FIVE ESTUARIES OFFSHORE WIND FARM

10.13 MARINE MAMMAL IPCOD MODELLING – PROJECT ALONE – REVISION B (TRACKED)

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In preparation of this document Five Estuaries Wind Farm Ltd has made reasonable efforts to ensure that the content is accurate, up to date and complete for purpose.

Revision	Date	Status/Reason for Issue	Originator	Checked	Approved
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DEFINITION OF ACRONYMS

Acronym	Definition
DAS	Digital Aerial Survey
ES	Environmental Statement
iPCoD	Interim Population Consequences of Disturbance
MU	Management Unit
OSP	Offshore Substation Platforms
PTS	Permanent Threshold Shift
WTG	Wind Turbine Generators

1 INTRODUCTION

1.1.1 This report was produced to address the following Relevant Representation from Natural England:

Natural England recommends the Applicant uses population modelling, for example iPCoD, to understand the impacts of the project alone and in combination with other activities at a population level.

1.1.2 This report provides population modelling for disturbance from pile driving at Five Estuaries alone, using disturbance values presented in 6.2.7 Marine Mammal Ecology [APP-076].

1.1.3 The Applicant has not undertaken iPCoD modelling for in-combination impacts. This is because this would require detailed piling schedules for every project included in the in-combination assessment, which the Applicant does not have. As a result, this is not an exercise the Applicant is in a position to undertake. The Applicant considers that it is not realistically practicable for any Developer to carry out such modelling. As such, this additional modelling and subsequent report is focussed on alone impacts.

1.1.4 As requested by Natural England in Ref NE77 [REP4-062], the median population size and 95% Confidence Intervals (CIs) have been added to the results tables and submitted into the Five Estuaries Examination at Deadline 5, see Table 5.1 and Table 5.2.

2 METHODOLOGY

2.1.1 The interim Population Consequences of Disturbance (iPCoD) framework (Harwood *et al.*, 2014, King *et al.*, 2015) was used to predict the potential population consequences of the predicted amount of Permanent Threshold Shift (PTS, auditory injury) and disturbance resulting from the piling. The iPCoD uses a stage structured model of population dynamics with nine age classes and one stage class (adults 10 years and older). The model is used to run a number of simulations of future population trajectory with and without the predicted level of impact, to allow an understanding of the potential future population level consequences of predicted behavioural responses and auditory injury.

2.1.2 Simulations were run comparing projections of the baseline population (i.e., under current conditions, assuming current estimates of demographic parameters persist into the future) with a series of paired 'impact' scenarios with identical demographic parameters, incorporating a range of estimates for disturbance. Each simulation was repeated 1,000 times and each simulation draws parameter values from a distribution describing the uncertainty in the parameters. This creates 1,000 matched pairs of population trajectories, differing only with respect to the effect of the disturbance and the distributions of the two trajectories can be compared to demonstrate the magnitude of the long-term effect of the predicted impact on the population, as well as demonstrating the uncertainty in predictions.

2.1.3 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 porpoise would be altered for 6 hours on the day of disturbance, and that no feeding (or nursing) would occur during the 6 hours of disturbance. For 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.

3 IPCOD MODEL LIMITATIONS

3.1 OVERVIEW

3.1.1 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. 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 100s of times to capture the uncertainty among experts.

3.1.2 There are several precautions built into the iPCoD model and this 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 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 which already include many levels of precaution.

3.2 LACK OF DENSITY DEPENDENCE

3.2.1 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 assumes 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 following disturbance. It is possible that populations with a positive growth rate (i.e. an increasing population) will continue to increase in the absence of disturbance.

3.2.2 At a recent expert elicitation, conducted for the purpose of modelling population impacts of the Deepwater Horizon oil spill (Schwacke *et al.*, 2021), experts agreed that there would likely be a concave density dependence on fertility. That means, for a population which is assumed to be stable (i.e., neither increasing or 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 – i.e., it is assumed the un-impacted population is at carrying capacity.

3.3 ENVIRONMENTAL AND DEMOGRAPHIC STOCHASTICITY

3.3.1 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 population. This includes demographic stochasticity and environmental variation. 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).

3.3.2 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 a Management Unit(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).

3.3.3 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 on environmental and demographic stochasticity. In the example provided in Figure 3.1, 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.

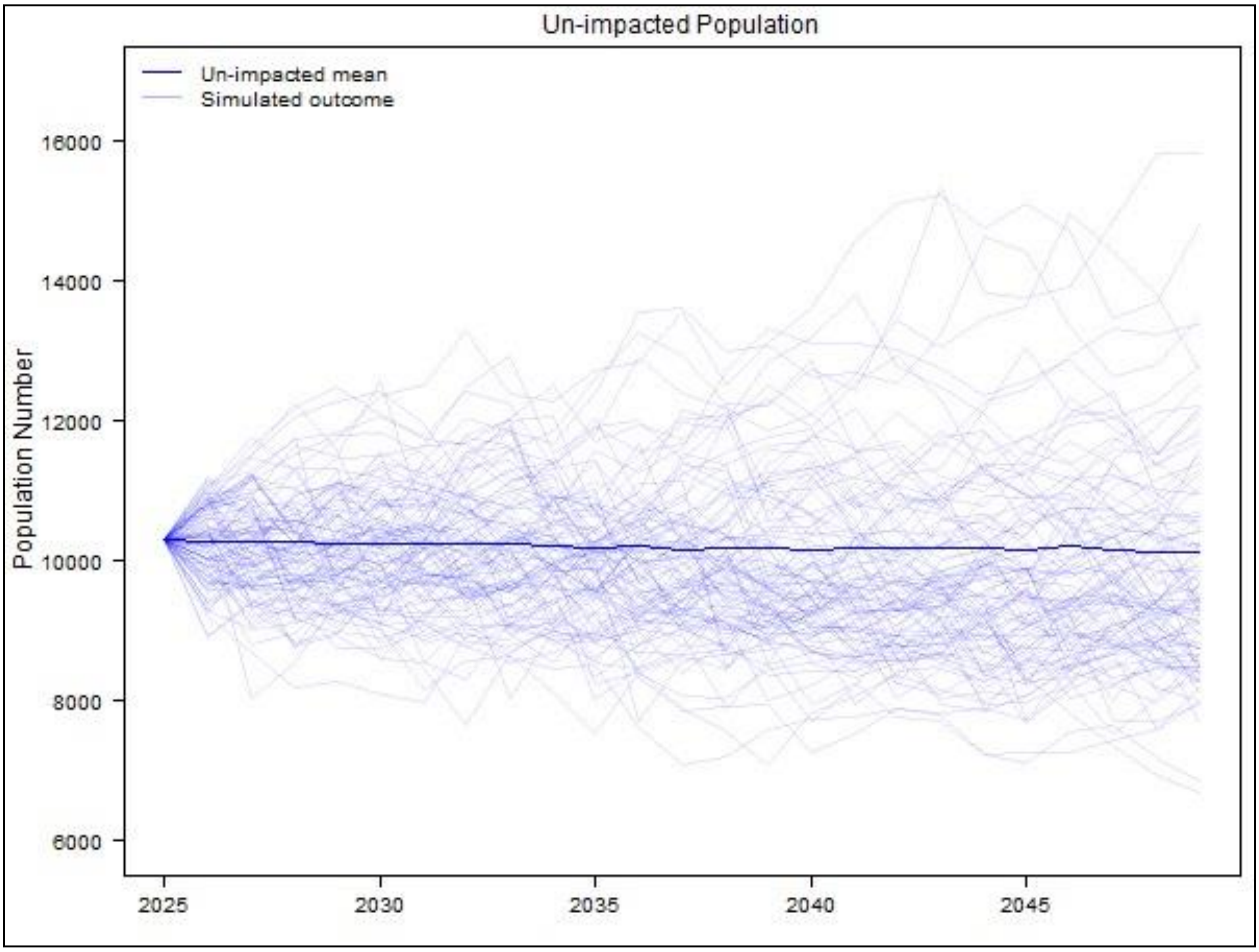

Figure 3.1: Simulated un-impacted (baseline) population size over the 25 years modelled.

3.4 SUMMARY

3.4.1 All of these precautions built into the iPCoD model mean that the results are considered to be highly conservative. Despite these limitations and uncertainties, this assessment has been carried out according to best practice and using the best available scientific information. 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.

4 IPCOD INPUTS

4.1 PILING SCHEDULES

4.1.1 Five Estuaries provided a piling schedule, with piling days assigned between 08/1/2029 and 01/11/2029 (Figure 4.1). This accounts for the piling restriction in place for herring spawning (currently proposed to be 6th November to 1st January). The piling schedule assumes 79 wind turbine generators (WTGs) and 2 offshore substation platforms (OSPs) on monopile foundations, with 1 monopile installed in a single day (total 81 piling days) as a realistic worst case.

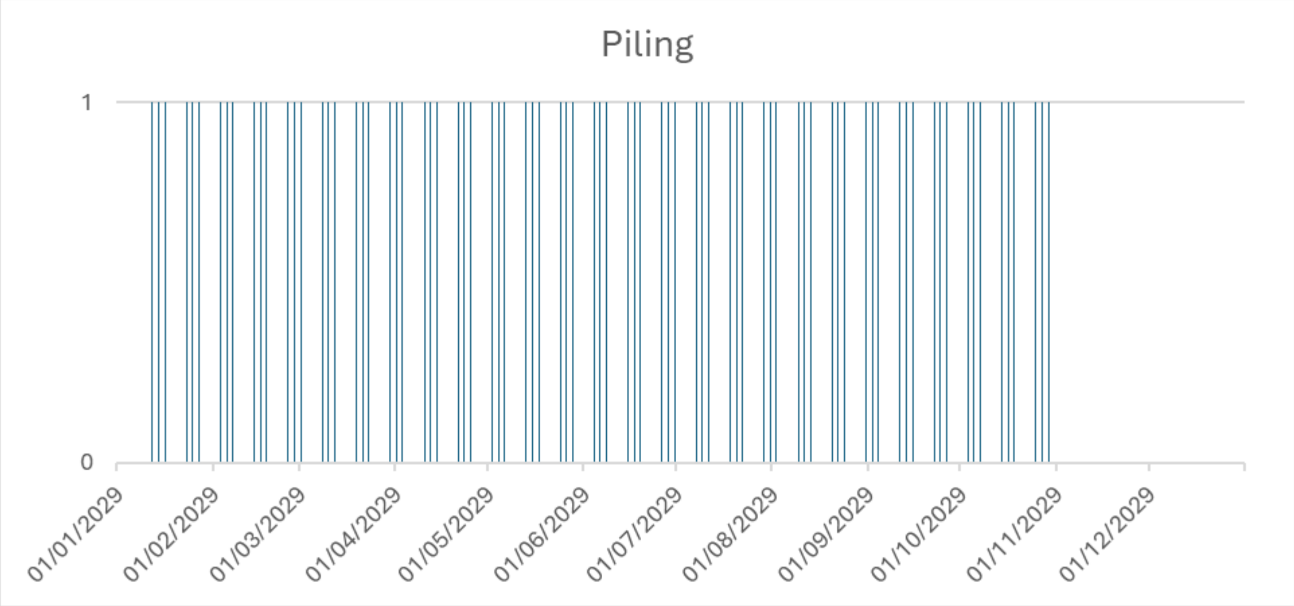

Figure 4.1: Five Estuaries piling schedule.

4.2 NUMBER DISTURBED

4.2.1 The iPCoD model was run using the maximum number of animals disturbed per day by WTG piling as presented in 6.2.7 Marine Mammal Ecology [APP-076]. For harbour porpoise, while the ES presented results using three different density estimates (site-specific surveys, SCANS III and SCANS IV), the highest density was obtained using the average 2-year site-specific digital aerial survey (DAS) data (1.82 porpoise/km^2) and as such, this is the worst case result and the only value presented here for porpoise. It is important to note here that while the site-specific density estimate has been used as requested by Natural England, there is no evidence that the density estimate is valid for impacted areas beyond the boundary of the site-specific surveys (i.e.: most of the disturbance contours).

Table 4.1: Number of animals predicted to be disturbed per piling day for monopile WTGs and OSP.

Species	MU	Source	WTG monopile
Harbour porpoise	346,601	DAS 1.82 porpoise/km^2	Unmitigated: 6,583 Mitigated: 2,839
Harbour seal	4,868	Habitat preference map (Carter *et al.*, 2022)	Unmitigated: 1 Mitigated: not run
Grey seal	65,505	Habitat preference map (Carter *et al.*, 2022)	Unmitigated: 102 Mitigated: 29

4.3 DEMOGRAPHIC PARAMETERS

4.3.1 The MU specific demographic parameters used in the iPCoD modelling were obtained from Sinclair *et al.* (2020) and are summarised in Table 4.2. In Sinclair *et al.* (2020) the southeast England harbour seal MU was modelled to be stable, however, recent counts show that this population is now in decline (SCOS, 2023). Therefore, both a stable and a declining population has been modelled.

Table 4.2: Demographic parameters used in the iPCoD modelling from Sinclair *et al.* (2020).

	Harbour porpoise	Harbour seal		Grey seal
Trend	Stable	Stable	Declining[1]	Increasing
Calf/pup survival	0.8455	0.4	0.24	0.222
Juvenile survival	0.85	0.78	0.86	0.94
Adult survival	0.925	0.92	0.8	0.94
Fertility	0.34	0.85	0.9	0.84
Age at independence	1	1	1	1
Age at first birth	5	4	4	6

[1] Using demographic parameters for the declining North Coast and Orkney harbour seal MU in the absence of declining parameters specific to the southeast England MU

5 RESULTS

5.1 HARBOUR PORPOISE

5.1.1 Table 5.1, Figure 5.1 and Figure 5.2 show the results for the iPCoD simulations for harbour porpoise. The counter-factual metric indicates that under both the un-mitigated and the mitigated scenarios, the impacted population size remains at 99.6-99.9% of the unimpacted population size, and the impacted population continues on a stable trajectory. **Therefore, disturbance from piling at Five Estuaries alone will not result in a change to the population size or trajectory.**

Table 5.1: Results of the harbour porpoise iPCoD simulations using the DAS site-specific density estimate and under both unmitigated and mitigated scenarios. Counter-factual percentage values rounded to 1 dp.

	Mean			Median			95% CIs	
	~~Mean u~~Un-impacted population size	~~Mean i~~Impacted population size	Impacted as % of un-impacted population size	Un-impacted population size	Impacted population size	Impacted as % of un-impacted population size	Unimpacted population size	Impacted population size
UNMITIGATED								
Start 2029 (before piling)	346,602	346,602	100.0%	346,602	346,602	100.0%	346,602 346,602	346,602 346,602
End 2029 (end piling)	345,828	345,752	100.0%	346,593	346,532	100.0%	317,630 369,224	317,567 369,093
2030 (1 year after piling)	345,799	345,647	100.0%	346,615	346,517	100.0%	307,486 381,789	307,465 381,779
2035 (6 years after piling)	346,198	346,092	100.0%	344,965	344,964	100.0%	288,254 409,320	288,254 409,318
2041 (12 years after piling)	345,719	345,614	100.0%	344,366	344,332	100.0%	275,152 428,917	274,949 428,917

	Mean			Median			95% CIs	
2047 (18 years after piling)	345,554	345,448	100.0%	343,462	343,427	100.0%	261,922 446,480	261,922 445,878
MITIGATED								
Start 2029 (before piling)	346,602	346,602	100.0%	346,602	346,602	100.0%	346,602 346,602	346,602 346,602
End 2029 (end piling)	346,393	346,366	100.0%	347,004	346,969	100.0%	317,657 371,135	317,657 371,135
2030 (1 year after piling)	346,858	346,807	100.0%	346,505	346,505	100.0%	309,027 381,773	309,027 381,773
2035 (6 years after piling)	345,604	345,569	100.0%	344,963	344,920	100.0%	288,689 405,155	288,554 404,886
2041 (12 years after piling)	346,888	346,852	100.0%	344,554	344,554	100.0%	273,732 436,945	273,732 436,912
2047 (18 years	345,237	345,201	100.0%	342,436	342,436	100.0%	260,573 449,732	260,573 449,489

	Mean			Median			95% CIs	
after piling)								

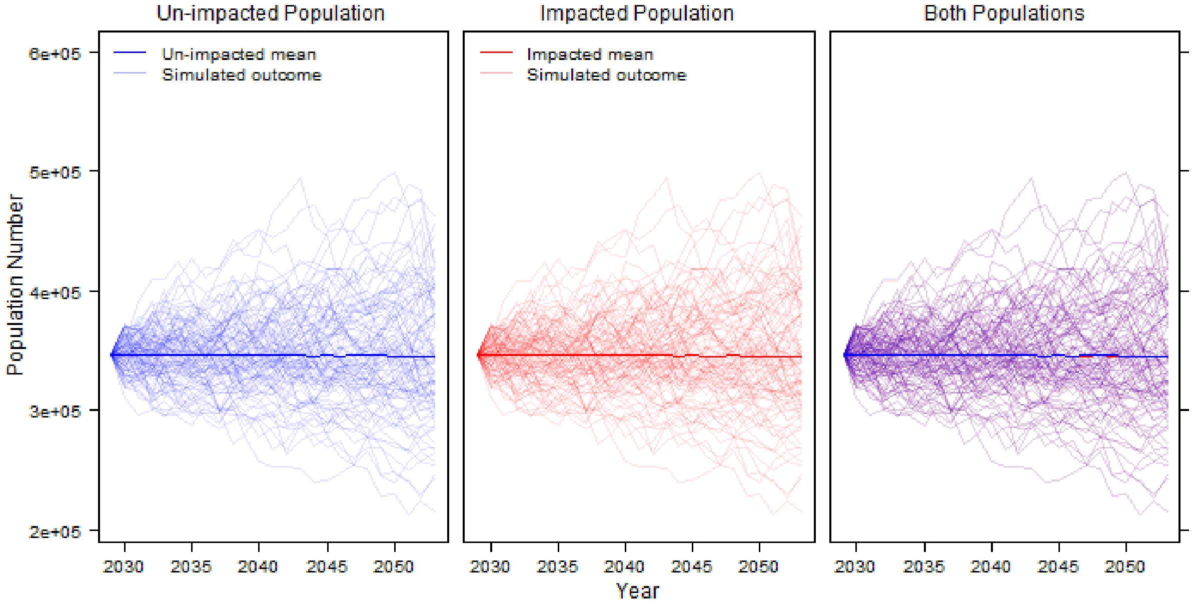

Figure 5.1: Results of the harbour porpoise iPCoD simulations for monopile foundations at Five Estuaries alone, using the DAS site-specific density estimate and un-mitigated piling.

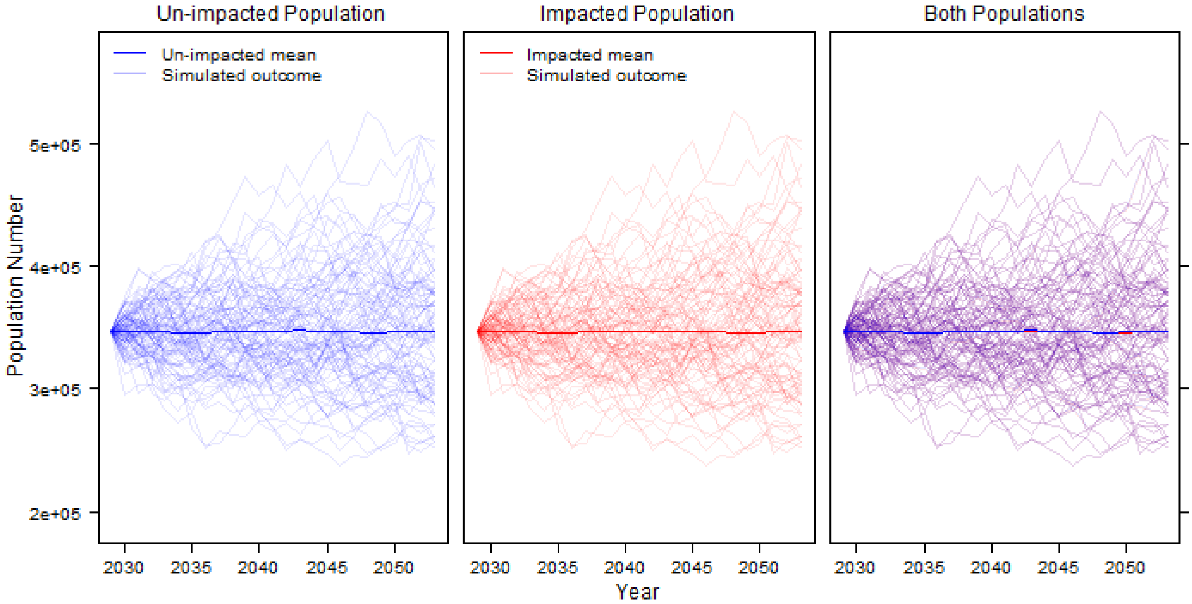

Figure 5.2: Results of the harbour porpoise iPCoD simulations for monopile foundations at Five Estuaries alone, using the DAS site-specific density estimate and mitigated piling.

5.2 HARBOUR SEAL

Table 5.2

5.2.1 ~~Table 5.2~~ and Figure 5.3 show the results for the iPCoD simulations for harbour seals assuming a stable population. The counter-factual metric indicates that the impacted population size remains at 100% of the unimpacted population size, and the impacted population continues on a stable trajectory. **Therefore, disturbance from piling at Five Estuaries alone will not result in a change to the population size or trajectory.** Because the southeast England MU has shown a decline in recent years, the modelling was also conducted assuming a declining harbour seal population.

5.2.2 Table 5.2 and Figure 5.4~~Figure 5.4~~ show the results for the iPCoD simulations for harbour seals assuming a declining population. The counter-factual metric indicates that the impacted population size remains at 100% of the unimpacted population size, and the impacted population continues on the same declining trajectory. **Therefore, disturbance from piling at Five Estuaries alone will not result in a change to the population size or trajectory.**

Table 5.2: Results of the harbour seal iPCoD simulations assuming both a stable population and a declining population.

	Mean			Median			95% CIs	
	~~Mean u~~Un-impacted population size	~~Mean i~~Impacted population size	Impacted as % of un-impacted population size	Un-impacted population size	Impacted population size	Impacted as % of un-impacted population size	Unimpacted population size	Impacted population size
STABLE POPULATION								
Start 2029 (before piling)	4,866	4,866	100%	4,866	4,866	100%	4,866 4,866	4,866 4,866
End 2029 (end piling)	4,862	4,862	100%	4,878	4,878	100%	4,471 5,210	4,471 5,210
2030 (1 year after piling)	4,862	4,862	100%	4,873	4,873	100%	4,372 5,308	4,372 5,308
2035 (6 years after piling)	4,876	4,876	100%	4,847	4,847	100%	4,126 5,762	4,126 5,762
2041 (12 years after piling)	4,891	4,891	100%	4,877	4,877	100%	3,928 6,018	3,928 6,018

	Mean			Median			95% CIs	
2047 (18 years after piling)	4,906	4,906	100%	4,862	4,862	100%	3,740 6,217	3,740 6,217
DECLINING POPULATION								
Start 2029 (before piling)	4,868	4,868	100%	4,868	4,868	100%	4,868 4,868	4,868 4,868
End 2029 (end piling)	4,359	4,359	100%	4,374	4,374	100%	3,966 4,676	3,966 4,676
2030 (1 year after piling)	3,902	3,902	100%	3,910	3,910	100%	3,466 4,296	3,466 4,296
2035 (6 years after piling)	2,244	2,244	100%	2,234	2,234	100%	1,820 2,750	1,820 2,750
2041 (12 years after piling)	1,155	1,155	100%	1,148	1,148	100%	836 1,548	836 1,548
2047 (18 years	593	593	100%	580	580	100%	384 860	384 860

	Mean			Median			95% CIs	
after piling)								

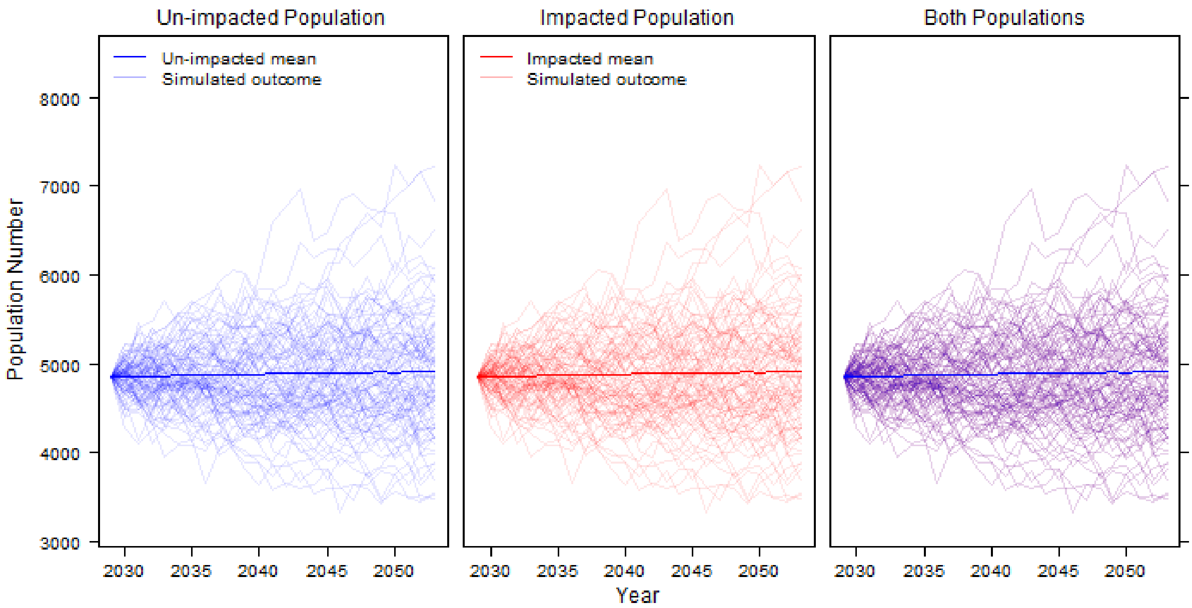

Figure 5.3: Results of the harbour seal iPCoD simulations for monopile foundations at Five Estuaries alone assuming a stable population.

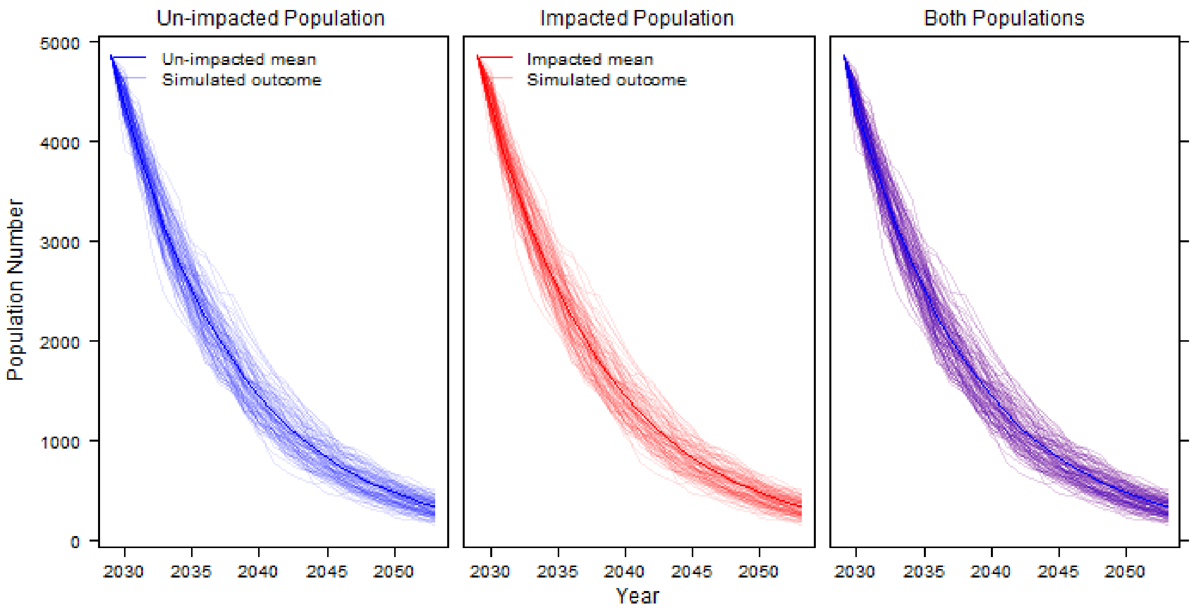

Figure 5.4: Results of the harbour seal iPCoD simulations for monopile foundations at Five Estuaries alone assuming a declining population.

5.3 GREY SEAL

5.3.1 Table 5.3, Figure 5.5 and Figure 5.6 show the results for the iPCoD simulations for grey seals. The counter-factual metric indicates that the impacted population size remains at 100% of the unimpacted population size, and the impacted population continues on the same increasing trajectory under both the un-mitigated and mitigated scenarios. **Therefore, disturbance from piling at Five Estuaries alone will not result in a change to the population size or trajectory.**

Table 5.3: Results of the grey seal iPCoD simulations under both unmitigated and mitigated scenarios.

	Mean			Median			95% CIs	
	~~Mean u~~Un-impacted population size	~~Mean i~~Impacted population size	Impacted as % of un-impacted population size	Un-impacted population size	Impacted population size	Impacted as % of un-impacted population size	Unimpacted population size	Impacted population size
UNMITIGATED								
Start 2029 (before piling)	52,356	52,356	100%	52,356	52,356	100%	52,356 52,356	52,356 52,356
End 2029 (end piling)	52,782	52,782	100%	53,049	53,049	100%	47,971 55,901	47,971 55,901
2030 (1 year after piling)	53,069	53,069	100%	53,400	53,400	100%	47,513 57,210	47,513 57,210
2035 (6 years after piling)	54,686	54,686	100%	54,815	54,815	100%	44,270 63,943	44,270 63,943
2041 (12 years after piling)	56,772	56,772	100%	56,816	56,816	100%	43,996 69,973	43,996 69,973

	Mean			Median			95% CIs	
2047 (18 years after piling)	58,832	58,832	100%	58,570	58,570	100%	42,096 76,309	42,096 76,309	
MITIGATED									
Start 2029 (before piling)	52,356	52,356	100%	52,356	52,356	100%	52,356 52,356	52,356 52,356	
End 2029 (end piling)	52,585	52,585	100%	52,759	52,759	100%	48,186 55,900	48,186 55,900	
2030 (1 year after piling)	52,961	52,961	100%	53,237	53,237	100%	47,260 57,572	47,260 57,572	
2035 (6 years after piling)	54,745	54,745	100%	54,833	54,833	100%	45,780 63,814	45,780 63,814	
2041 (12 years after piling)	56,903	56,903	100%	56,674	56,674	100%	44,423 70,236	44,423 70,236	
2047 (18 years	59,017	59,017	100%	58,782	58,782	100%	43,093 76,267	43,093 76,267	

	Mean			Median			95% CIs	
after piling)								

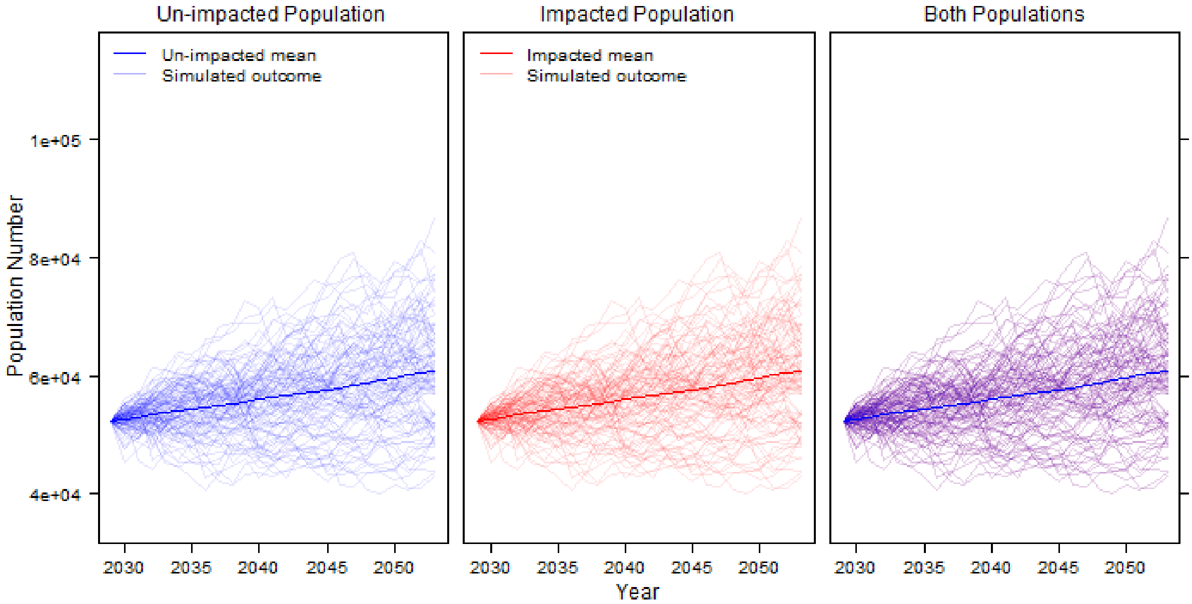

Figure 5.5: Results of the grey seal iPCoD simulations for monopile foundations at Five Estuaries alone with un-mitigated piling.

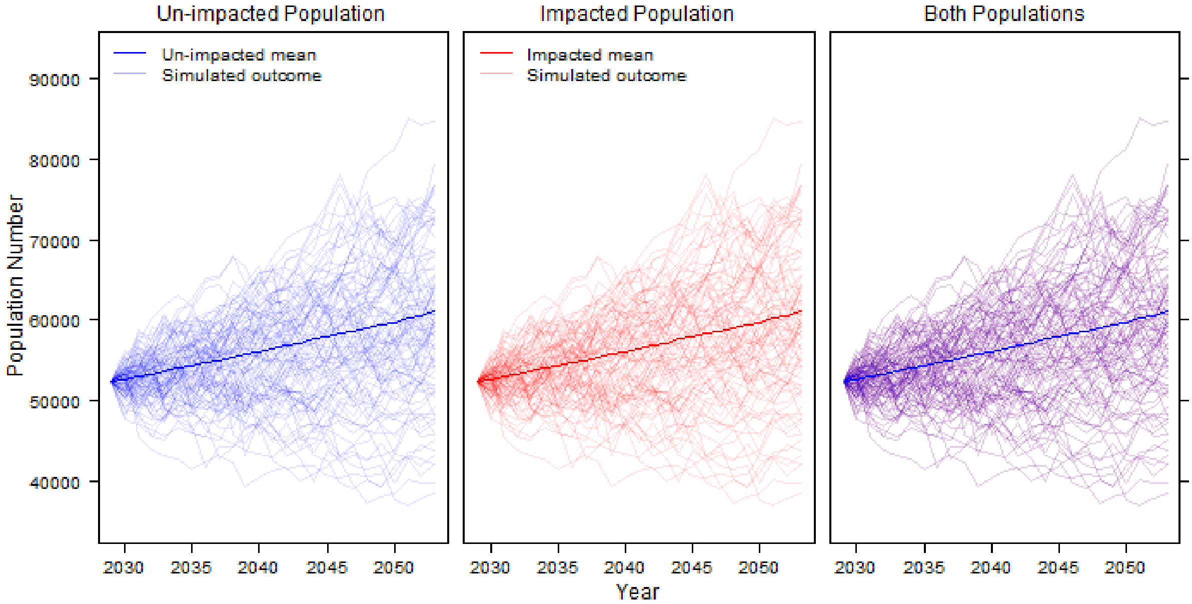

Figure 5.6: Results of the grey seal iPCoD simulations for monopile foundations at Five Estuaries alone with mitigated piling.

6 CONCLUSION

6.1.1 The iPCoD modelling shows that for disturbance from piling of WTGs and OSPs at Five Estuaries alone, the magnitude score is Negligible for all species, whereby there is predicted to be short-term and/or intermittent and temporary behavioural effects in a small proportion of the population, however there is no change to the population size or trajectory. This aligns with the magnitude scores assigned in 6.2.7 Marine Mammal Ecology [APP-076](Table 6.1).

Table 6.1: Magnitude score assigned in the ES chapter compared to those assigned given the iPCoD modelling.

Species	Magnitude conclusion in ES	Magnitude conclusion from iPCoD
Harbour porpoise	**Un-mitigated:** Low **Mitigated:** Negligible	**Un-mitigated:** Negligible – impacted population is 100% (rounded to nearest dp) of the un-impacted population size and continues on a stable trajectory. **Mitigated:** Negligible – impacted population is 100% (rounded to nearest dp) of the un-impacted population size and continues on a stable trajectory.
Harbour seal	**Un-mitigated:** Negligible **Mitigated:** Negligible	**Un-mitigated:** Negligible – impacted population is exactly the same size as the un-impacted population and continues on the same trajectory.
Grey seal	**Un-mitigated:** Negligible **Mitigated:** Negligible	**Un-mitigated:** Negligible – impacted population is exactly the same size as the un-impacted population and continues on the same increasing trajectory. **Mitigated:** Negligible – impacted population is exactly the same size as the un-impacted population and continues on the same increasing trajectory.

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