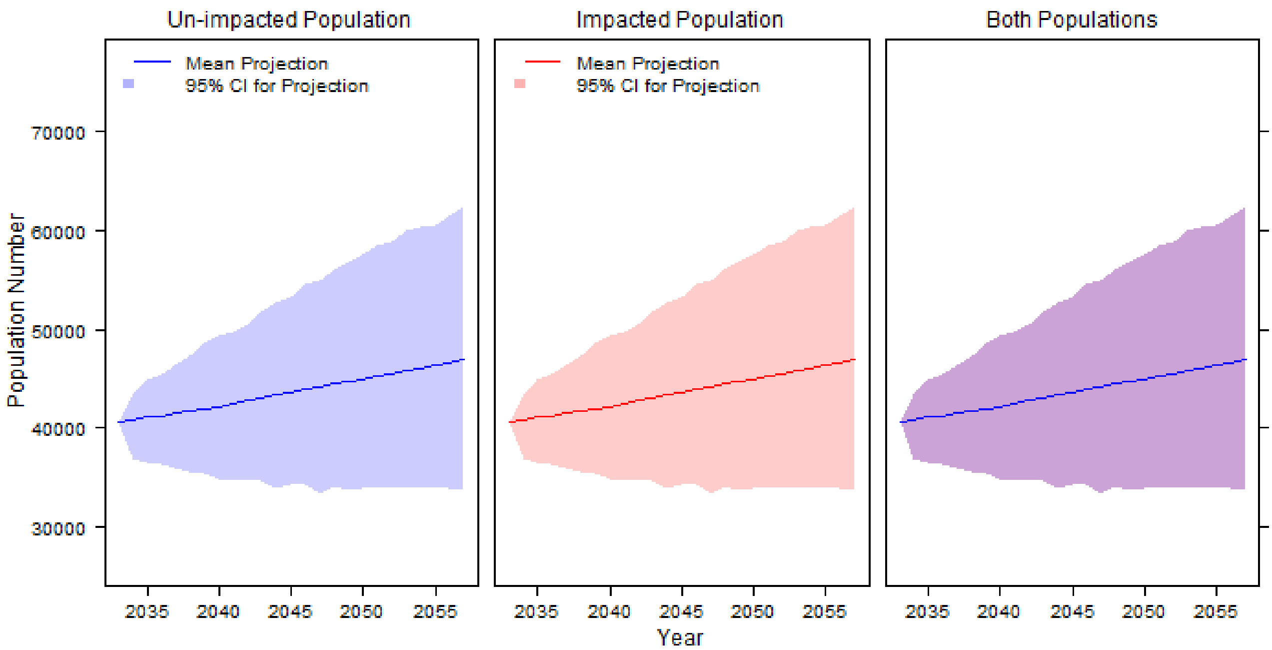


Plate 4.20 Predicted population trajectories for the un-impacted (baseline) and impacted grey seals iPCoD simulations for the ES and NC&O SMAs. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2033 to 2039 inclusive

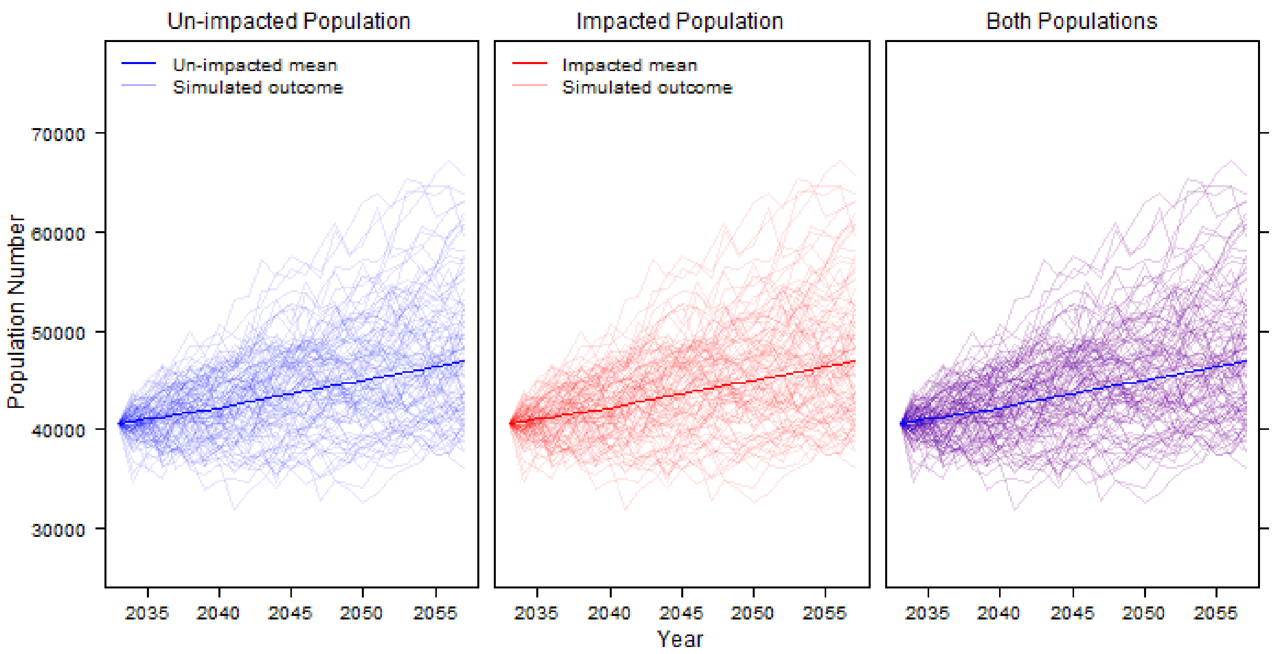


Table 4.10 Mean un-impacted and impacted population sizes for the ES and NC&O SMAs for grey seals

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2033 (pre-piling)	40,566	40,566	100%
End 2033 (end piling year 1)	40,798	40,798	100%
End 2036 (end piling year 2)	41,581	41,581	100%
End 2038 (end piling year 3)	41,979	41,979	100%
End 2039 (end piling year 4)	42,207	42,207	100%
End 2040 (1 year after piling ends)	42,470	42,470	100%
End 2045 (6 years after piling ends)	43,935	43,935	100%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after piling ends)	45,425	45,425	100%
End 2057 (18 years after piling ends)	47,358	47,358	100%

5. Cumulative iPCoD Model Results

5.1 Harbour porpoise NS MU

5.1.1.1 For the cumulative scenario for harbour porpoise in the NS MU, there were nine offshore wind farms that met the screening criteria that were modelled alongside the Project. The disturbance numbers for harbour porpoise used in the modelling are presented in **Table 5.1**.

5.1.1.2 The cumulative iPCoD modelling shows that the mean impacted population size of harbour porpoise in the NS MU is predicted to reduce from 100 to 98.51% of the size of the un-impacted population mean during the cumulative piling period and then remains at ~98.5%. The impacted population is then predicted to continue on a stable trajectory, the same as the un-impacted population, albeit at a lower population level (**Plate 5.1, Plate 5.2** and **Table 5.2**).

Table 5.1 Number of harbour porpoise in the NS MU disturbed per piling day per offshore wind farm development in the cumulative iPCoD simulation

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Marram	2033	2039	14,787	EIA Report.
Arven offshore substation	2030	2033	365	EDR
Arven WTG	2030	2033	365	EDR
Ayre offshore substation	2030	2033	199	EDR
Ayre WTG	2030	2033	199	EDR
Bowdun	2029	2032	424	EDR
Buchan	2029	2033	365	EDR
Caledonia WTG fixed	2028	2032	8,201	EIA Report.
Caledonia WTG floating	2030	2032	6,648	EIA Report.
Cenos WTG	2031	2033	8,863	EIA Report.
Cenos offshore substation	2031	2031	9,529	EIA Report.
Ossian WTG	2031	2037	3,856	EIA Report.
Ossian offshore substation	2031	2038	7,309	EIA Report.
Seagreen 1A	2029	2032	1,882	Piling Strategy.

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Stromar WTG	2029	2032	199	EDR
Stromar offshore substation	2029	2031	199	EDR

Plate 5.1 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted harbour porpoise cumulative iPCoD simulations for the NS MU. Piling is occurring between 2028 to 2039 inclusive

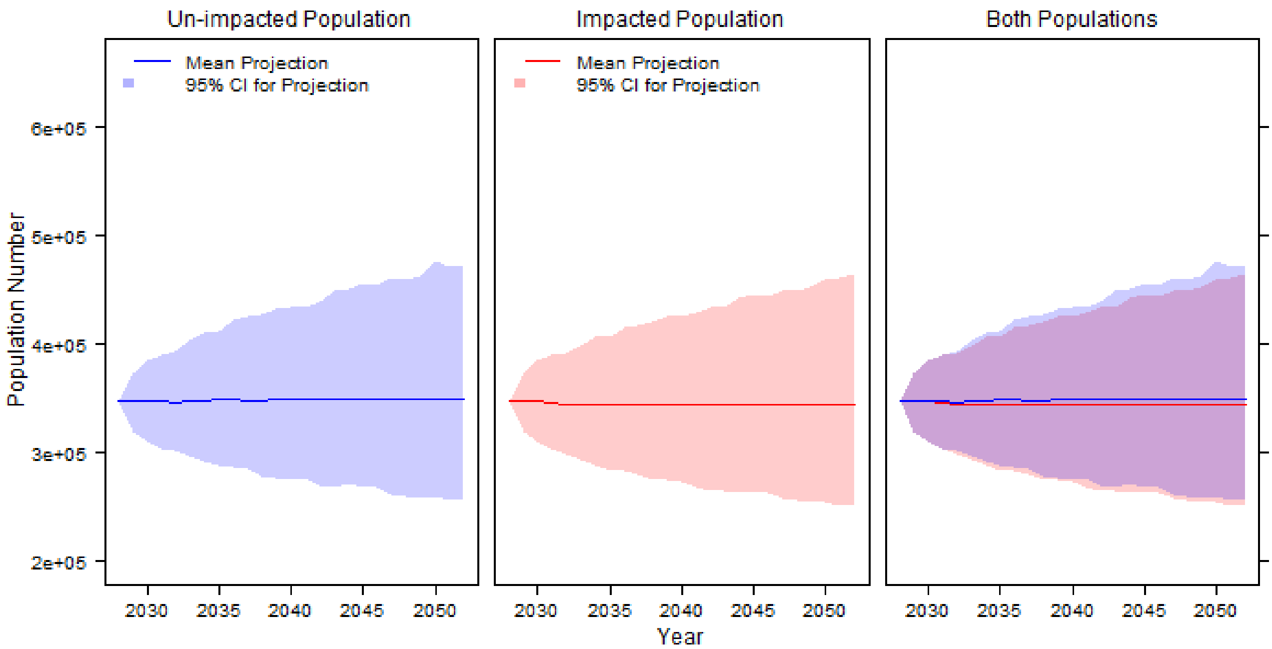


Plate 5.2 Predicted population trajectories for the un-impacted (baseline) and impacted harbour porpoise cumulative iPCoD simulations for the NS MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2028 to 2039 inclusive

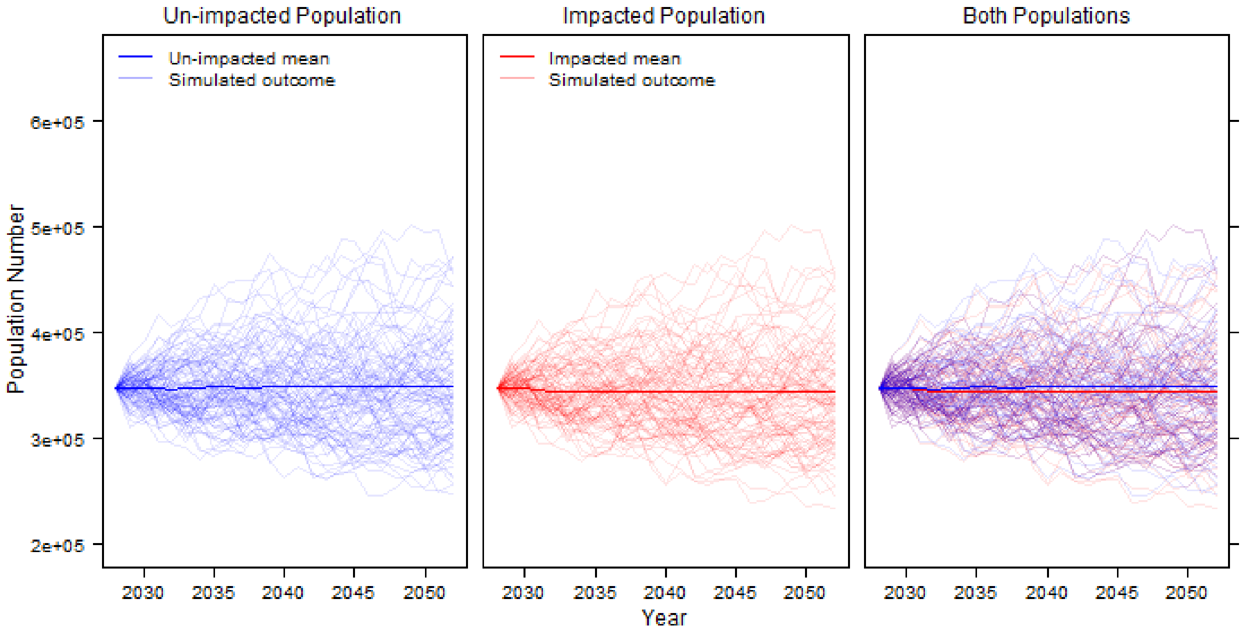


Table 5.2 Mean un-impacted and impacted population sizes for the NS MU for harbour porpoise

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2028 (pre-piling)	346,602	346,602	100.00%
End 2028 (end cumulative piling year 1)	346,777	346,777	100.00%
End 2033 (end Project piling year 1)	347,029	342,932	98.82%
End 2039 (end Project piling and cumulative piling year 12))	348,092	342,913	98.51%
End 2040 (one year after cumulative piling ends)	348,176	342,906	98.49%
End 2045 (six years after cumulative piling ends)	348,954	343,813	98.53%

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
End 2051 (12 years after cumulative piling ends)	348,353	343,231	98.53%

5.2 Bottlenose dolphins CES MU

5.2.1.1 For the cumulative scenario for bottlenose dolphins in the CES MU, there were two offshore wind farms that met the screening criteria that were modelled alongside the Project. The disturbance numbers for bottlenose dolphins used in the modelling are presented in **Table 5.3**.

5.2.1.2 The cumulative iPCoD modelling shows that the mean impacted population size of bottlenose dolphins in the CES MU is predicted to reduce to 86.04% of the size of the un-impacted population mean during the cumulative piling period and then remains at ~86% after piling ceases. The impacted population is then predicted to continue on an increasing trajectory, the same as the un-impacted population, albeit at a lower population size (**Plate 5.3, Plate 5.4** and **Table 5.4**).

Table 5.3 Number of bottlenose dolphins in the CES MU disturbed per piling day per offshore wind farm development in the cumulative iPCoD simulation

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Marram	2033	2039	31	EIA Report.
Ayre offshore substation	2030	2033	0	EDR
Ayre WTG	2030	2033	0	EDR
Caledonia WTG fixed	2028	2032	52	EIA Report.
Caledonia WTG floating	2030	2032	46	EIA Report.

Plate 5.3 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted bottlenose dolphin cumulative iPCoD simulations for the CES MU. Piling is occurring between 2028 to 2039 inclusive

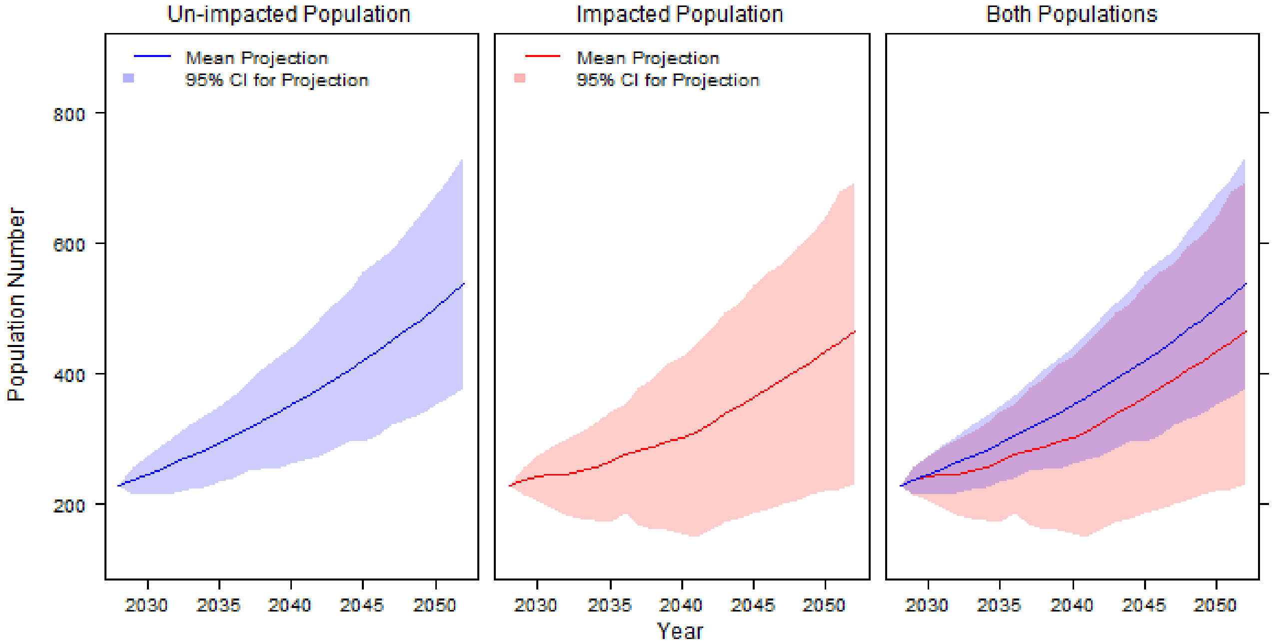


Plate 5.4 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin cumulative iPCoD simulations for the CES MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2028 to 2039 inclusive

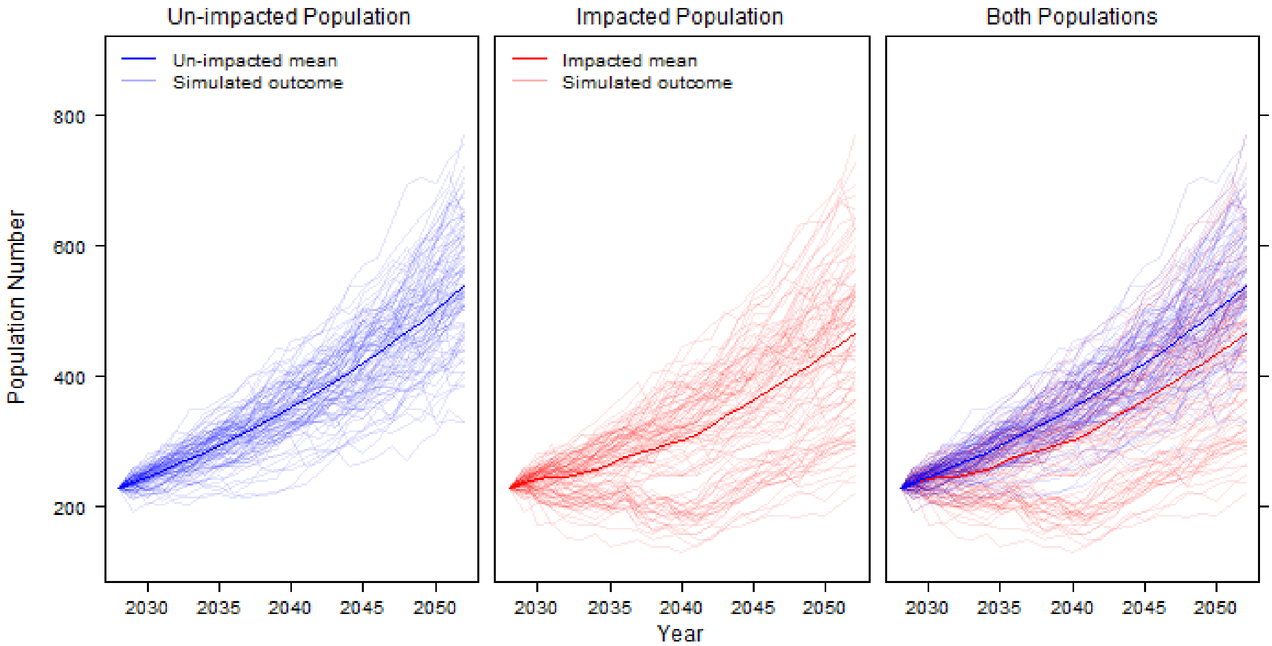


Table 5.4 Mean un-impacted and impacted population sizes for the CES MU for bottlenose dolphins.

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2028 (pre-piling)	228	228	100.00%
End 2028 (end cumulative piling year 1)	236	236	100.00%
End 2033 (end Project piling year 1)	282	257	91.13%
End 2039 (end Project piling and cumulative piling year 12))	351	302	86.04%
End 2040 (one year after cumulative piling ends)	363	310	85.40%
End 2045 (six years after cumulative piling ends)	434	376	86.64%
End 2051 (12 years after cumulative piling ends)	538	465	86.43%

5.3 Bottlenose dolphin GNS MU

5.3.1.1 For the cumulative scenario for bottlenose dolphins in the GNS MU, there were nine offshore wind farms that met the screening criteria that were modelled alongside the Project. The disturbance numbers for bottlenose dolphins used in the modelling are presented in **Table 5.5**.

5.3.1.2 The cumulative iPCoD modelling shows that the mean impacted population size of bottlenose dolphin in the GNS MU is predicted to reduce to 96.07% of the size of the un-impacted population mean during the cumulative piling period and then remains at ~95.9%. The impacted population is then predicted to continue on a stable trajectory, the same as the un-impacted population, albeit at a lower population size (**Plate 5.5, Plate 5.6** and **Table 5.6**).

Table 5.5 Number of bottlenose dolphins in the GNS MU disturbed per piling day per offshore wind farm development in the cumulative iPCoD simulation

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Marram	2033	2039	20	EIA Report.
Arven offshore substation	2030	2033	0	EDR
Arven WTG	2030	2033	0	EDR
Ayre offshore substation	2030	2033	0	EDR
Ayre WTG	2030	2033	0	EDR
Bowdun	2029	2032	0	EDR
Buchan	2029	2033	0	EDR
Caledonia WTG fixed	2028	2032	35	EIA Report.
Caledonia WTG floating	2030	2032	27	EIA Report.
Cenos WTG	2031	2033	254	EIA Report.
Cenos offshore substation	2031	2031	273	EIA Report.
Ossian WTG	2031	2037	0	EIA Report.
Ossian offshore substation	2031	2038	0	EIA Report.
Seagreen 1A	2029	2032	2	Piling Strategy.
Stromar WTG	2029	2032	0	EDR
Stromar offshore substation	2029	2031	0	EDR

Plate 5.5 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted bottlenose dolphin cumulative iPCoD simulations for the GNS MU. Piling is occurring between 2028 to 2039 inclusive

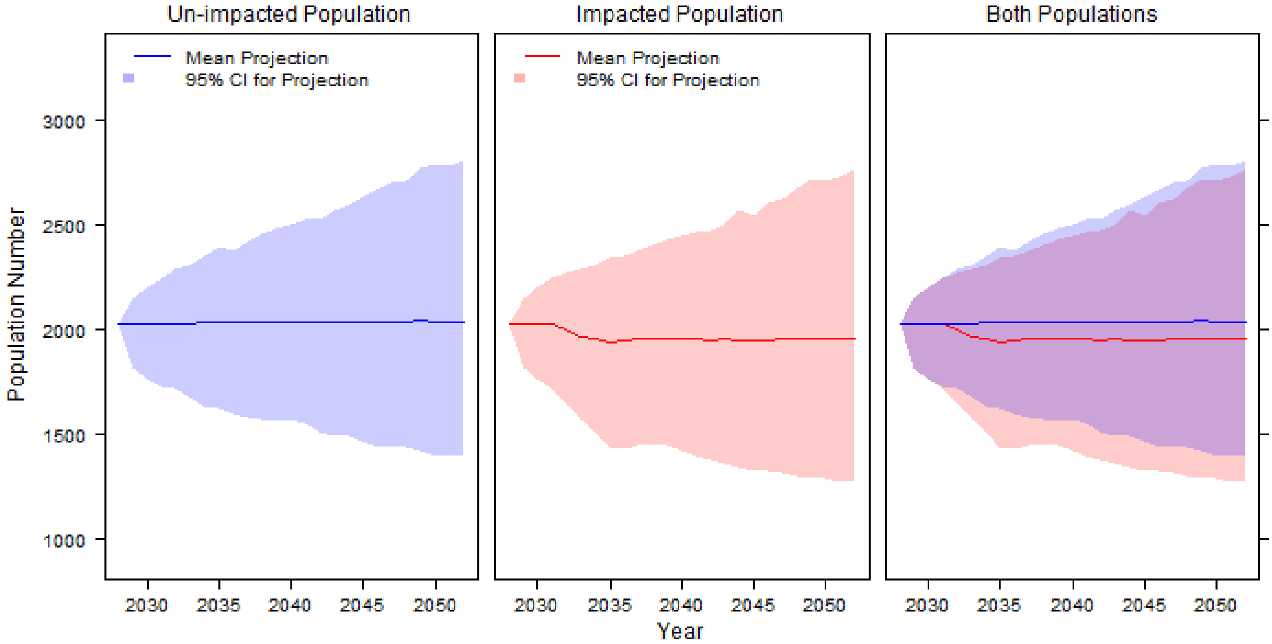


Plate 5.6 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin cumulative iPCoD simulations for the GNS MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2028 to 2039 inclusive

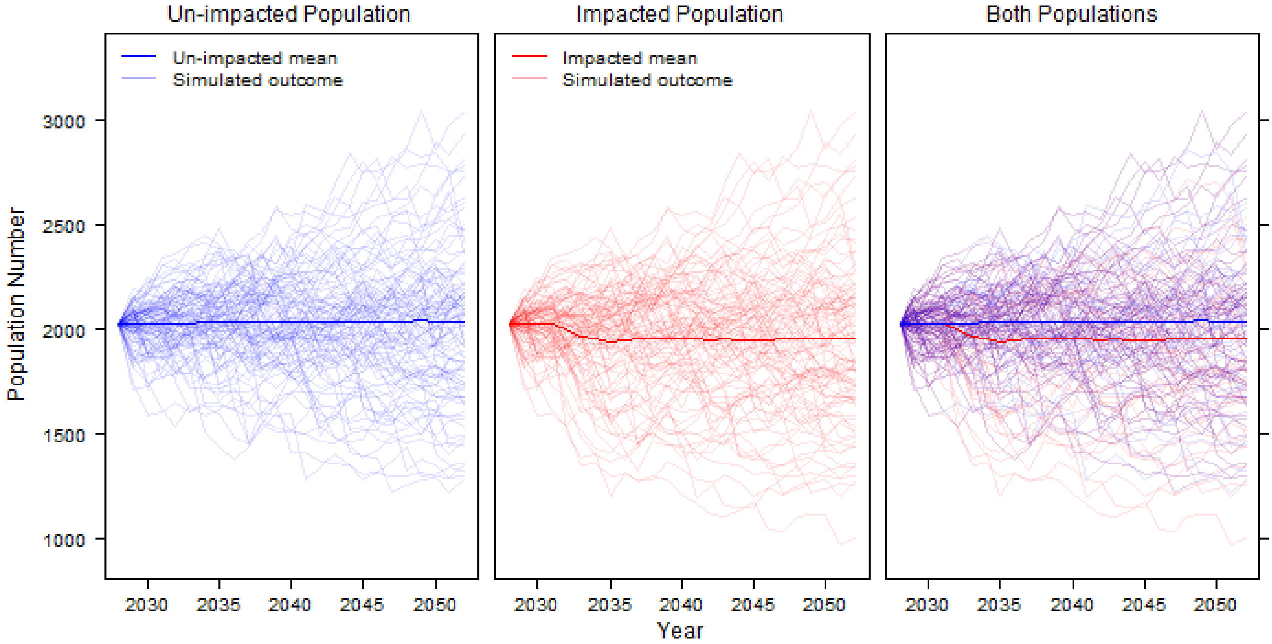


Table 5.6 Mean un-impacted and impacted population sizes for the GNS MU for bottlenose dolphins

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2028 (pre-piling)	2,024	2,024	100.00%
End 2028 (end cumulative piling year 1)	2,024	2,024	100.00%
End 2033 (end Project piling year 1)	2,033	1,954	96.11%
End 2039 (end Project piling and cumulative piling year 12)	2,035	1,955	96.07%
End 2040 (1 year after cumulative piling ends)	2,035	1,954	96.02%
End 2045 (6 years after cumulative piling ends)	2,034	1,951	95.92%
End 2051 (12 years after cumulative piling ends)	2,041	1,957	95.88%

5.4 Minke whale CGNS MU

5.4.1.1 For the cumulative scenario for minke whales in the CGNS MU, there were nine offshore wind farms that met the screening criteria that were modelled alongside the Project. The disturbance numbers for minke whales used in the modelling are presented in **Table 5.7**.

5.4.1.2 The cumulative iPCoD modelling shows that the mean impacted population size of minke whale in the CGNS MU is predicted to remain within 99% of the size of the un-impacted population mean. The impacted population is predicted to continue on a stable trajectory, the same as the un-impacted population (**Plate 5.7, Plate 5.8** and **Table 5.8**).

Table 5.7 Number of minke whale in the CGNS MU disturbed per piling day per offshore wind farm development in the cumulative iPCoD simulation

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Marram	2033	2039	984	EIA Report.
Arven offshore substation	2030	2033	9	EDR
Arven WTG	2030	2033	9	EDR
Ayre offshore substation	2030	2033	9	EDR
Ayre WTG	2030	2033	9	EDR
Bowdun	2029	2032	30	EDR
Buchan	2029	2033	9	EDR
Caledonia WTG fixed	2028	2032	502	EIA Report.
Caledonia WTG floating	2030	2032	415	EIA Report.
Cenos WTG	2031	2033	357	EIA Report.
Cenos offshore substation	2031	2031	384	EIA Report.
Ossian WTG	2031	2037	168	EIA Report.
Ossian offshore substation	2031	2038	318	EIA Report.
Seagreen 1A	2029	2032	89	Piling Strategy.
Stromar WTG	2029	2032	9	EDR
Stromar offshore substation	2029	2031	9	EDR

Plate 5.7 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted minke whale cumulative iPCoD simulations for the CGNS MU. Piling is occurring between 2028 to 2039 inclusive

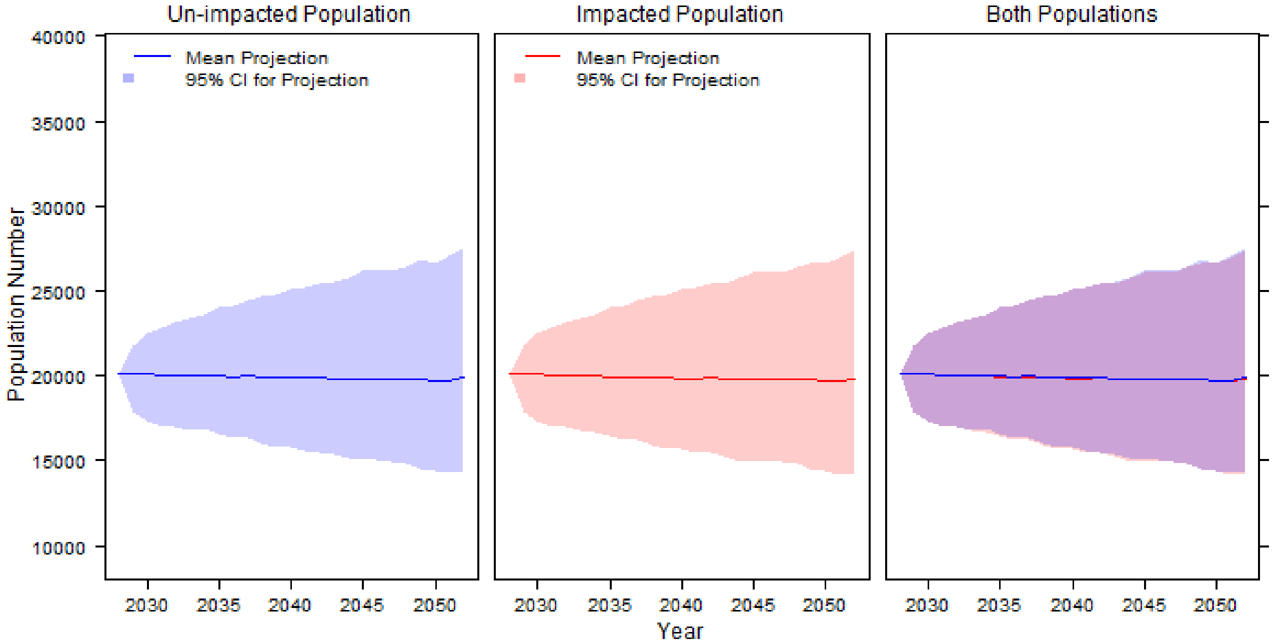


Plate 5.8 Predicted population trajectories for the un-impacted (baseline) and impacted minke whale cumulative iPCoD simulations for the CGNS MU. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2028 - 2039 inclusive

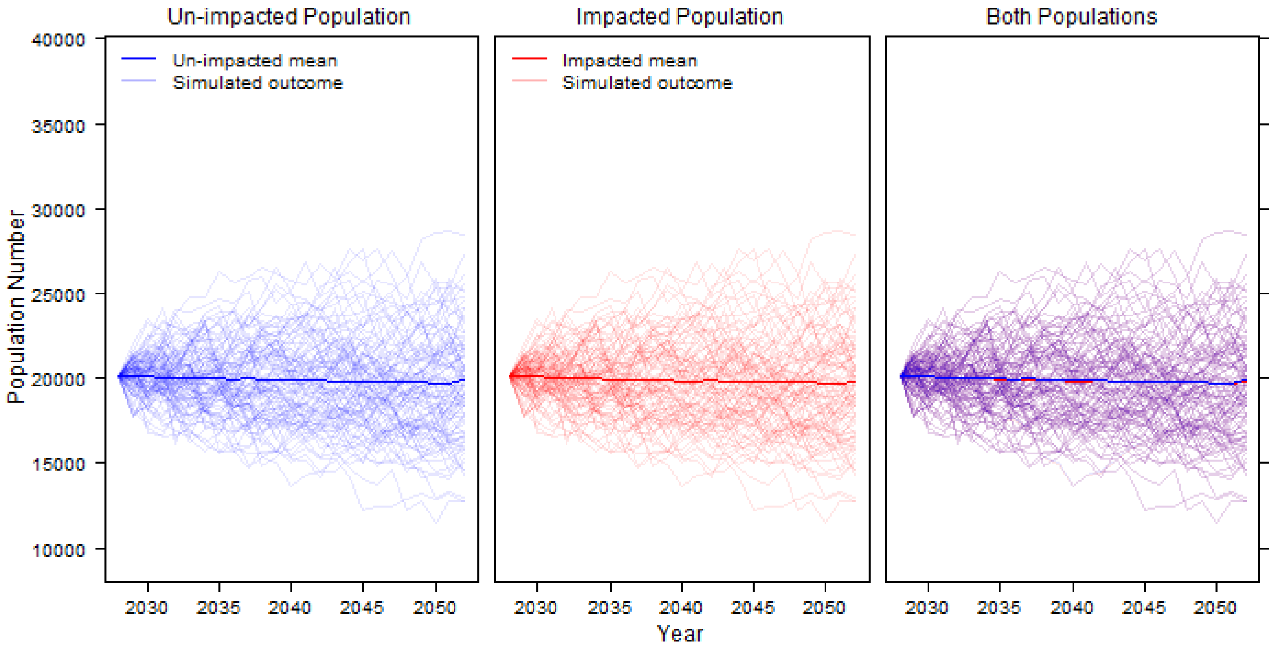


Table 5.8 Mean un-impacted and impacted population sizes for the CGNS MU for minke whale

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2028 (pre-piling)	20,120	20,120	100.00%
End 2028 (end cumulative piling year 1)	20,112	20,112	100.00%
End 2033 (end Project piling year 1)	20,056	20,036	99.90%
End 2039 (end Project piling and cumulative piling year 12))	19,870	19,826	99.78%
End 2040 (one year after cumulative piling ends)	19,873	19,831	99.79%
End 2045 (six years after cumulative piling ends)	19,830	19,812	99.91%
End 2051 (12 years after cumulative piling ends)	19,864	19,844	99.90%

5.5 Harbour seals ES SMA

5.5.1.1 For the cumulative scenario for harbour seals in the ES SMA, there were four offshore wind farms that met the screening criteria that were modelled alongside the Project. The disturbance numbers for harbour seals used in the modelling are presented in **Table 5.9**.

5.5.1.2 The cumulative iPCoD modelling shows that the mean impacted population size of harbour seals in the ES SMA is predicted to remain at 100% of the size of the un-impacted population mean. The impacted population is predicted to continue on a stable trajectory, the same as the un-impacted population (**Plate 5.9, Plate 5.10** and **Table 5.10**).

Table 5.9 Number of harbour seals in the ES SMA disturbed per piling day per offshore wind farm development in the cumulative iPCoD simulation

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Marram	2033	2039	1	EIA Report.
Bowdun	2029	2032	5	EDR
Cenos WTG	2031	2033	5	EIA Report.
Cenos offshore substation	2031	2031	5	EIA Report.
Ossian WTG	2031	2037	5	EIA Report.
Ossian offshore substation	2031	2038	5	EIA Report.
Seagreen 1A	2029	2032	51	Piling Strategy.

Plate 5.9 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted harbour seal cumulative iPCoD simulations for the ES SMA. Piling is occurring between 2028 to 2039 inclusive

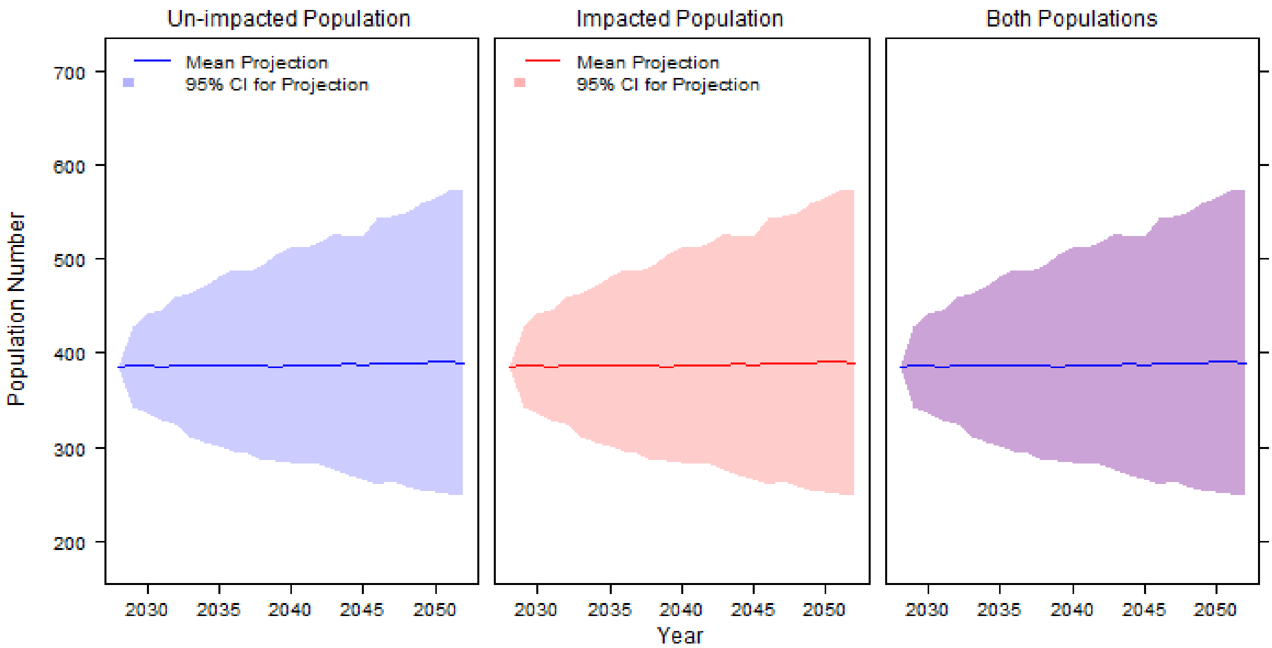


Plate 5.10 Predicted population trajectories for the un-impacted (baseline) and impacted harbour seal cumulative iPCoD simulations for the ES SMA. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2028 to 2039 inclusive

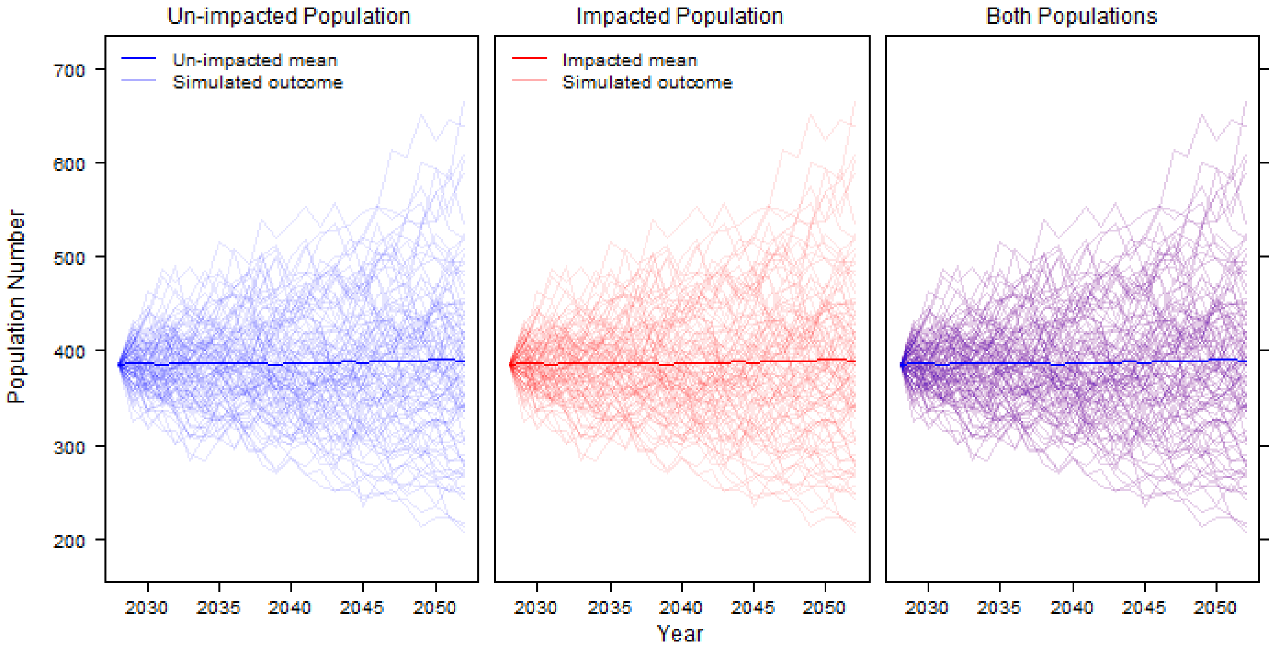


Table 5.10 Mean un-impacted and impacted population sizes for the ES SMA for harbour seals

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2028 (pre-piling)	386	386	100%
End 2028 (end cumulative piling year 1)	387	387	100%
End 2033 (end Project piling year 1)	387	387	100%
End 2039 (end Project piling and cumulative piling year 12)	388	388	100%
End 2040 (one year after cumulative piling ends)	388	388	100%
End 2045 (six years after cumulative piling ends)	389	389	100%
End 2051 (12 years after cumulative piling ends)	389	389	100%

5.6 Harbour seals NC&O SMA

5.6.1.1 For the cumulative scenario for harbour seals in the NC&O SMA, there were three offshore wind farms that met the screening criteria that were modelled alongside the Project. The disturbance numbers for harbour seals used in the modelling are presented in **Table 5.11**.

5.6.1.2 The cumulative iPCoD modelling shows that the mean impacted population size of harbour seals in the NC&O SMA is predicted to remain at 100% of the size of the un-impacted population mean. The impacted population is predicted to continue on a declining trajectory, the same as the un-impacted population (**Plate 5.11, Plate 5.12** and **Table 5.12**).

Table 5.11 Number of harbour seals in the NC&O SMA disturbed per piling day per offshore wind farm development in the cumulative iPCoD simulation

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Marram	2033	2039	1	EIA Report.
Ayre offshore substation	2030	2033	26	EDR
Ayre WTG	2030	2033	26	EDR
Buchan	2029	2033	26	EDR
Stromar WTG	2029	2032	26	EDR
Stromar offshore substation	2029	2031	26	EDR

Plate 5.11 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted harbour seal cumulative iPCoD simulations for the NC&O SMA. Piling is occurring between 2029 to 2039 inclusive

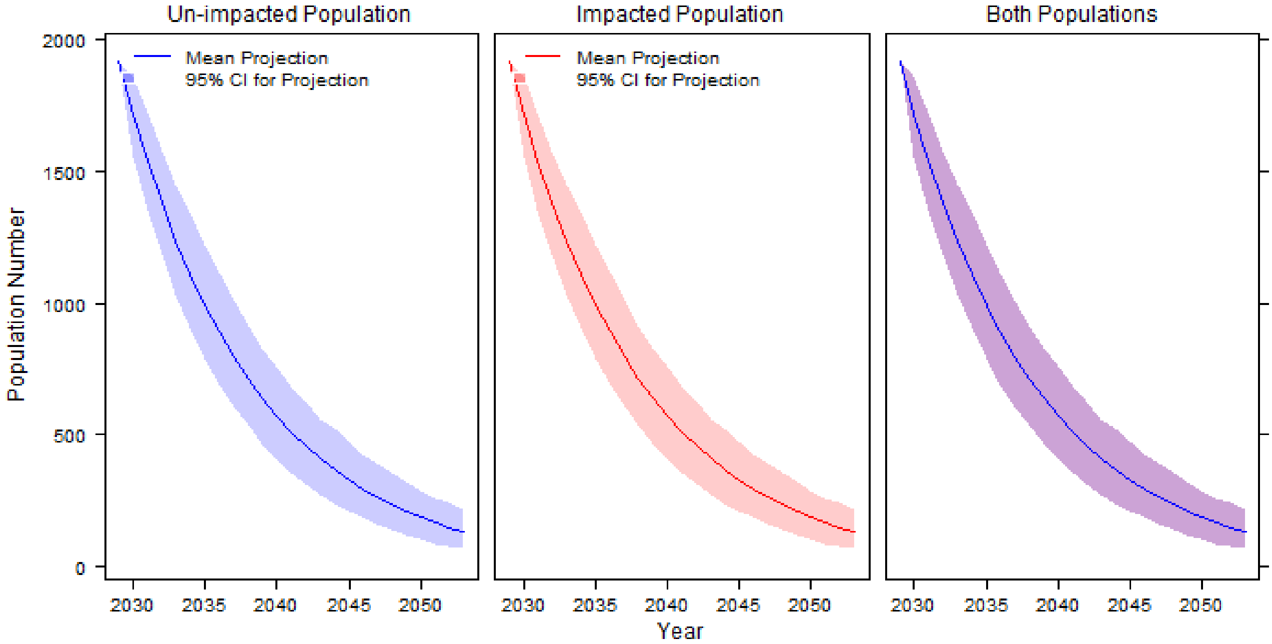


Plate 5.12 Predicted population trajectories for the un-impacted (baseline) and impacted harbour seal cumulative iPCoD simulations for the NC&O SMA. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2029 to 2039 inclusive

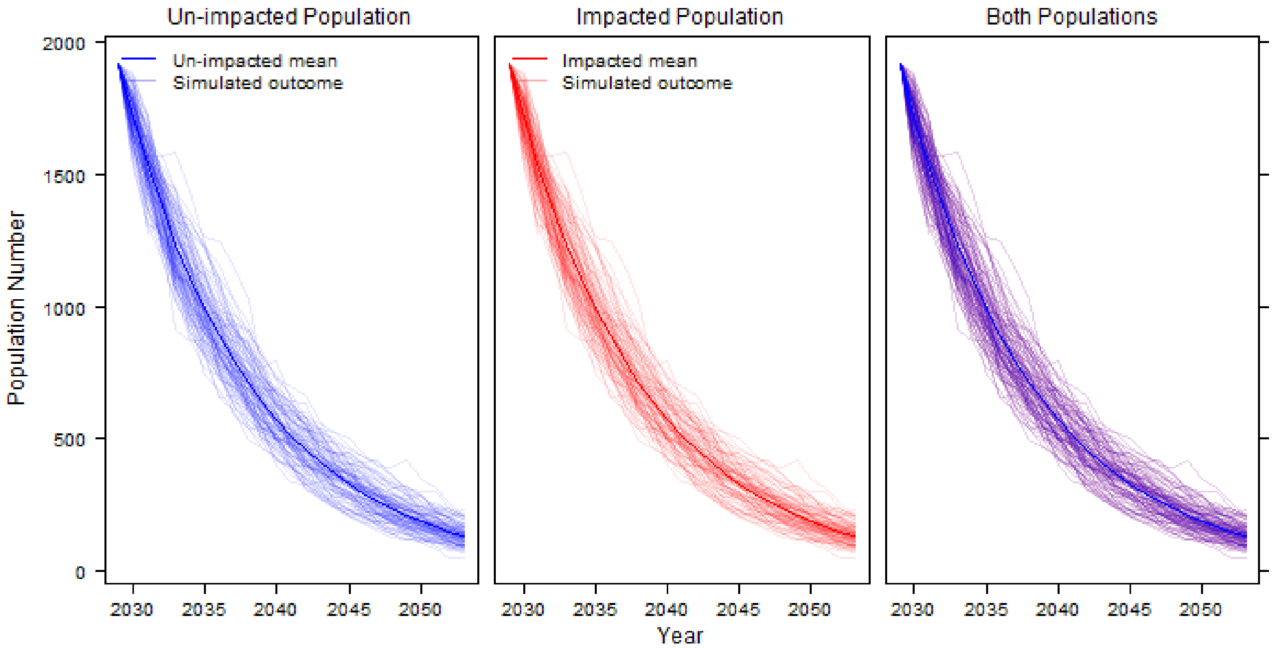


Table 5.12 Mean un-impacted and impacted population sizes for the ES SMA for harbour seals

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2029 (pre-piling)	1,916	1,916	100%
End 2029 (end cumulative piling year 1)	1,716	1,716	100%
End 2033 (end Project piling year 1)	1,110	1,110	100%
End 2039 (end Project piling and cumulative piling year 12))	573	573	100%
End 2040 (one year after cumulative piling ends)	513	513	100%
End 2045 (six years after cumulative piling ends)	295	295	100%
End 2051 (12 years after cumulative piling ends)	151	151	100%

5.7 Grey seals ES and NC&O SMA

5.7.1.1 For the cumulative scenario for grey seals in the ES and NC&O SMA, there were seven offshore wind farms that met the screening criteria that were modelled alongside the Project. The disturbance numbers for grey seals used in the modelling are presented in **Table 5.13**.

5.7.1.2 The cumulative iPCoD modelling shows that the mean impacted population size of grey seals in the ES and NC&O SMAs is predicted to remain at 100% of the size of the un-impacted population mean. The impacted population is predicted to continue on an increasing trajectory, the same as the un-impacted population (**Plate 5.13, Plate 5.14** and **Table 5.14**).

Table 5.13 Number of grey seals in the ES and NC&O SMAs disturbed per piling day per offshore wind farm development in the cumulative iPCoD simulation

Offshore wind farm	Piling start year	Piling end year	Number of animals disturbed per day	Source
Marram	2033	2039	183	EIA Report.
Ayre offshore substation	2030	2033	457	EDR
Ayre WTG	2030	2033	457	EDR
Bowdun	2029	2032	79	EDR
Buchan	2029	2033	457	EDR
Cenos WTG	2031	2033	127	EIA Report.
Cenos offshore substation	2031	2031	137	EIA Report.
Ossian WTG	2031	2037	131	EIA Report.
Ossian offshore substation	2031	2038	343	EIA Report.
Seagreen 1A	2029	2032	398	Piling Strategy.
Stromar WTG	2029	2032	457	EDR
Stromar offshore substation	2029	2031	457	EDR

Plate 5.13 Predicted population trajectories (mean and 95% CIs) for the un-impacted (baseline) and impacted grey seal cumulative iPCoD simulations for the ES and NC&O SMAs. Piling is occurring between 2028 to 2039 inclusive

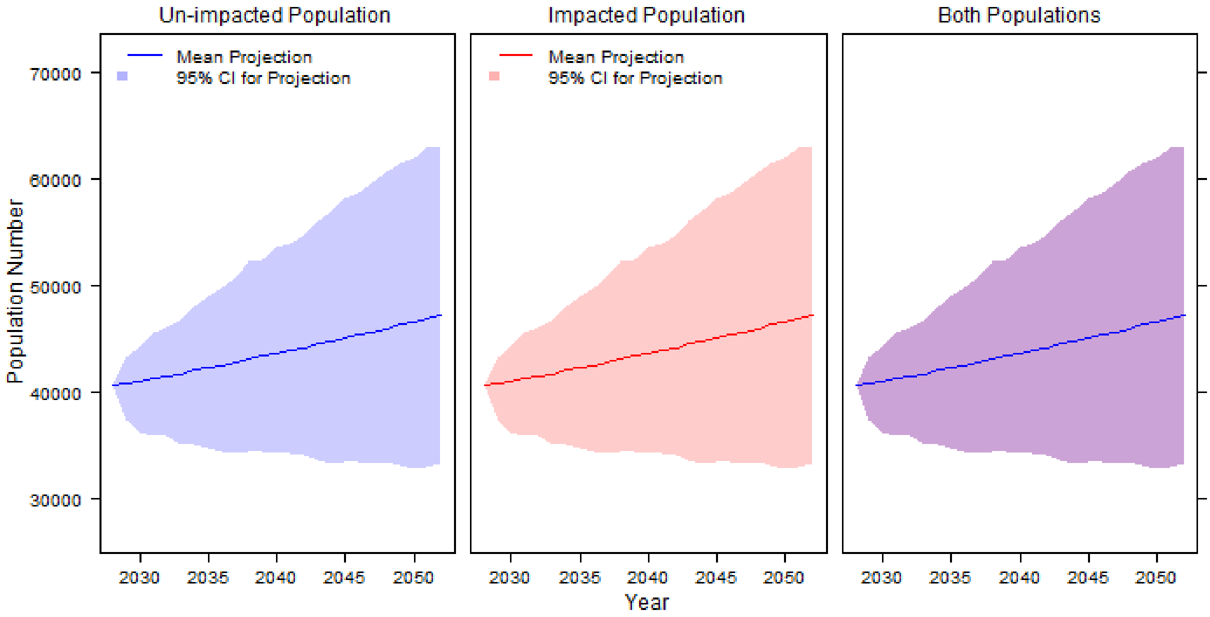


Plate 5.14 Predicted population trajectories for the un-impacted (baseline) and impacted grey seal cumulative iPCoD simulations for the ES and NC&O SMAs. Results show a subset of 100 simulations of the 1,000 run. Piling is occurring between 2028 to 2039 inclusive

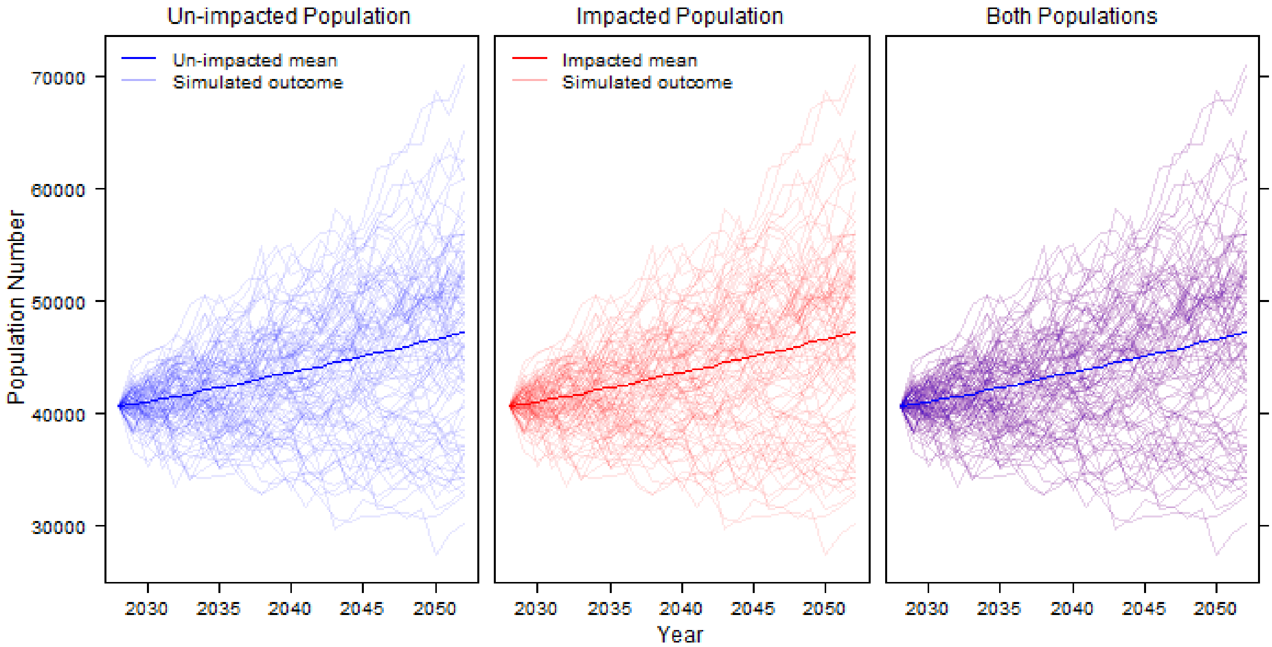


Table 5.14 Mean un-impacted and impacted population sizes for the ES and NC&O SMAs for grey seals

Year	Mean un-impacted population size	Mean impacted population size	Mean impacted population size as a proportion of the mean un-impacted population size
Start 2028 (pre-piling)	40,566	40,566	100%
End 2028 (end cumulative piling year 1)	40,733	40,733	100%
End 2033 (end Project piling year 1)	42,023	42,023	100%
End 2039 (end Project piling and cumulative piling year 12))	43,652	43,652	100%
End 2040 (one year after cumulative piling ends)	43,838	43,838	100%
End 2045 (six years after cumulative piling ends)	45,382	45,382	100%
End 2051 (12 years after cumulative piling ends)	47,211	47,211	100%

6. Conclusion

6.1.1.1 The Project alone iPCoD model results show:

- For harbour porpoise in the NS MU, the impacted population mean decreased to 98.25% of the size of the un-impacted population mean during piling and then remained at ~98.3% on a stable trajectory (similar to the un-impacted population) once the piling ceases.
- For harbour porpoise in the NS UK MU, the impacted populations decreased to 95.59% and of the size of the un-impacted population mean during piling and then remained at ~95.66% on a stable trajectory (similar to the un-impacted population) once the piling ceases.
- For bottlenose dolphins in the CES MU, the impacted population mean decreased to 90.48% of the size of the un-impacted population mean during piling and then remained at ~91.2% on an increasing trajectory (similar to the un-impacted population) once the piling ceases.
- For bottlenose dolphins in the GNS MU and GNS UK MU, minke whales in the CGNS MU and CGNS UK MU and harbour seals in the ES SMA, the impacted population is predicted to continue at the same size and on a stable trajectory, the same as the un-impacted population.
- For harbour seals in the NC&O SMA, the impacted population is predicted to continue at the same size and on a declining trajectory, the same as the un-impacted population.
- For grey seals, the impacted population is predicted to continue at the same size and on an increasing trajectory, the same as the un-impacted population.

6.1.1.2 The cumulative iPCoD model results show:

- For harbour porpoise in the NS MU, the impacted population mean decreased to 98.51% of the size of the un-impacted population mean during cumulative piling and then remained at ~98.5% on a stable trajectory (similar to the un-impacted population) once the cumulative piling ceases.
- For bottlenose dolphins in the CES MU, the impacted population mean decreased to 86.04% of the size of the un-impacted population mean during cumulative piling and then remained at ~86% on an increasing trajectory (similar to the un-impacted population) once the cumulative piling ceases.
- For bottlenose dolphins in the GNS MU, the impacted population mean decreased to 96.07% of the size of the un-impacted population mean during cumulative piling and then remained at ~95.9% on a stable trajectory (similar to the un-impacted population) once the cumulative piling ceases.
- For minke whales in the CGNS and harbour seals in the ES SMA, the impacted population mean is predicted to continue at the same size and on a stable trajectory, the same as the un-impacted population.
- For harbour seals in the NC&O SMA, the impacted population mean is predicted to continue at the same size and on a declining trajectory, the same as the un-impacted population.
- For grey seals in the ES and NC&O SMA, the impacted population mean is predicted to continue at the same size and on an increasing trajectory, the same as the un-impacted population.

6.1.1.3 Full interpretation of these results in terms of the magnitude of impact and resulting impact significance of effect is presented in **Volume 1, Chapter 11: Marine Mammals**.

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8. Glossary of Terms and Abbreviations

8.1 Abbreviations

Acronym	Definition
CES	Coastal East Scotland
CGNS	Celtic and Greater North Sea
CI	Confidence Interval
EDR	Effective Deterrent Range
EIA	Environmental Impact Assessment
ES	East Scotland
GNS	Greater North Sea
iPCoD	Interim Population Consequences of Disturbance
JNCC	Joint Nature Conservation Committee
km	kilometre
MU	Management Unit
NC&O	North Coast and Orkney
NS	North Sea
PTS	Permanent Threshold Shift
RCP	Reactive Compensation Platform
SMA	Seal Management Area
UK	United Kingdom
WTG	Wind Turbine Generator

8.2 Glossary of terms

Term	Definition
Joint Nature Conservation Committee	The public body that advises the UK Government and devolved administrations on UK-wide and international nature conservation.

MarramWind