Cenos Offshore Windfarm Limited

Cenos EIA

Appendix 18 – Interim Population Consequences of Disturbance (iPCoD) Modelling Report

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Cenos Offshore Windfarm EIA (Volume 4) Appendix 18 – iPCoD Technical Note

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1 Introduction

1 Cenos Offshore Windfarm (hereafter 'the Project') is a proposed floating offshore wind farm, located approximately 200km offshore from the north-east coast of Aberdeen, Scotland. The Project is proposed by Cenos Offshore Windfarm Ltd. ('the Applicant') and is a Joint Venture (JV) between Flotation Energy (FE) and Vårgrønn As (Vårgrønn).

2 This Technical Note to the Environmental Impact Assessment Report (EIAR) has been prepared by HiDef Aerial Surveying Ltd (HiDef) and provides results of interim Population Consequences of Disturbance (iPCoD) modelling (Harwood *et al.* 2014; King *et al.* 2015), which was undertaken to assess potential population-level impacts on marine mammals during the construction phase of windfarm the Project. Within this Technical Note, disturbance inputs to the model are entirely related to increased underwater noise due to piling activity.

3 iPCoD is used to simulate potential changes in a population over time, for disturbed and undisturbed populations, the results of which are compared to identify the magnitude of potential impacts. This approach allows investigation of different development scenarios, as well as incorporation of demographic stochasticity (i.e. variability in population growth rates), and natural environmental variation (Harwood *et al.* 2014; King *et al.* 2015).

4 The iPCoD approach combines information on population size, growth rate, age of reproduction, fertility rates, etc., as well as estimates of animals' responses to disturbance identified from expert elicitation (Booth, Heinis, and Harwood 2019) to assess how future populations of relevant marine mammal species may with and without disturbance. Expert elicitation is a widely accepted process in conservation science by which 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). In the case of iPCoD, experts were consulted to estimate values for two parameters that define the shape of the relationships between the number of disturbance days an individual experiences and its vital rates. These parameter estimates are used in functions that are integral to the iPCoD model (Harwood *et al.* 2014).

5 iPCoD modelling has been performed to assess potential impact of behavioural disturbance for harbour porpoise (*Phocoena phocoena*), minke whale (*Balaenoptera acutorostrata*), and grey seal (*Halichoerus grypus*). The species considered within modelling is based on information from site-specific Digital Aerial Surveys (DAS) and information for the wider region as described in EIAR Vol. 2, Chapter 10: Marine Mammal Ecology and EIAR Vol. 4, Appendix 3 Marine Mammal Baseline.

6 The reference populations (expressed as the abundance of marine mammals) used with iPCoD modelling are taken from species-specific Management Units (MUs) for cetaceans as defined by the Inter-Agency Marine Mammal Working Group (IAMMWG) (IAMMWG, 2022) and Seal Management Units (SMUs) as determined by the Special Committee on Seals (SCOS) for grey seal (SCOS, 2022). The relevant MU/SMU per species was determined based on the location of the Project within these pre-determined boundaries and are presented in Table 1. Data on the abundance of each species in each reference population are used as the population size inputted to iPCoD with the density of animals presented per species used to calculate the numbers of animals potentially disturbed from piling activity, as presented in EIAR Vol. 2, Chapter 10: Marine Mammal Ecology.

7 Due to the proposed use of standard mitigation methods (e.g. visual Marine Mammal Observers (MMOs), Acoustic Deterrent Devices (ADDs) etc., as detailed within the Marine Mammal Mitigation Plan (MMMP)),

the risk of Permanent Threshold Shift (PTS) to hearing is considered to be negligible and was therefore not included in iPCoD modelling. As such, only disturbance to marine mammals from underwater noise during construction is considered within this report. The removal of PTS from iPCoD modelling was agreed with NatureScot through written consultation received via email on 4th November 2024.

8 Modelling has been performed for the Project alone and cumulatively with other relevant offshore windfarm developments to assess underwater noise impacts per species.

9 The offshore part of the Project with relevance to iPCoD modelling will consist of:

- Up to 95 Floating Turbine Units (FTUs) with floating substructure, likely to be Tension Leg Platform (TLP), or semi-submersible (semi-sub) design; and
- Up to two Offshore Substation Converter Platforms (OSCP) on fixed steel jacket structures with up to 12 pin piles (three per leg).

10 Numbers of animals susceptible to behavioural disturbance from piling for each type of foundation (OSCP, semi-sub, TLP) are presented in Table 3 and EIAR Vol. 2, Chapter 10: Marine Mammal Ecology. The number of animals disturbed by the Project during the construction phase due to underwater noise during piling is derived through site-specific underwater noise modelling (EIAR Vol. 3, Appendix 15: Underwater Noise Modelling Report) and the application of dose-response curves to derived underwater noise predictions (EIAR Vol. 2, Chapter 10: Marine Mammal Ecology and EIAR Vol. 3, Appendix 15: Underwater Noise Modelling Report).

11 The use of iPCoD to assess the potential impact of underwater noise associated with piling during construction was discussed and agreed with NatureScot during the Marine Mammal Consultation Meeting on 2nd October 2024. Clearance of Unexploded Ordinance (UXO) was discussed and agreed with NatureScot as part of the same consultation, where it was agreed UXO would not be included in iPCoD modelling due to the following:

- The risk of any UXO requiring clearance for the Project is very low;
- Base case of low-order deflagration means that PTS will be mitigated (<300m PTS radius); and
- There is no evidence that a single impulse elicits a behavioural disturbance effect, beyond a startle response, and baseline conditions resume immediately following the impulse.

12 This Appendix supports EIAR Vol. 2, Chapter 10: Marine Mammal Ecology and the Report to Inform Appropriate Assessment (RIAA).

Table 1 Species-specific management units for cetacean species (IAMMWG, 2022) and Seal Monitoring Units (SCOS, 2022) assessed using iPCoD. Cetacean population estimates derived from Hammond *et al.* (2021) and Rogan *et al.* (2018). CV = Coefficient of Variation

Species	MU	Entire MU		UK portion of MU		Density (animals/km^2)
		Abundance (CV)	95% Confidence Interval (CI)	Abundance (CV)	95% Confidence Interval (CI)	
Harbour porpoise	North Sea	346,601 (0.09)	289,498 – 419,967	159,632 (0.12)	127,442 – 199,954	1.0398
Minke whale	Celtic and Greater North Seas	20,118 (0.18)	14,061 – 28,786	10,288 (0.26)	6,210 – 17,042	0.0419
Grey seal*	East Scotland	2,707	N/A	N/A	N/A	0.012
	Moray Firth	1,082				

** 2021 August count (SCOS, 2022) NOTE: this count has not been scaled for the proportion of seals in water, so is extremely precautionary, as the population used for assessment is smaller than the true population of grey seals.*

2 Methods

2.1 Overview

13 The iPCoD framework (Harwood *et al.* 2014; King *et al.* 2015) has been used to assess whether the predicted levels of disturbance from underwater noise anticipated from piling for the Project during the construction phase would result in population-level impacts to marine mammal species. A conservative approach was used, in which the worst-case scenario was selected at each opportunity, likely resulting in considerable over-estimation of potential impacts.

14 The iPCoD framework has been developed for five marine mammal species: harbour porpoise, minke whale, bottlenose dolphin (*Tursiops truncatus*), grey seal, and harbour seal (*Phoca vitulina*) (Sinclair *et al.* 2019). Following information derived through site-specific DAS and information presented for the wider region (as described in EIAR Vol. 4, Appendix 16 Marine Mammal Baseline Report), iPCoD modelling for the Project was only carried out for harbour porpoise, minke whale, and grey seal, as consulted and agreed with NatureScot during the Marine Mammal Consultation Meeting on 2nd October 2024. iPCoD version 5.2 was used for all analysis. Neither harbour seal or grey seal were included in iPCoD modelling because the predicted impacts to those species from impact piling were negligible, due to the offshore (>200 km) location of the Cenos Array Area where piling will take place, and the generally coastal distribution of those species in the North Sea.

2.2 Input parameters – project-alone

2.2.1 Demographic parameters

15 Demographic parameters for the species assessed in iPCoD modelling are presented in Table 2. The standard input parameters for high adult survival was used for harbour porpoise. The proportion of animals that are female was set at 0.5 for all species. Demographic parameters used within iPCoD are presented in Table 2.

16 iPCoD was run with multiple values of disturbance to see how alteration of this parameter may affect estimated impacted population size (Table 5; Table 8). Expert elicitation for harbour porpoise has estimated that behaviour could be altered up to six hours after disturbance (Booth, Heinis, and Harwood 2019) and so durations of disturbance of six hours, 12 hours, one day and two days were used. For six hours, 12 hours and one day, this is the only day of disturbance while for two days there is one day of original disturbance plus one additional day of residual disturbance. For minke whale and grey seal, two days of disturbance was assumed (one day of original disturbance and one day of residual disturbance).

Table 2 Demographic parameters recommended for each species for the relevant Management Unit (MU) or Seal Management Unit (SMU) (Sinclair, Sparling, and Harwood 2020)

Species	Calf/pup survival	Juvenile survival	Adult survival	Fertility	Age calf/pup becomes independent	Age of first birth
Harbour porpoise	0.600	0.850	0.925	0.479	1	5
Minke whale	0.720	0.770	0.960	0.900	1	9
Grey seal	0.222	0.940	0.940	0.840	1	5

2.2.2 Piling parameters

17 The piling schedule used in iPCoD for the Project spanned between 2031 and 2033 and assumed four days of piling for each of the two OSCPs (eight days total) in March 2031, and subsequent piling for FTUs occurring for 23 days each month starting 1st April 2031.

18 The piling window was assumed to occur between 1st April and 30th September in each year with 75% of this time expected to be viable for piling. OSCP and FTU piling were included as separate piling operations as each are predicted to disturb different numbers of animals and require different numbers of piles. For each piling year (2031 - 2033) one third of piles were assumed to be installed. Separate models were run for semi-sub and TLP scenarios.

19 For the semi-sub scenario, a total of 285 days of piling were assumed (95 days of piling each year), and for TLP, 95 days of piling were assumed (32 days each year). Taking into account the 23 days/month piling duty cycle, semi-sub piling occurred between 1st April until 5th August each year, and TLP from 1st April until 12th May each year.

20 For all species, three years of piling were assumed, 100% of animals were assumed to be disturbed, and two piling operations were included (e.g. one for OSCP and one for either semi-sub or TLP).

2.2.3 Impact parameters

21 The model was run using the worst-case numbers of animals at risk of disturbance generated (as presented in EIAR Vol. 3, Appendix 15: Underwater Noise Modelling Report and EIAR Vol. 2, Chapter 10: Marine Mammal Ecology.

Table 3 Number of animals experiencing behavioural disturbance per day of piling under each scenario, as inputted into project alone iPCoD modelling

Species	Behavioural disturbance		
	OSCP	Semi-sub	TLP
Harbour porpoise	9528.9	8862.5	7365.3
Minke whale	384.0	357.1	296.8
Grey seal	136.3	126.3	104.0

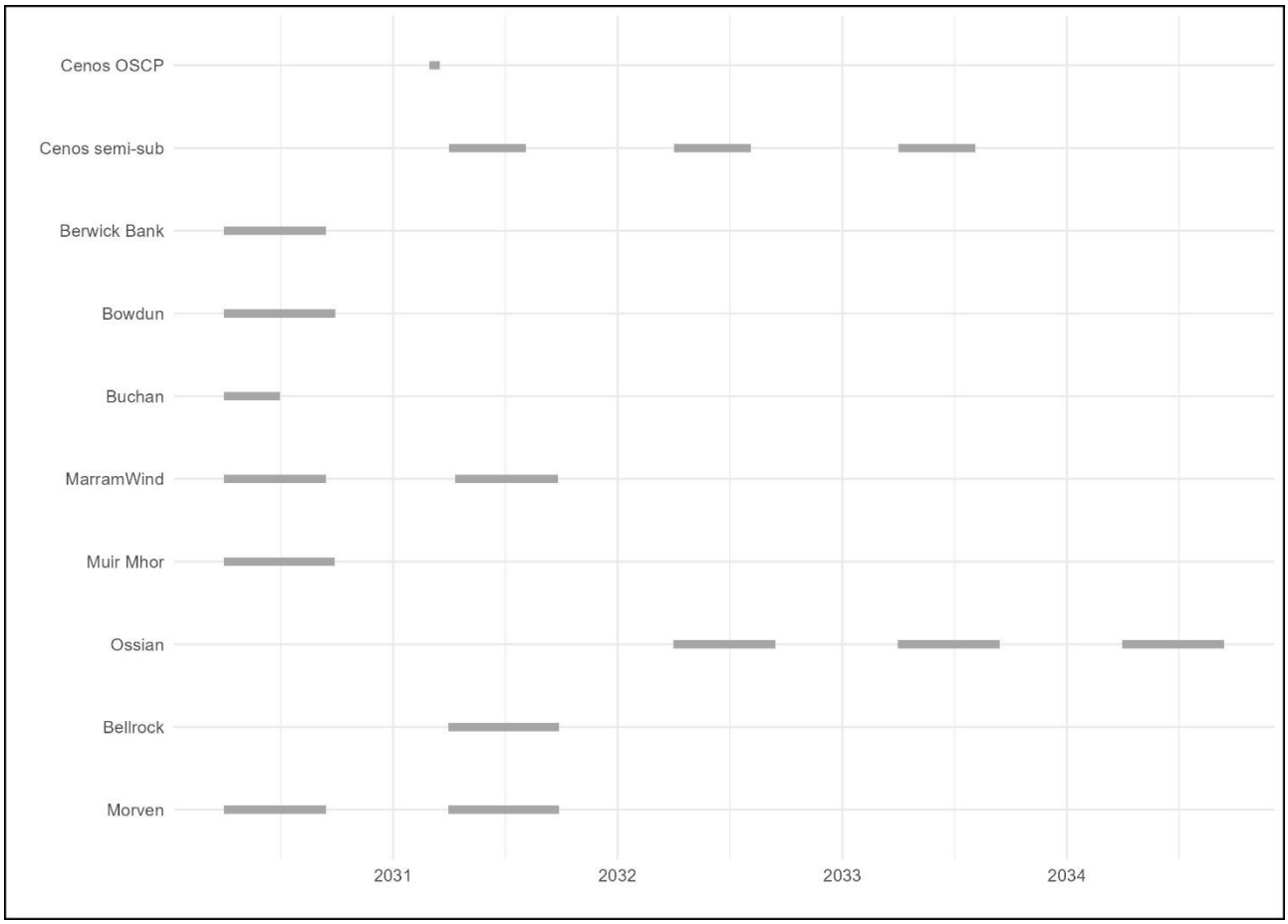
2.3 Input parameters – cumulative

22 For cumulative modelling, the worst-case scenario from the Project alone assessment was used. That is, results from semi-sub piling rather than TLP piling were used within models when imputing predicted impacts from the Project. To these values, predicted impacts from OSCP piling was added. For all species, one day of residual disturbance was used, to allow comparability with other offshore wind assessments. This provides precautionary results that demonstrate worst-case predicted impacts from windfarm construction and the approach was discussed and agreed with NatureScot at the Marine Mammal Consultation Meeting on 2nd October 2024.

23 Other windfarms were selected for inclusion in cumulative modelling based on distance from the Project, and anticipated piling year. Offshore windfarm projects within 200 km (two x the maximum Temporary Threshold Shift (TTS) range (100km for low frequency cetaceans, as derived from underwater noise modelling); EIAR Vol. 3, Appendix 15: Underwater Noise Modelling Report and EIAR Vol. 2, Chapter 10: Marine Mammal Ecology) were assessed. Of those, only windfarms with piling anticipated to occur within ± one year of piling at the Project were taken forward for modelling (e.g. piling in 2030 - 2034). The windfarms selected for inclusion, and associated piling windows are shown in Figure 1.

24 Species-specific input parameters were as per project alone scenarios except for piling parameters and impact days, which are presented in Table 4.

Figure 1 Piling timelines for the Project (OSCP and semi-sub (top)) and other offshore windfarms included in cumulative iPCoD models



2.3.1 Piling parameters

25 Unless details were available which indicated otherwise, the piling window was assumed to be the same as for Project-alone modelling (1st April to 30th September each year) due to the likelihood of suitable weather conditions and this constituting the worst-case scenario for cumulative noise. Furthermore, piling was assumed to be performed on 23 days per month using the piling parameters for the project-alone scenario.

26 The maximum number of piles at each development was identified, as well as the type of foundation (i.e. monopile, pin or jacket). It was assumed that monopiles could be installed in one day of piling, and due to their increased number of piles, pin or jacket types would take two days to install all piles for one turbine.

27 For all species, the number of piling years was set to five, all individuals were considered susceptible to disturbance (i.e. no vulnerable sub-populations) and ten piling operations were included within the models. These collectively constitute a worst-case characterisation of piling activity and disturbance impact for the cumulative piling scenario.

2.3.2 Impact parameters

28 Where numbers of animals experiencing disturbance were publicly available (i.e. from environmental information supporting individual development consent applications), these were used. These were only available for Berwick Bank (SSE Renewables, 2022). In all other instances where this information was not available, Effective Deterrence Ranges (EDRs), as presented in JNCC (2020), were used to calculate number of animals disturbed: a radius of 26km for monopiles; and a radius of 15km for jacket (pin) and anchor piles. The area of disturbance was multiplied by the species-specific density as presented in individual EIARs (or from Project location with respect to the relevant SCANS IV survey block) to calculate the number of animals disturbed (Table 4). The values used in modelling are shown in Table 4.

Table 4 **Details of piling used for assessment in cumulative modelling. NA indicates project-specific values available for number animals deterred per day, otherwise, EDR was used to calculate number deterred**

Project	Type of turbine	Type of piling for EDR	Area of disturbance	Animal density			Number animals disturbed per day			Max no turbines	Number of days piling per turbine	Total number of piling days
				HP	MW	GS	HP	MW	GS			
Berwick Bank Windfarm	Fixed	Jacket	NA	NA	NA	NA	2815	132	1940	307	2	614
Bowdun Offshore Windfarm	Both	Monopile	2123.72	1.0398	0.0419	0.012	2208.3	89	25.5	67	1	67
Buchan Offshore Windfarm	Floating	Pin pile	706.86	1.0398	0.0419	0.012	735	29.7	8.5	70	2	140
MarramWind Floating Offshore Windfarm	Both	Monopile	2123.72	1.0398	0.0419	0.012	2208.3	89	25.5	225	1	225
Muir Mhòr Offshore Windfarm	Floating	Pin pile	706.86	1.0398	0.0419	0.012	735	29.7	8.5	67	2	134
Ossian Offshore Windfarm	Floating	Pin pile	706.86	0.651	0.028	0.18	460.2	19.8	127.3	270	2	540
Bellrock Offshore Windfarm	Both	Monopile	2123.72	1.0398	0.0419	0.012	2208.3	89	25.5	80	1	80
Morven Offshore Windfarm	Fixed	Monopile	2123.72	1.0398	0.0419	0.012	2208.3	89	25.5	191	1	191

3 Results

29 Results of the iPCoD modelling for harbour porpoise, minke whale and grey seal are presented in this section. The results shown in Table 5 to Table 13 display the unimpacted and impacted population means, the impacted population as a percentage of the unimpacted population and the median of the ratio of impacted to unimpacted population size (also referred to as the 'median counterfactual of population size' (Sinclair *et al.* 2019)). This ratio shows the predicted difference between the mean population size of an unimpacted population versus an impacted population. Therefore, a ratio of one indicates that there is no difference between the trajectories of impacted versus unimpacted populations. Table 5 to Table 13 show the results after one year, six years, 12 years and 25 years to demonstrate how the population size is predicted to change.

30 The results for the Project-alone scenarios show that harbour porpoise, minke whale and grey seal populations are predicted to be broadly similar between unimpacted and impacted scenarios after 25 years. Results for harbour porpoise using semi-sub piling suggest an initial decrease in population size due to piling activity. The models using TLP piling produced results that do not differ markedly between unimpacted and impacted scenarios for all species. With respect to the cumulative scenarios, impacts to population size were greater for harbour porpoise than for other assessed species.

3.1 Project-alone scenarios

3.1.1 Semi-sub piling

3.1.1.1 Harbour porpoise

31 For harbour porpoise, the number of days of residual disturbance was varied to assess how this influenced results (see Section 2.2.1). Results of each iPCoD model using varying levels of residual disturbance are presented in Figure 2 to Figure 5. A summary of all outputs can be seen in Table 5.

32 There is very little difference between models using a quarter day and a half day of disturbance; however, as would be expected, a longer period of disturbance results in greater impacts to the population. Two days of disturbance (i.e. one day of original disturbance plus one day of residual disturbance) resulted in a median counterfactual of population size of 0.978 (i.e. the impacted population is 97.8% of the size of the unimpacted population or experiences a 2.2% decrease in population size) over the 25-year modelled scenario. For comparability to other studies, one complete day of residual disturbance (i.e. two days total disturbance) was the only scenario taken forward for cumulative modelling, as agreed with NatureScot during the Marine Mammal Consultation Meeting on 2nd October 2024. This is also more conservative than the six hours of residual disturbance identified through the expert elicitation process (Booth, Heinis, and Harwood 2019). The median counterfactual of population size for one day of residual disturbance was 0.997 after one year, reducing to 0.988 after six years. It increased slightly to 0.989 after 12 years, which is likely due to the stochasticity of the model. The final ratio of impacted to unimpacted population size was 0.988 after 25 years, where the impacted population was 98.62% of the unimpacted population size, indicating roughly a 1.4% decline.

Figure 2 **Population trajectory for impacted and unimpacted harbour porpoise populations based on a Project-alone scenario with semi-sub piling and quarter of a day (six hours) of disturbance**

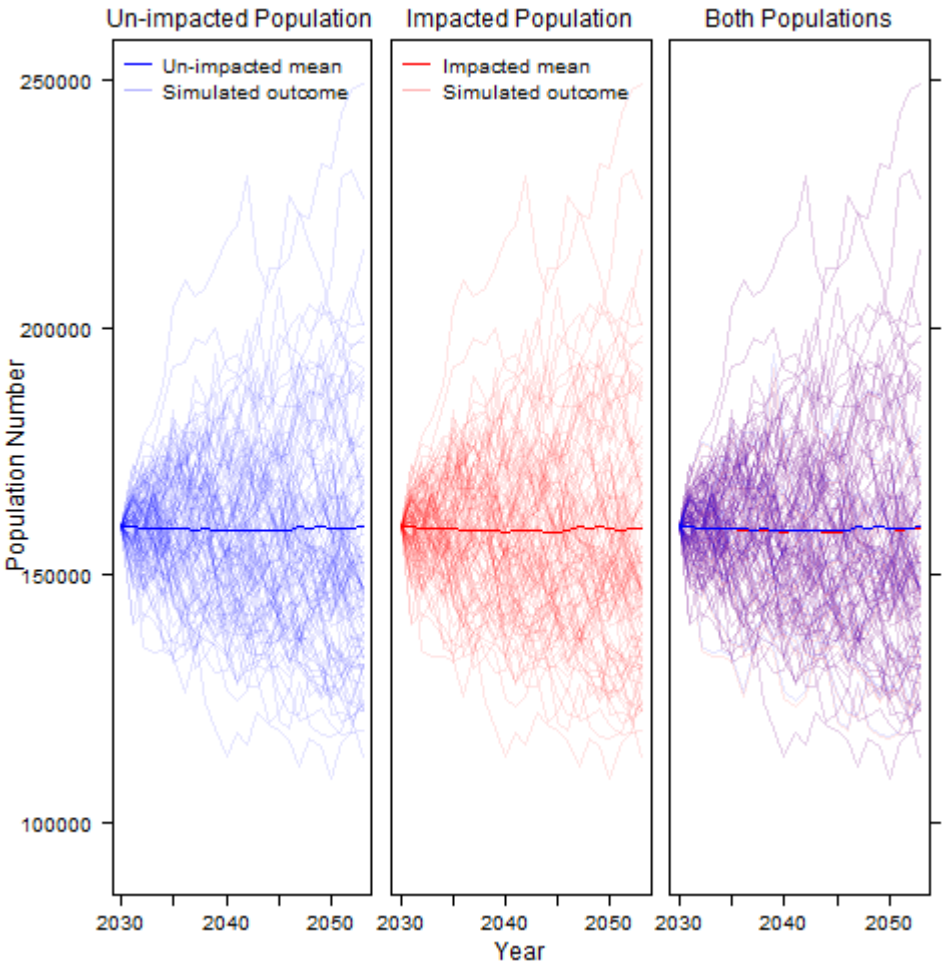


Figure 3 **Population trajectory for impacted and unimpacted harbour porpoise populations based on a Project-alone scenario with semi-sub piling and a half day (12 hours) of disturbance**

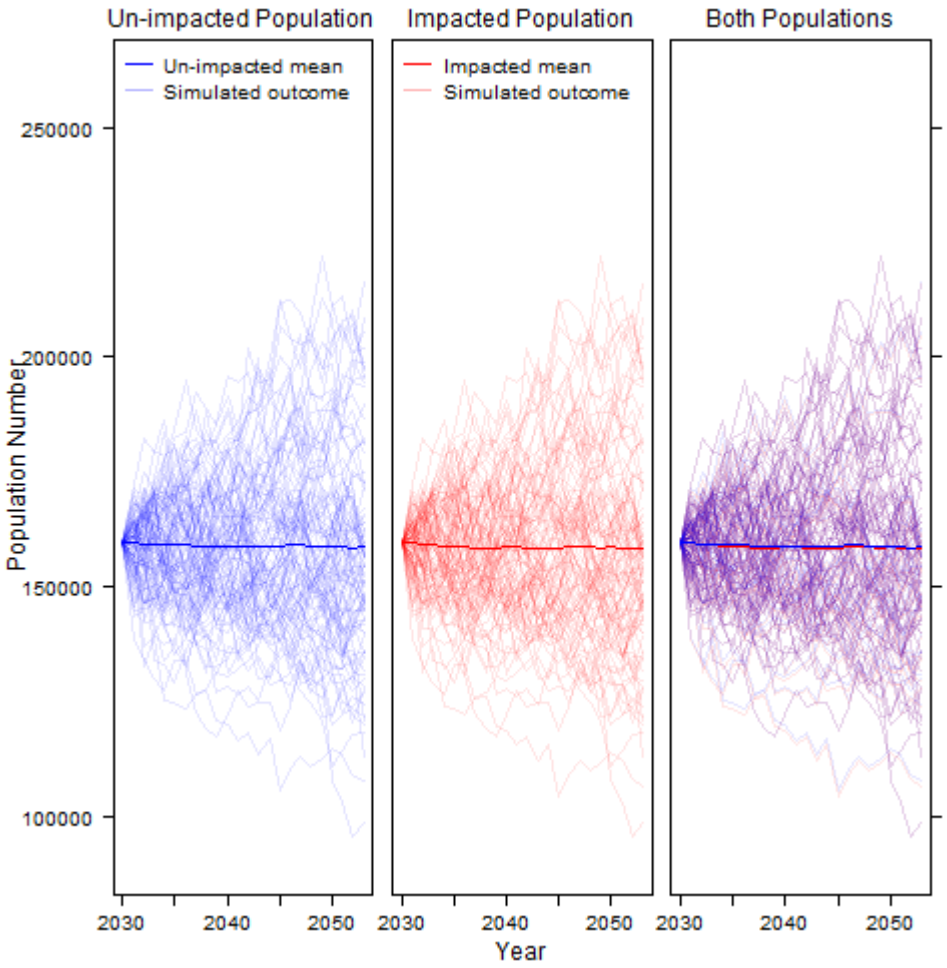


Figure 4 **Population trajectory for impacted and unimpacted harbour porpoise populations based on a Project-alone scenario with semi-sub piling and one day of disturbance**

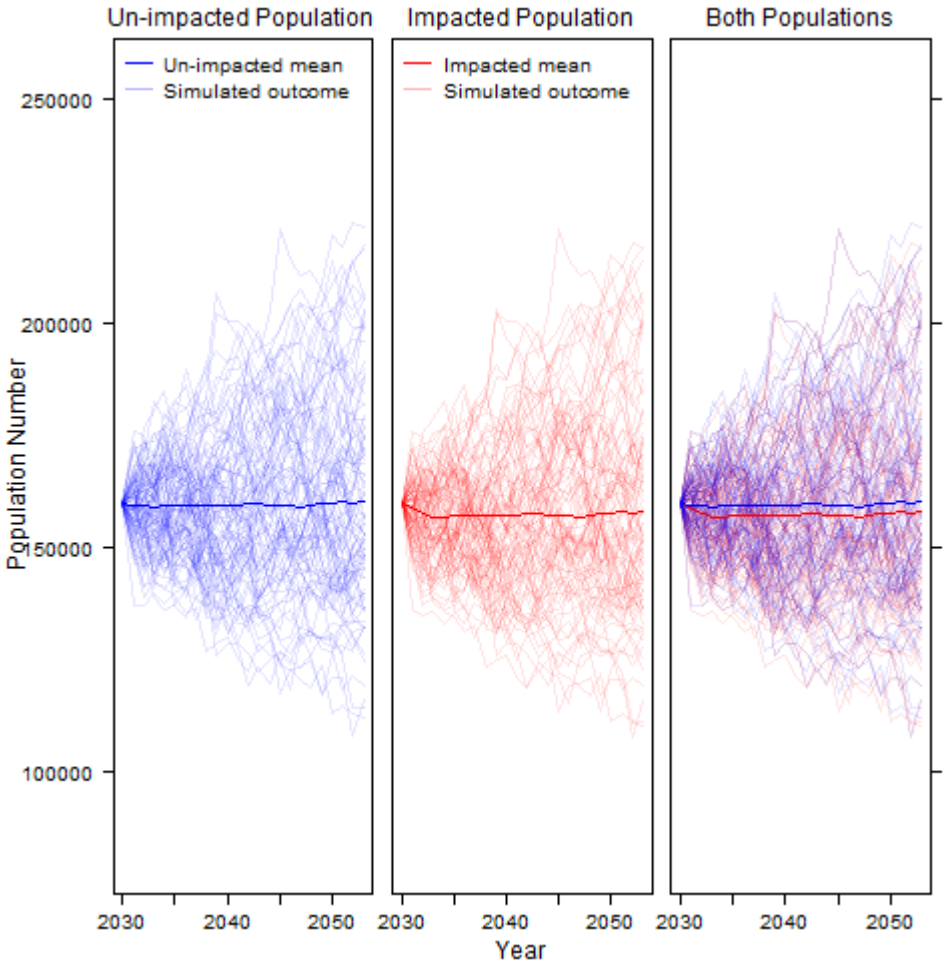


Figure 5 **Population trajectory for impacted and unimpacted harbour porpoise populations based on a Project-alone scenario with semi-sub piling and two days of disturbance (i.e. one day of residual disturbance)**

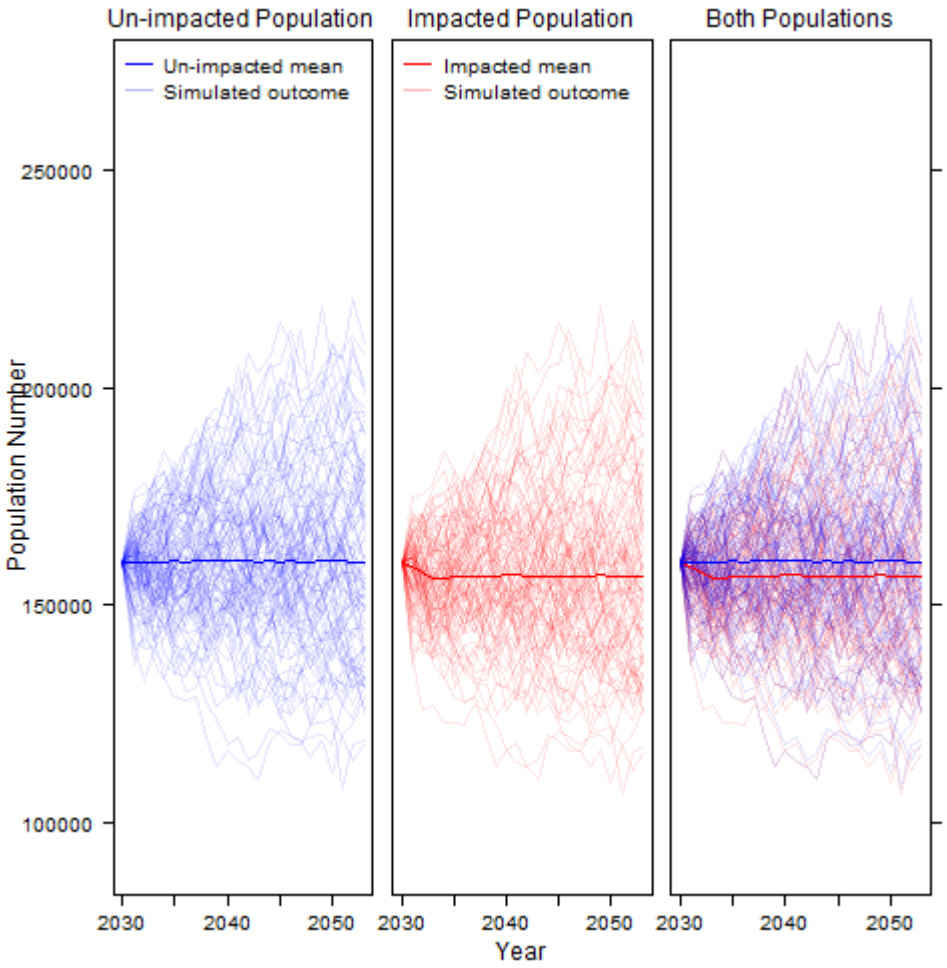


Table 5 Harbour porpoise iPCoD modelling results for the Project-alone scenario with semi-sub piling and ¼ day, ½ day, one day and two days of disturbance

Output variable	¼ day	½ day	one day	two days
Unimpacted population mean (after 1 year)	159,701	159,606	159,331	159,833
Impacted population mean (after 1 year)	159,662	159,536	158,788	158,988
Impacted population as % of un-impacted population (after 1 year)	99.98%	99.96%	99.66%	99.47%
Ratio of median impacted: un-impacted population size (after 1 year)	0.999	0.999	0.997	0.994
Unimpacted population mean (after 6 years)	159,269	159,127	159,386	159,989
Impacted population mean (after 6 years)	159,131	158,840	157,281	156,692
Impacted population as % of un-impacted population (after 6 years)	99.91%	99.82%	98.68%	97.94%
Ratio of median impacted: un-impacted population size (after 6 years)	0.999	0.997	0.988	0.980
Unimpacted population mean (after 12 years)	158,952	158,516	159,727	160,023
Impacted population mean (after 12 years)	158,809	158,218	157,527	156,568
Impacted population as % of un-impacted population (after 12 years)	99.91%	99.81%	98.62%	97.84%
Ratio of median impacted: un-impacted population size (after 12 years)	1.000	0.998	0.989	0.974
Unimpacted population mean (after 25 years)	159,471	158,984	160,327	159,757
Impacted population mean (after 25 years)	159,330	158,684	158,115	156,312
Impacted population as % of un-impacted population (after 25 years)	99.91%	99.81%	98.62%	97.84%
Ratio of median impacted: un-impacted population size (after 25 years)	0.997	0.997	0.988	0.978

3.1.1.2 Minke whale

33 The results for minke whale for the Project-alone scenario show that the population retains a stable trajectory, as presented in Figure 6, where the impacted and unimpacted populations remain very similar for the 25-year modelling duration. Furthermore, in Table 6, the impacted population is 99.99% of the unimpacted population after 25 years of simulation and the median counterfactual of population size remains 1 throughout the simulation, which indicates that there is no difference between the trajectories of disturbed versus undisturbed populations. This implies that the minke whale population is not likely to change substantially as a result of piling and construction activities for the Project when semi-sub piling is used.

Figure 6 Population trajectory for impacted and unimpacted minke whale populations for the Project-alone scenario with semi-sub piling

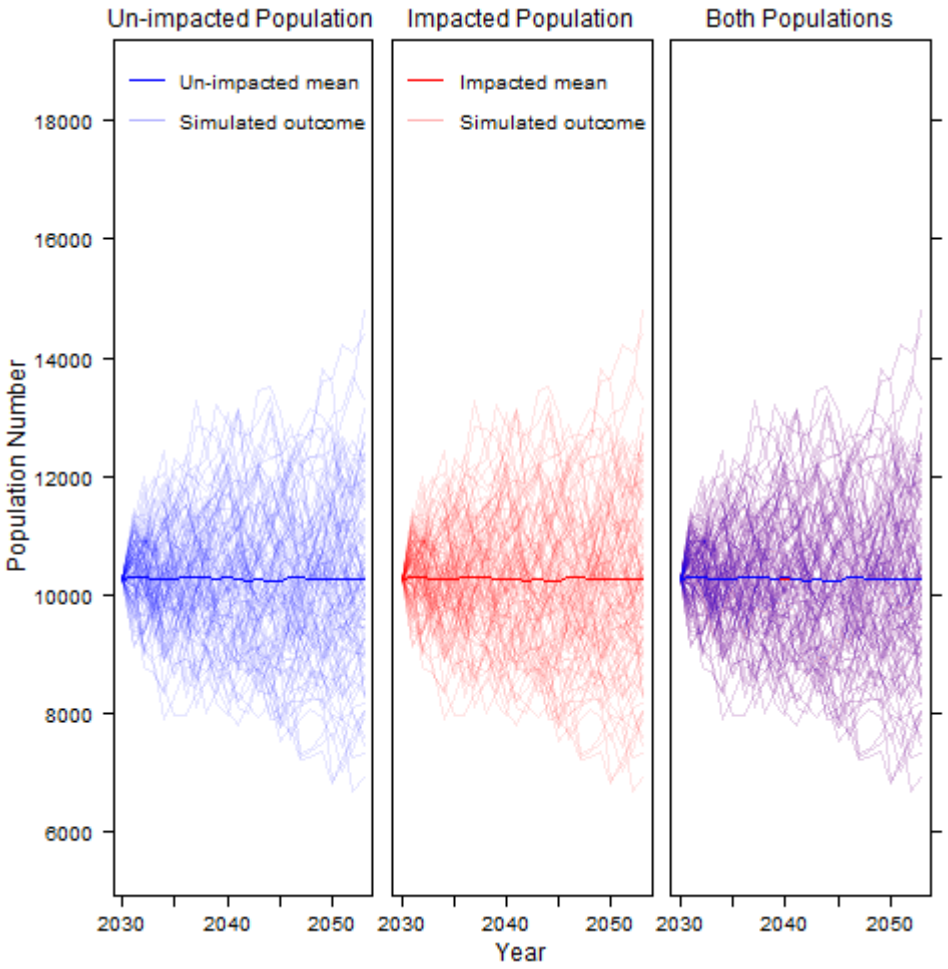


Table 6 Minke whale iPCoD modelling results for the Project-alone scenario with semi-sub piling

Output variable	Value
Unimpacted population mean (after 1 year)	10,309
Impacted population mean (after 1 year)	10,308
Impacted population as % of un-impacted population (after 1 year)	99.99%
Ratio of median impacted: un-impacted population size (after 1 year)	1.000
Unimpacted population mean (after 6 years)	10,289
Impacted population mean (after 6 years)	10,287
Impacted population as % of un-impacted population (after 6 years)	99.98%
Ratio of median impacted: un-impacted population size (after 6 years)	1.000
Unimpacted population mean (after 12 years)	10,249
Impacted population mean (after 12 years)	10,248
Impacted population as % of un-impacted population (after 12 years)	99.99%
Ratio of median impacted: un-impacted population size (after 12 years)	1.000
Unimpacted population mean (after 25 years)	10,255
Impacted population mean (after 25 years)	10,254
Impacted population as % of un-impacted population (after 25 years)	99.99%
Ratio of median impacted: un-impacted population size (after 25 years)	1.000

3.1.1.3 Grey seal

34 The iPCoD results for grey seal for the Project-alone scenario show that both the unimpacted and the impacted populations increase from around 2,700 to just under 3,500 after 25 years (Figure 7). Table 7 shows that the impacted population is 100% of the unimpacted population after the piling period, and the median counterfactual of population size is one after 25 years. This indicates that there is no difference between the trajectories of disturbed versus undisturbed populations. This implies that the grey seal population is not likely to change as a result of piling and construction activities for the Project when semi-sub piling is used.

Figure 7 Population trajectory for impacted and unimpacted grey seal populations for the Project-alone scenario with semi-sub piling

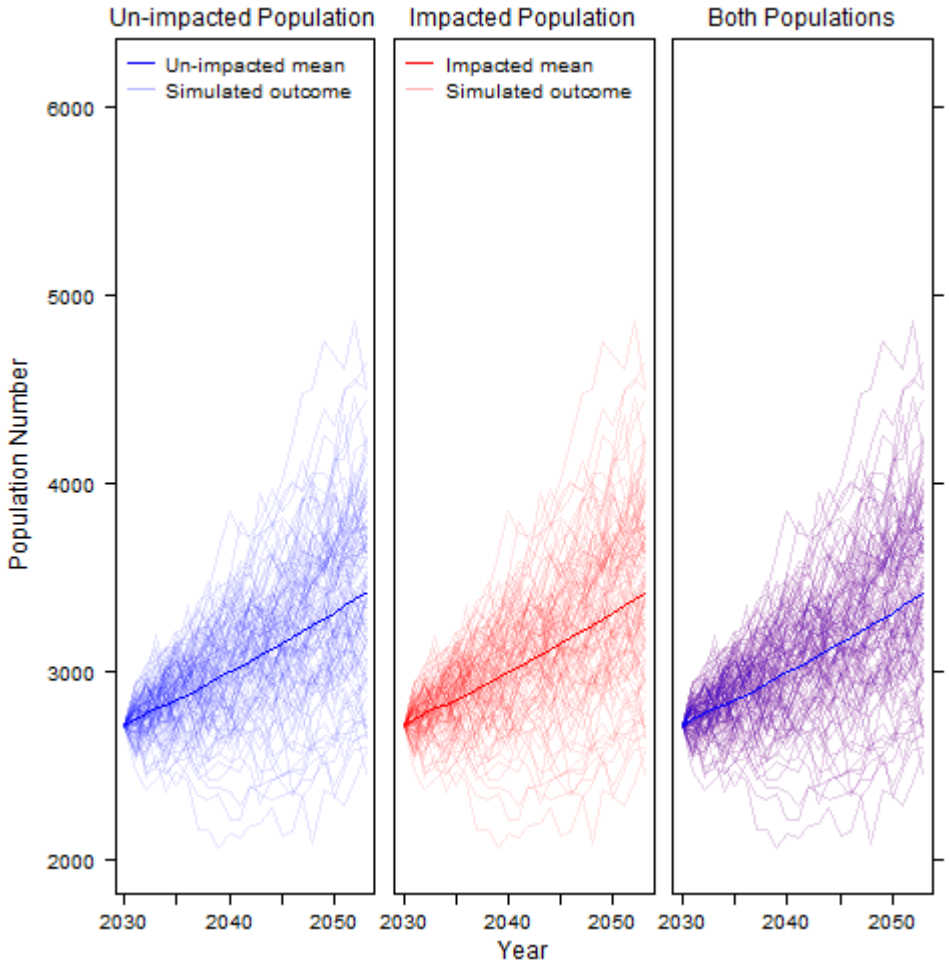


Table 7 Grey seal iPCoD modelling results for the Project-alone scenario with semi-sub piling

Output variable	Value
Unimpacted population mean (after 1 year)	2,742
Impacted population mean (after 1 year)	2,742
Impacted population as % of un-impacted population (after 1 year)	100.00%
Ratio of median impacted: un-impacted population size (after 1 year)	1.000
Unimpacted population mean (after 6 years)	2,875
Impacted population mean (after 6 years)	2,875
Impacted population as % of un-impacted population (after 6 years)	100.00%
Ratio of median impacted: un-impacted population size (after 6 years)	1.000
Unimpacted population mean (after 12 years)	3,054
Impacted population mean (after 12 years)	3,054
Impacted population as % of un-impacted population (after 12 years)	100.00%
Ratio of median impacted: un-impacted population size (after 12 years)	1.000
Unimpacted population mean (after 25 years)	3,484
Impacted population mean (after 25 years)	3,484
Impacted population as % of un-impacted population (after 25 years)	100.00%
Ratio of median impacted: un-impacted population size (after 25 years)	1.000

3.1.2 TLP piling

3.1.2.1 Harbour porpoise

35 As with semi-sub piling, different numbers of days of disturbance were used in a Project-alone scenario to identify whether changing this parameter would cause any variation in population-level results for harbour porpoise when using the schedule described for TLP piling (Table 3). The results are shown in Figure 8 to Figure 11 for each level of residual disturbance and summarised in Table 8. As a result of the reduced number of days of piling, and also the smaller number of animals disturbed each day, these modelled scenarios show reduced impacts when compared to semi-sub (Section 3.1.1). There is no difference in estimated population size for a quarter and half day of disturbance, and a 0.004% reduction with two days of disturbance.

36 The ratio of median impacted to unimpacted population size shows a slight decline of 0.998 and 0.996 with one and two days of disturbance (i.e. zero and one day of residual disturbance, respectively), after 25 years of simulation. In addition, even though the population size decreases consistently throughout the simulation, the ratio of median impacted to unimpacted population size decreases and then increases again for one and two days of disturbance. For one day of disturbance, it decreases from 0.998 to 0.995 and increases back to 0.998 after 25 years. For two days of disturbance (one day residual disturbance), the ratio decreases

from 0.997 to 0.993 and increases back to 0.996 after 25 years. This slight fluctuation may be due to the stochasticity of the models. For a quarter and a half day of disturbance, the median counterfactual of population size remains one or 0.999. This being slightly lower than one may also be due to the stochasticity of the model, as it is expected that there is no difference between population sizes for a quarter of a day and half of a day of disturbance.

Figure 8 Population trajectory for impacted and unimpacted harbour porpoise populations for the Project-alone scenario with TLP piling and a quarter day (six hours) of disturbance

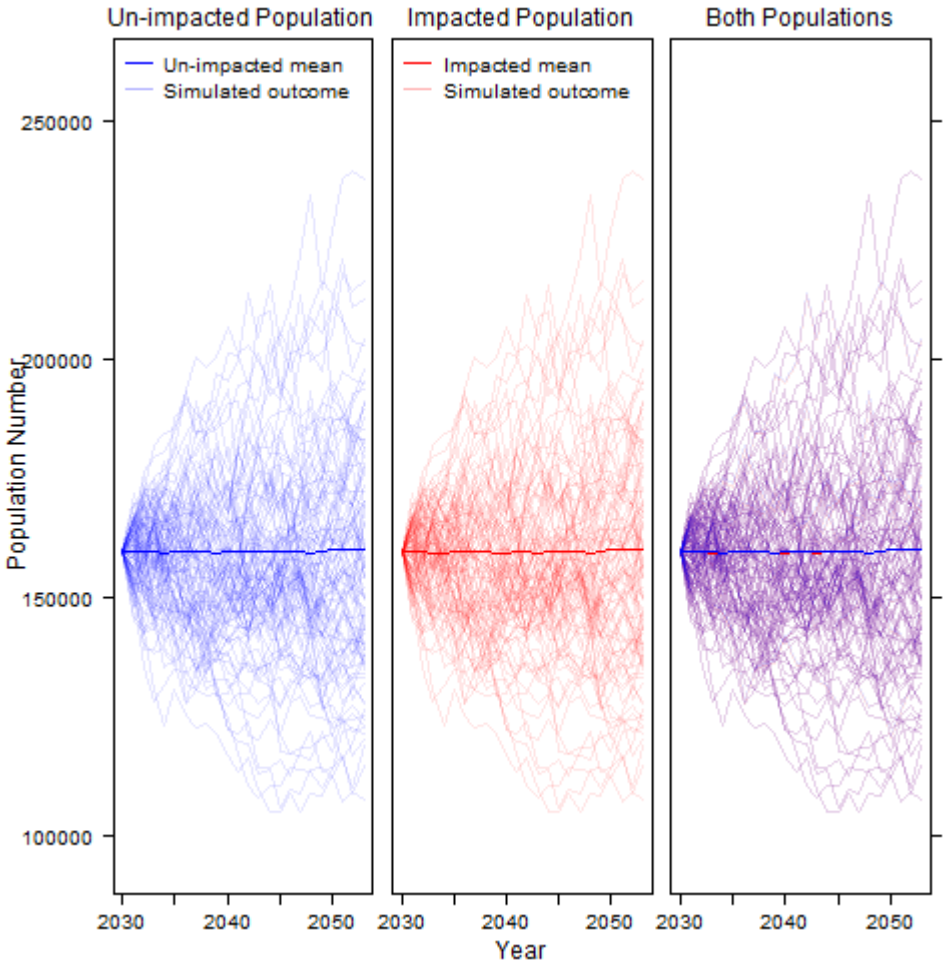


Figure 9 **Population trajectory for impacted and unimpacted harbour porpoise populations for the Project-alone scenario with TLP piling and a half day (12 hours) of disturbance**

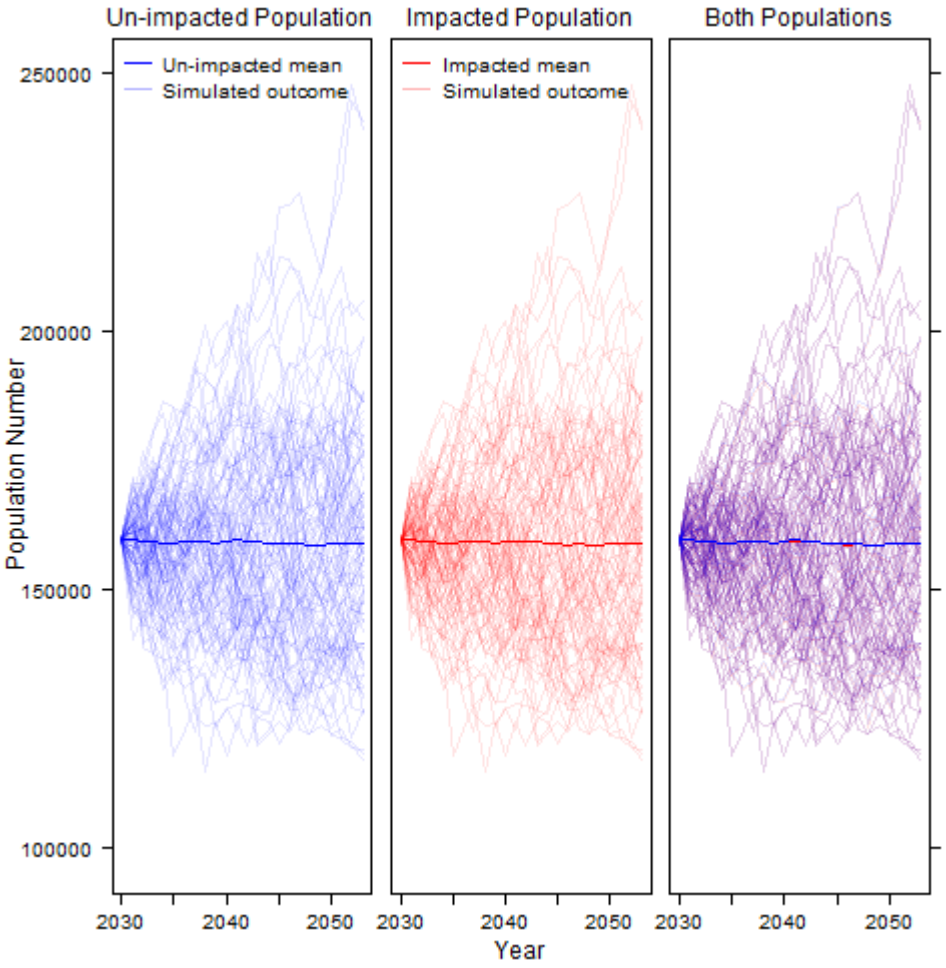


Figure 10 **Population trajectory for impacted and unimpacted harbour porpoise populations for the Project-alone scenario with TLP piling and one day of disturbance**

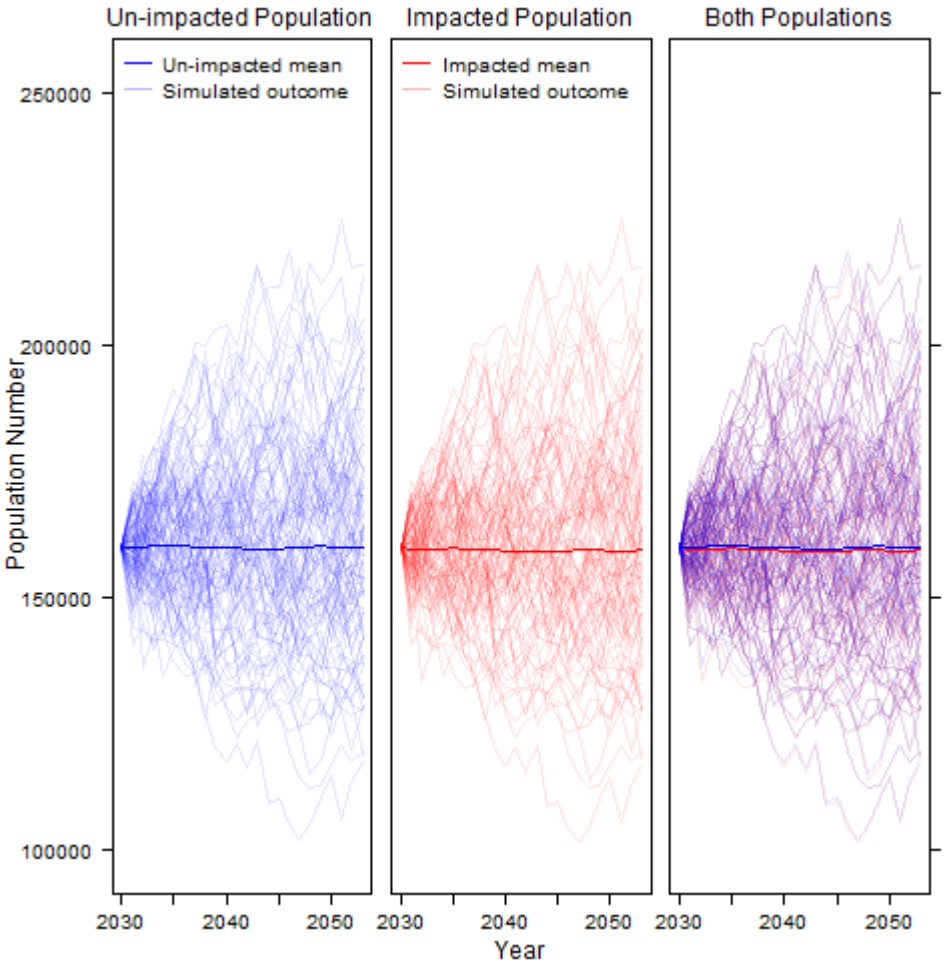


Figure 11 **Population trajectory for impacted and unimpacted harbour porpoise populations for the Project-alone scenario with TLP piling and two days of disturbance (i.e. one day of residual disturbance)**

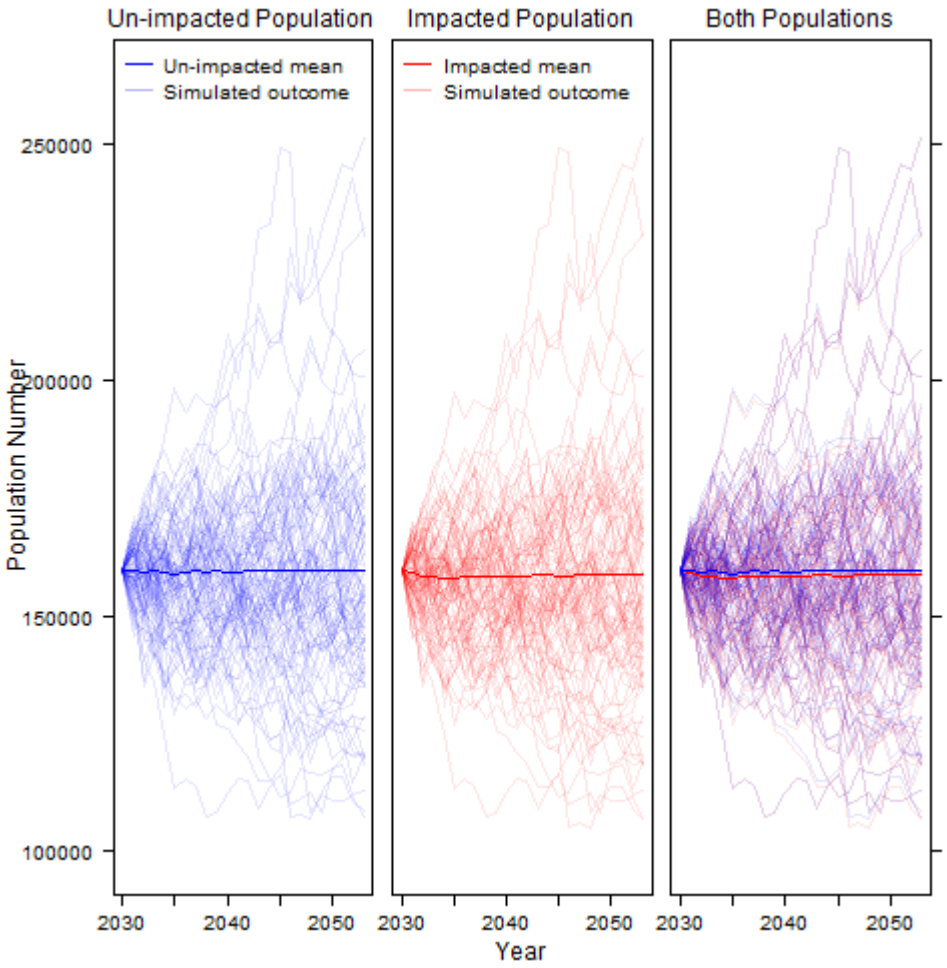


Table 8 Harbour porpoise iPCoD modelling results for the Project-alone scenario with TLP piling and ¼ day, ½ day, one day and two days of disturbance

Output variable	¼ day	½ day	1 day	2 days
Unimpacted population mean (after 1 year)	159,745	159,618	159,876	159,603
Impacted population mean (after 1 year)	159,717	159,571	159,550	159,063
Impacted population as % of un-impacted population (after 1 year)	99.98%	99.97%	99.80%	99.66%
Ratio of median impacted: un-impacted population size (after 1 year)	1.000	1.000	0.998	0.997
Unimpacted population mean (after 6 years)	159,576	159,224	160,058	159,039
Impacted population mean (after 6 years)	159,537	159,148	159,529	158,152
Impacted population as % of un-impacted population (after 6 years)	99.98%	99.95%	99.67%	99.44%
Ratio of median impacted: un-impacted population size (after 6 years)	1.000	1.000	0.995	0.995
Unimpacted population mean (after 12 years)	159,553	159,313	159,527	159,449
Impacted population mean (after 12 years)	159,513	159,233	158,971	158,511
Impacted population as % of un-impacted population (after 12 years)	99.97%	99.95%	99.65%	99.41%
Ratio of median impacted: un-impacted population size (after 12 years)	0.999	1.000	0.996	0.993
Unimpacted population mean (after 25 years)	160,065	159,407	159,402	159,661
Impacted population mean (after 25 years)	160,025	159,328	158,843	158,723
Impacted population as % of un-impacted population (after 25 years)	99.98%	99.95%	99.65%	99.41%
Ratio of median impacted: un-impacted population size (after 25 years)	0.999	1.000	0.998	0.996

3.1.2.2 Minke whale

37 The results for minke whales using the Project-alone scenario with TLP piling schedule show no reduction in the impacted population after 25 years (Figure 12 and Table 9). Compared to the semi-sub piling results for minke whale (Figure 6), the minke whale population is predicted to experience less impacted population reduction and slightly less fluctuation in population size with TLP piling. However, the median counterfactual of population size remains the same at one, which indicates that there is no difference between the trajectories of disturbed versus undisturbed populations. Therefore, there is not likely to be a potential for a long-term effect on minke whales for both semi-sub and TLP piling.

Figure 12 Population trajectory for impacted and unimpacted minke whale populations for the Project-alone scenario with TLP piling

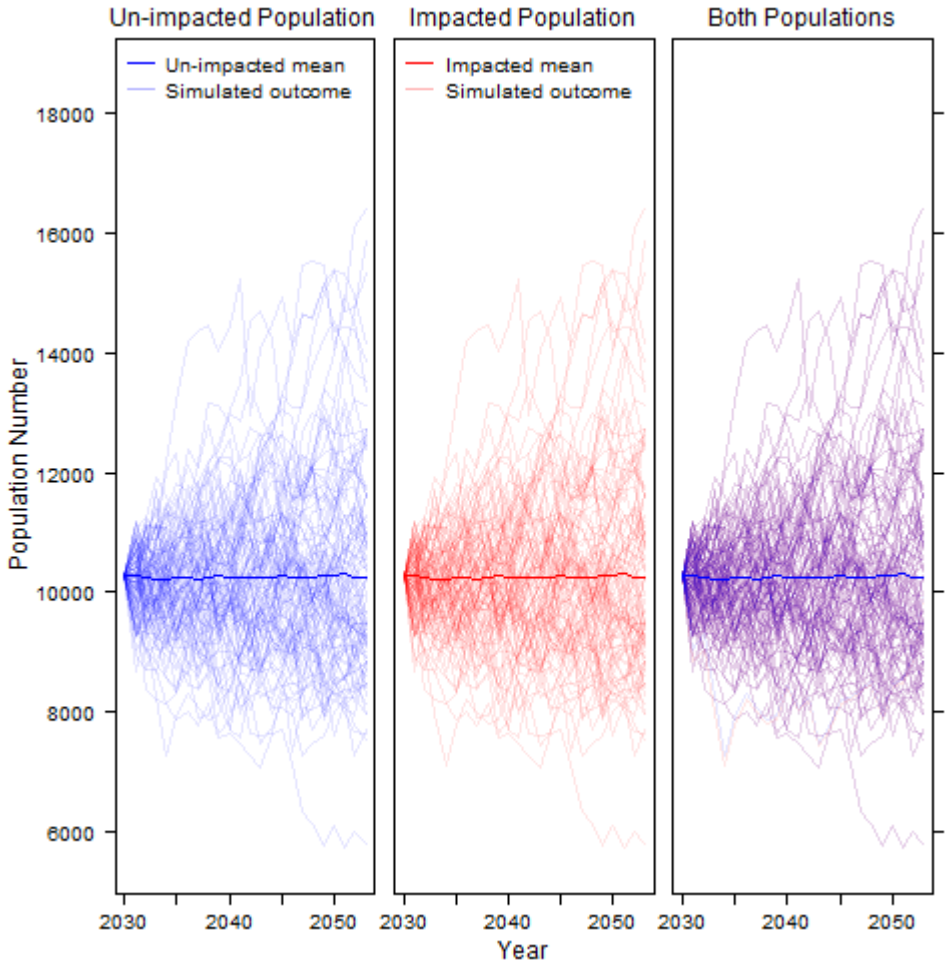


Table 9 Minke whale iPCoD modelling results for the Project-alone scenario with TLP piling

Output variable	Value
Unimpacted population mean (after 1 year)	10,291
Impacted population mean (after 1 year)	10,290
Impacted population as % of un-impacted population (after 1 year)	99.99%
Ratio of median impacted: un-impacted population size (after 1 year)	1.000
Unimpacted population mean (after 6 years)	10,257
Impacted population mean (after 6 years)	10,257
Impacted population as % of un-impacted population (after 6 years)	100.00%
Ratio of median impacted: un-impacted population size (after 6 years)	1.000
Unimpacted population mean (after 12 years)	10,235
Impacted population mean (after 12 years)	10,235
Impacted population as % of un-impacted population (after 12 years)	100.00%
Ratio of median impacted: un-impacted population size (after 12 years)	1.000
Unimpacted population mean (after 25 years)	10,322
Impacted population mean (after 25 years)	10,322
Impacted population as % of un-impacted population (after 25 years)	100.00%
Ratio of median impacted: un-impacted population size (after 25 years)	1.000

3.1.2.3 Grey seal

38 Figure 13 shows predicted population trajectory for grey seal when for the Project-alone scenario with TLP foundations. iPCoD predicted both the impacted and unimpacted populations will rise from ~2,700 animals in year one, to just under 3,500 animals after 25 years. Piling of the Project is not expected to alter the predicted population trajectory. The impacted and unimpacted populations are exactly the same throughout the simulations. Table 10 shows that the impacted population is predicted to be 100.00% of the unimpacted population after 25 years. Furthermore, the median counterfactual of population size is one throughout the simulation, which indicates that there is no difference between the trajectories of disturbed versus undisturbed populations. Therefore, there is not likely to be a potential for a long-term effect on grey seal for both semi-sub and TLP piling.

Figure 13 Population trajectory for impacted and unimpacted grey seal populations for the Project-alone scenario with TLP piling

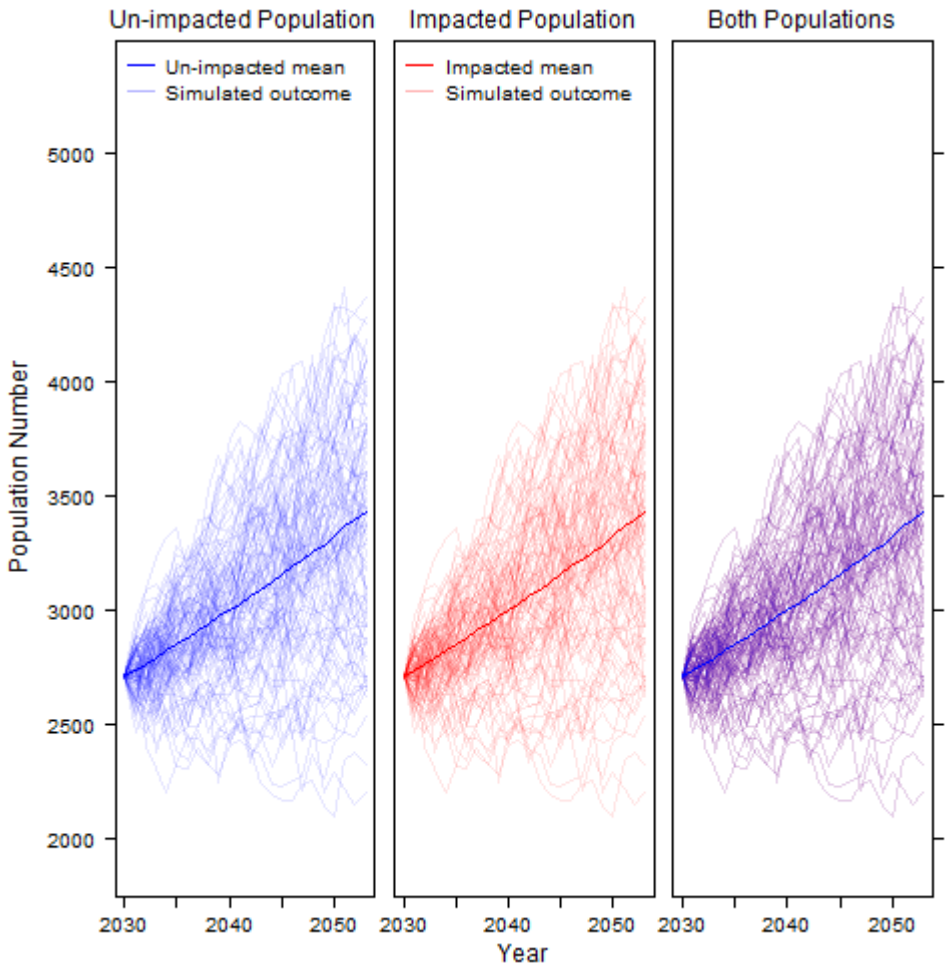


Table 10 Grey seal iPCoD modelling results for the Project-alone scenario with TLP piling

Output variable	Value
Unimpacted population mean (after 1 year)	2,735
Impacted population mean (after 1 year)	2,735
Impacted population as % of un-impacted population (after 1 year)	100.00%
Ratio of median impacted: un-impacted population size (after 1 year)	1.000
Unimpacted population mean (after 6 years)	2,876
Impacted population mean (after 6 years)	2,876
Impacted population as % of un-impacted population (after 6 years)	100.00%
Ratio of median impacted: un-impacted population size (after 6 years)	1.000
Unimpacted population mean (after 12 years)	3,059
Impacted population mean (after 12 years)	3,059
Impacted population as % of un-impacted population (after 12 years)	100.00%
Ratio of median impacted: un-impacted population size (after 12 years)	1.000
Unimpacted population mean (after 25 years)	3,509
Impacted population mean (after 25 years)	3,509
Impacted population as % of un-impacted population (after 25 years)	100.00%
Ratio of median impacted: un-impacted population size (after 25 years)	1.000

3.2 Cumulative scenarios

39 Cumulative modelling included values from the Project for the two OSCPs plus semi-sub scenario, as the semi-sub piling was predicted as the worst-case scenarios in project-alone models. Cumulative models additionally included eight windfarms located within 200km of the Cenos site. This Zone of Influence (ZOI) to screen in projects for cumulative scenarios was based on two times the maximum estimated area for TTS SEL_{cum} radius for low frequency cetaceans, as derived from underwater noise modelling. This approach was discussed and agreed with NatureScot in the Marine Mammal Consultation Meeting on 2nd October 2024.

40 The included sites and schedules are shown in Figure 1.

3.2.1 Harbour porpoise

41 After an initial decline during piling, harbour porpoise population size is predicted to remain constant throughout the simulation, with the impacted population estimated to remain slightly lower than the unimpacted population, but to follow a similar trend (Figure 14). The results in Table 11 show that after 25 years, the impacted population is 97.92% of the unimpacted population. This equates to approximately 161,000 animals and 157,000 animals for the unimpacted and impacted populations, respectively. The median counterfactual of population size declines the most between years one and six, where it falls from 0.997 to 0.981. This follows the trend shown in Figure 14 where initially there is a steeper decline in population size.

Figure 14 Population trajectory for impacted and unimpacted harbour porpoise populations under the cumulative scenario

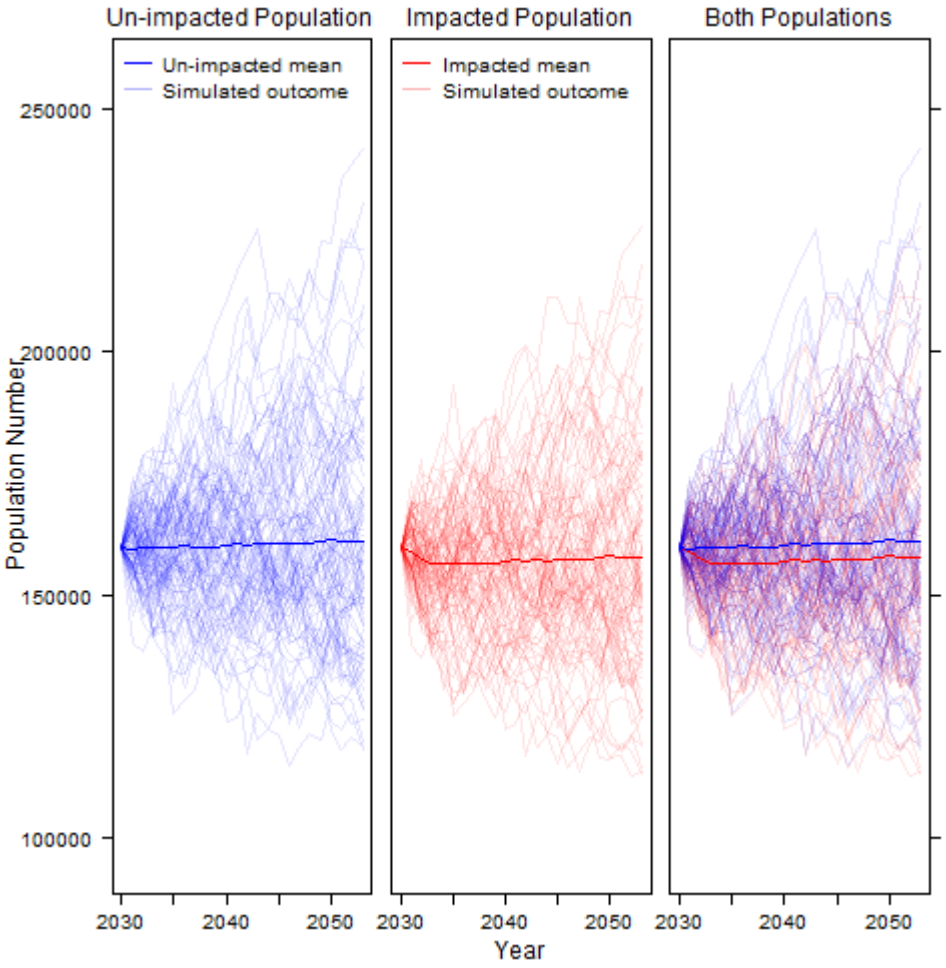


Table 11 Predicted impacts to harbour porpoise under the cumulative scenario

Output variable	Value
Unimpacted population mean (after 1 year)	159,381
Impacted population mean (after 1 year)	158,749
Impacted population as % of un-impacted population (after 1 year)	99.60%
Ratio of median impacted: un-impacted population size (after 1 year)	0.997
Unimpacted population mean (after 6 years)	160,034
Impacted population mean (after 6 years)	156,628
Impacted population as % of un-impacted population (after 6 years)	97.87%
Ratio of median impacted: un-impacted population size (after 6 years)	0.981
Unimpacted population mean (after 12 years)	160,247
Impacted population mean (after 12 years)	156,910
Impacted population as % of un-impacted population (after 12 years)	97.92%
Ratio of median impacted: un-impacted population size (after 12 years)	0.980
Unimpacted population mean (after 25 years)	161,018
Impacted population mean (after 25 years)	157,669
Impacted population as % of un-impacted population (after 25 years)	97.92%
Ratio of median impacted: un-impacted population size (after 25 years)	0.983

3.2.2 Minke whale

42 The cumulative results for minke whale in Figure 15 show that both the impacted and unimpacted populations are predicted to remain relatively consistent, with both population sizes of approximately 10,300 animals. After 25 years, it is predicted the impacted population will be around 99.99% of the unimpacted, and the median counterfactual of population size remains one (Table 12).This implies that the minke whale population is not likely to change substantially as a result of piling and construction activities for the Project in combination with nearby developments.

Figure 15 Population trajectory impacted and unimpacted minke whale populations under the cumulative scenario

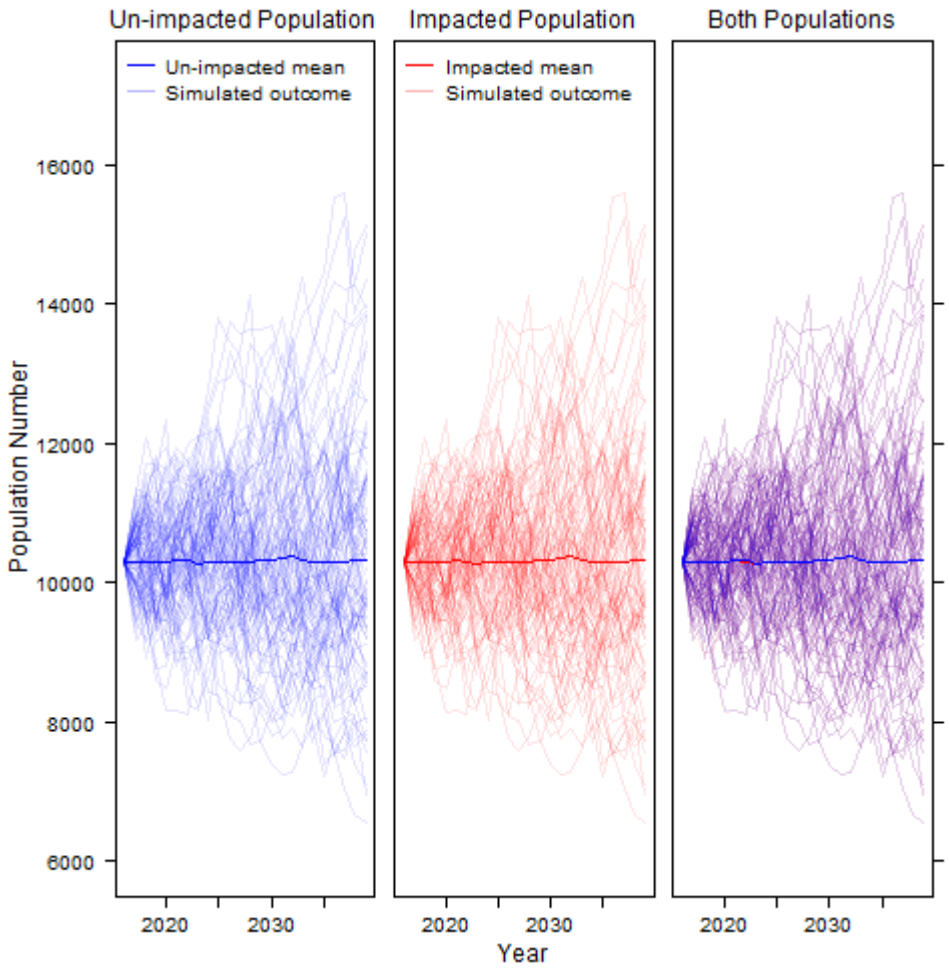


Table 12 Predicted impacts to minke whale under the cumulative scenario

Output variable	Value
Unimpacted population mean (after 1 year)	10,301
Impacted population mean (after 1 year)	10,301
Impacted population as % of un-impacted population (after 1 year)	100.00%
Ratio of median impacted: un-impacted population size (after 1 year)	1.000
Unimpacted population mean (after 6 years)	10,309
Impacted population mean (after 6 years)	10,306
Impacted population as % of un-impacted population (after 6 years)	99.97%
Ratio of median impacted: un-impacted population size (after 6 years)	1.000
Unimpacted population mean (after 12 years)	10,301
Impacted population mean (after 12 years)	10,300
Impacted population as % of un-impacted population (after 12 years)	99.99%
Ratio of median impacted: un-impacted population size (after 12 years)	1.000
Unimpacted population mean (after 25 years)	10,318
Impacted population mean (after 25 years)	10,317
Impacted population as % of un-impacted population (after 25 years)	99.99%
Ratio of median impacted: un-impacted population size (after 25 years)	1.000

3.2.3 Grey seal

43 iPCoD modelling suggests that after 25 years, unimpacted grey seal populations will increase from around 2,700 animals to over 3,400 animals. The modelling estimates that cumulative impacts will cause the impacted population to increase at a slower rate, initially, than the unimpacted population; therefore after 25 years, the impacted population will be slightly smaller than the unimpacted population (Figure 16). The impacted population is estimated to be 98.7% of the unimpacted population after 25 years (Table 13).

44 The median counterfactual ratio is estimated to decrease from 0.997 to 0.985 between years one and six and increase back to 0.989 after 12 years. This ratio remains the same after the 25 years of modelling. These results suggest that the grey seal population is estimated to be affected more by the surrounding sites of the Project.

Figure 16 Population trajectory for impacted and unimpacted grey seal populations under the cumulative scenario

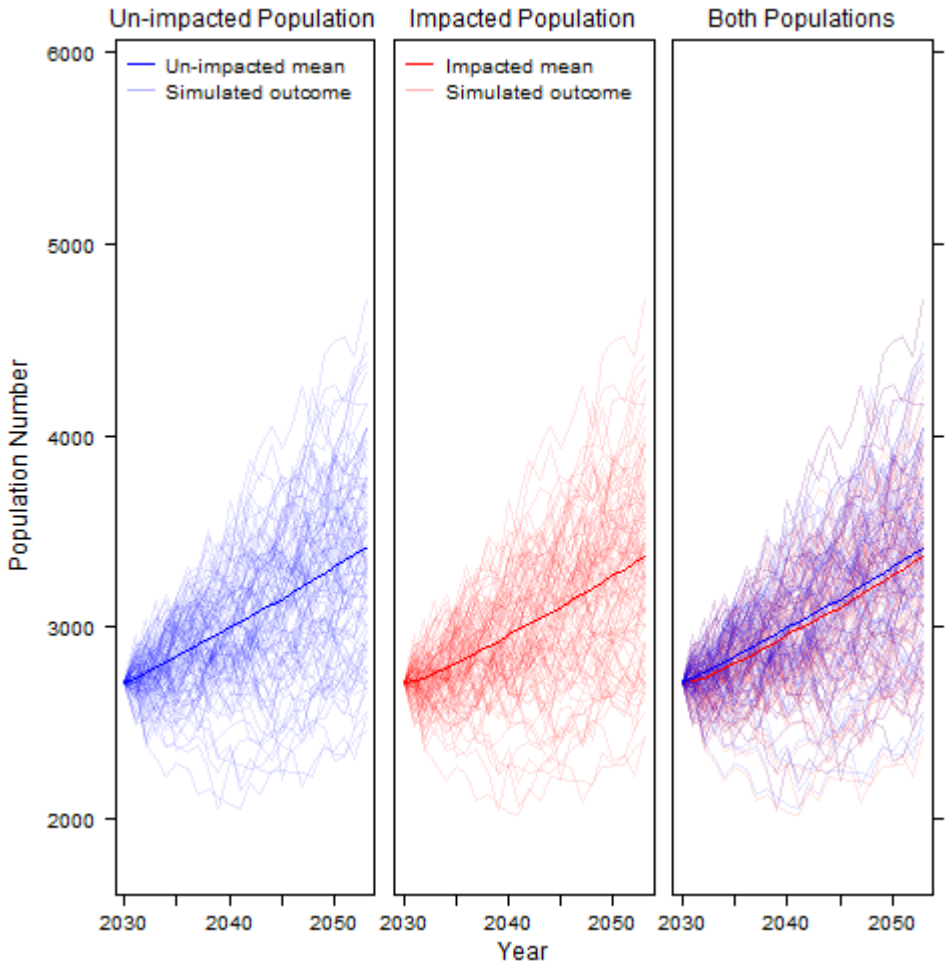


Table 13 Predicted impacts to grey seal under the cumulative scenario

Output variable	Value
Unimpacted population mean (after 1 year)	2,734
Impacted population mean (after 1 year)	2,726
Impacted population as % of un-impacted population (after 1 year)	99.71%
Ratio of median impacted: un-impacted population size (after 1 year)	0.997
Unimpacted population mean (after 6 years)	2,880
Impacted population mean (after 6 years)	2,841
Impacted population as % of un-impacted population (after 6 years)	98.65%
Ratio of median impacted: un-impacted population size (after 6 years)	0.985
Unimpacted population mean (after 12 years)	3,054
Impacted population mean (after 12 years)	3,014
Impacted population as % of un-impacted population (after 12 years)	98.69%
Ratio of median impacted: un-impacted population size (after 12 years)	0.989
Unimpacted population mean (after 25 years)	3,469
Impacted population mean (after 25 years)	3,424
Impacted population as % of un-impacted population (after 25 years)	98.70%
Ratio of median impacted: un-impacted population size (after 25 years)	0.989

4 Model limitations

45 There is a lack of empirical data which can be used within marine mammal population modelling (Donovan *et al*. 2016), and as such the model is based on information from expert elicitation to predict the effect of disturbance on marine mammal populations. Consequently, it is likely that information used within the iPCoD model may differ from reality, although the extent of this cannot be determined. The expert elicitation used to parameterise iPCoD serves as a semi-quantitative alternative to empirical data until such a time that those empirical data are available.

46 Additionally, the model does not account for density dependence and therefore assumes populations do not tend to recover after initial impact. This is unlikely to be true in reality, as typically the population growth rate will increase when the population size decreases (Harwood *et al*. 2014). The effects of this lack of population recovery is demonstrated in the results for harbour porpoise (Figure 5 and Figure 11, where populations experience declines during the initial piling period (years 1-5) and never recover, based on the model's integrated assumptions. In reality, recovery is likely to occur over time, however, this persistent difference between the unimpacted and impacted populations adds additional conservatism within the results. The level of residual disturbance typically used within models (one day) may also be unrepresentative and an overestimation, especially at greater distances from the piling operation (Brandt *et al*. 2018; Booth, Heinis, and Harwood 2019).

47 Environmental and demographic stochasticity are included models, but as presented in iPCoD documentation (Harwood *et al*. 2014), this can cause identical populations with the same conditions applied to follow different population trajectories over time. This can be seen in plots of population trend for unimpacted populations, where some variation in population size is observed over time. As such, variation in population trends can be influenced by stochastic parameters as well as disturbance, with disturbance possibly having a smaller impact than environmental and demographic stochasticity, in some cases (Sinclair, Sparling, and Harwood 2020), as can be seen by the this simulated outcome lines in all plots, which fluctuate considerably around the mean.

48 Following the above, it is likely that estimated impacts to populations using iPCoD can be considered precautionary. Despite these shortcomings, the Project has applied the model following industry best-practice and with due consideration given to the advice received from NatureScot during the Marine Mammal Consultation Meeting on 2nd October 2024.

5 Discussion

49 This Technical Note presents results of iPCoD modelling performed for the Project alone and cumulatively with other offshore windfarm developments, for harbour porpoise, minke whale and grey seal. iPCoD considers the difference in population trajectory between an impacted (with construction) and an unimpacted (no construction) population, known as counterfactual assessment.

50 For harbour porpoise, impacts estimated for the Project-alone scenarios using TLP piling are minimal (<1% population decline). This is opposed to a slight decline in population size for project alone scenarios using semi-sub piling, where there was a maximum of 2.2% decline in the harbour porpoise population. For minke whale and grey seals, there was negligible impact in both scenarios. Predicted impacts for semi-sub foundations compared to TLP are expected to be larger since semi-sub piling is estimated to disturb a higher number of animals per day and this foundation type requires more piling days to install. Significance of these potential disturbance scenarios is addressed in EIAR Vol. 2, Chapter 10: Marine Mammal Ecology and the RIAA.

51 For cumulative scenarios, harbour porpoise and grey seal had a counterfactual ratio of impacted to non-impacted populations of 0.983 and 0.989, respectively, suggesting a larger reduction in population size due to concurrent construction of nearby windfarms, particularly for grey seal. Despite this, the grey seal population was predicted to continue increasing with and without the impacts of the Project, either alone or cumulatively, and this is likely to be reflected in reality given the observed population growth in recent years (SCOS 2022). Minke whale had a counterfactual ratio of impacted to non-impacted populations of 1.000, implying that the construction of nearby windfarm sites is not likely to affect the population trajectory of this species.

52 Various sources of conservatism are included within the iPCoD modelling which compound to make results the worst-case scenario. For example, semi-sub piling (which was selected as the worst-case scenario) may not be used and all individuals within the UK portion of each MU are vulnerable to disturbance, which is likely to be unrealistic. Animals may also experience less than two days of disturbance (one day original plus one day residual disturbance; Booth, Heinis, and Harwood 2019). Additionally, dose-response curves derived for the harbour porpoise were applied to minke whale and grey seal to determine the numbers of animals disturbed to be inputted to the models, which given the known shyness of harbour porpoise in comparison to other marine mammal species, is likely a precautionary approach (EIAR Vol. 3, Appendix 15: Underwater Noise Modelling Report).

53 It is also possible that marine mammals habituate to construction noise when piling occurs on successive days or across a long construction campaign, as observed in porpoises by Graham *et al.* (2019), but this has also been disregarded as a precautionary measure.

6 References

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