Environmental Impact Assessment Report

Volume 4

Appendix 11.4 Phase 1 Irish Offshore Wind Farms – Cumulative iPCoD modelling

SMRU Consulting

understand ♦ assess ♦ mitigate

Phase 1 Irish Offshore Wind Farms - Cumulative iPCoD modelling

Authors:	Sinclair, RRS
Report Code:	SMRUC-XXX-2024-005
Date:	Sunday, 18 August 2024

THIS REPORT IS TO BE CITED AS: SINCLAIR, RR (2024). PHASE 1 IRISH OFFSHORE WIND FARMS: CUMULATIVE IPCOD MODELLING. SMRU CONSULTING REPORT NUMBER SMRUC-XXX-2024-005, SUBMITTED TO ARKLOW BANK WIND PARK PHASE 2, CODLING WIND PARK, DUBLIN ARRAY WIND FARM, NORTH IRISH SEA ARRAY OFFSHORE WIND FARM AND ORIEL WIND FARM (UNPUBLISHED).

Document Control

Please consider this document as uncontrolled copy when printed

Rev.	Date.	Reason for Issue.	Prep.	Chk.	Apr.	Client
1	March 2024	Final for issue	RRS	RRS	RRS	CWP

CONTENTS

FIGURES

TABLES

1 Introduction

The purpose of this report is to assess whether cumulative disturbance resulting from pile driving activities across the five Irish Phase 1 Offshore Windfarm Projects is predicted to result in population level impacts to four marine mammal species (harbour porpoise, bottlenose dolphins, harbour and grey seals). For this assessment each Phase 1 Project was required to provide an indicative piling schedule and the number of animals predicted to be disturbed per piling day.

Auditory injury (or permanent threshold shift (PTS)) was not included in this cumulative assessment since it was assumed that each Project would put in place mitigation measures to negate the risk of auditory injury to marine mammals.

2 Methods

2.1 iPCoD model

The iPCoD framework (Harwood *et al.*, 2014, King *et al.*, 2015) was used to predict the potential population consequences of the predicted amount of disturbance resulting from the piling. iPCoD uses a stage-structured model of population dynamics with nine age classes and one stage class (adults 10 years and older). The model was 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.

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.

2.1.1 Expert elicitation

Much of the empirical information required to parameterise a PCoD model does not exist for many marine mammal species. Therefore, the iPCoD framework was developed in 2013 to forecast the potential effects of disturbance and hearing damage (PTS) that might result from the construction or operation of offshore renewable energy devices in UK waters using an expert elicitation (EE) process to quantify the potential effects of behavioural and physiological changes on vital rates. Expert elicitation is a formal technique (Brown, 1968, O'Hagan *et al.*, 2006) that is widely used in a range of scientific fields to combine the opinions of experts in situations where there is a relative lack of data but an urgent need for conservation or management decisions (Runge *et al.*, 2011, Martin *et al.*, 2012). Specifically, Morgan (2014) indicates: *“Expert elicitation should build on and use the best available research and analysis and be undertaken only when the state of knowledge will remain insufficient to support timely informed assessment and decision making”*. Martin *et al.* (2012) describe how this technique can be used to access substantive knowledge on particular topics held by experts and such techniques have been discussed and used widely over the past two decades (MacMillan and Marshall, 2006, Aspinall, 2010, Knol *et al.*, 2010, European Food Safety Authority, 2014, Sivle *et al.*, 2015). The technique can also be used to translate and combine information obtained from multiple experts into quantitative statements that can be incorporated into a model, minimize bias in the elicited information, and ensure that uncertainty is accurately captured. The formal process of expert elicitation therefore avoids many of the well documented problems, heuristics and biases that arise when the judgements of only a few experts are canvassed or where expert knowledge is sought in an unstructured matter (Kynn, 2008, Kahneman, 2011, Morgan, 2014).

The original 2013 expert elicitation for iPCoD was recognised as an interim solution to the assessment of the potential effects of disturbance and PTS on vital rates, and there remained an urgent need for additional scientific research to address the knowledge gaps that were identified by Harwood *et al.* (2014). Since the 2013 expert elicitation, significant advances in our understanding of the elicitation processes have been made and methods in eliciting expert opinion have been refined. Given the advances in the expert elicitation process and continued developments on our knowledge of the marine mammalian auditory system and mechanisms affecting vital rates, two additional expert elicitations were conducted in 2018 (Booth and Heinis, 2018, Booth *et al.*, 2019) to determine how PTS and behavioural disturbance affect the vital rates of UK marine mammals. These elicitations resulted in changes to the transfer functions for the expected effects of PTS and disturbance on vital rates and an updated iPCoD model.

2.1.1.1 Harbour porpoise

The iPCoD model for harbour porpoise was last updated following the expert elicitation in 2018.

Previous studies have shown that harbour porpoise are displaced from the vicinity of piling events (Brandt *et al.*, 2011, Dähne *et al.*, 2013, Brandt *et al.*, 2016, Brandt *et al.*, 2018, Graham *et al.*, 2019, Rose *et al.*, 2019). Harbour porpoise are small cetaceans which makes them vulnerable to heat loss and requires them to maintain a high metabolic rate with little energy remaining for fat storage. This makes them vulnerable to starvation if they are unable to obtain sufficient levels of prey intake. The results from Wisniewska *et al.* (2016) could also suggest that porpoises have an ability to respond to short term reductions in food intake, implying a resilience to disturbance. As Hoekendijk *et al.* (2018) suggest, this could help explain why porpoises are such an abundant and successful species.

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. The experts agreed that first year calf survival (post-weaning) and fertility were the most likely vital rates to be affected by disturbance, but that juvenile and adult survival were unlikely to be significantly affected as these life-stages were considered to be more robust.

- Experts agreed it would likely take high levels of repeated disturbance to an individual before there was any effect on that individual's fertility (Figure 1), and that it was very unlikely an animal would terminate a pregnancy early.
- Experts considered that there are critical periods in the first year where calf survival could be reduced by a relatively small number of days of disturbance (Figure 2).

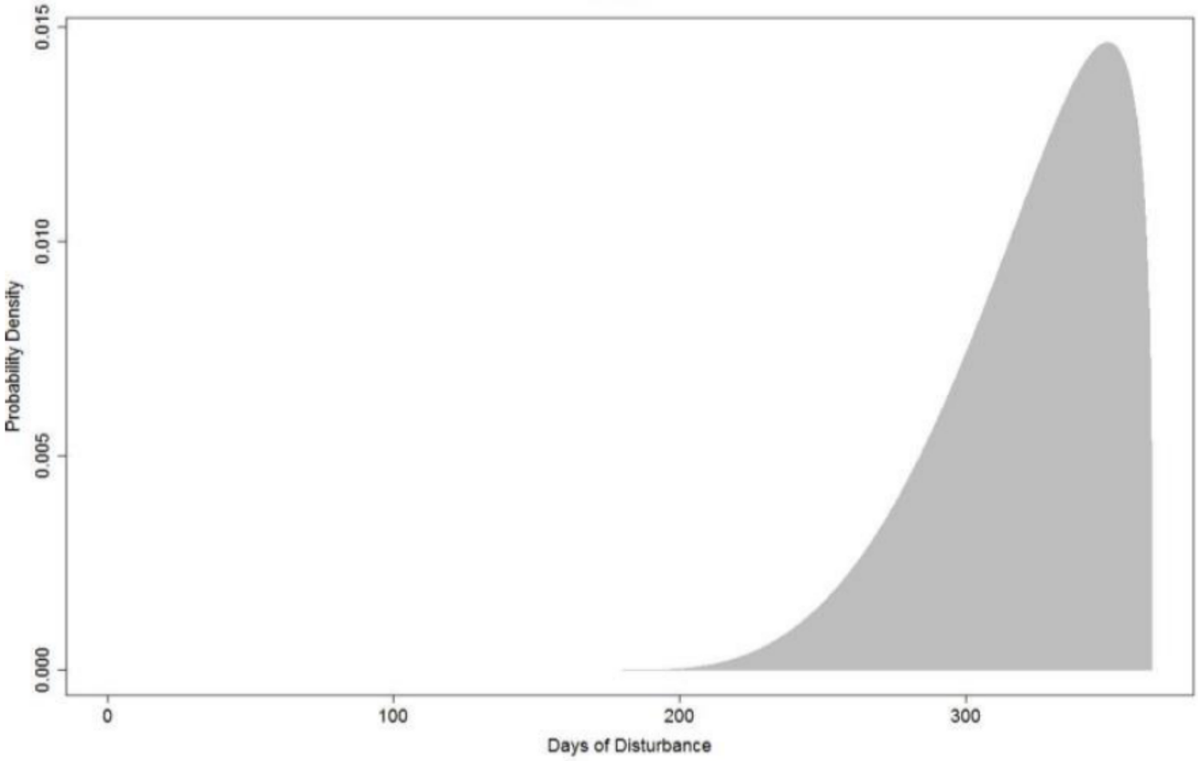

Figure 1 Probability distribution showing the consensus of the EE: the number of days of disturbance (i.e. days on which an animal does not feed for 6 hours) a pregnant female porpoise could 'tolerate' before it has any effect on fertility.

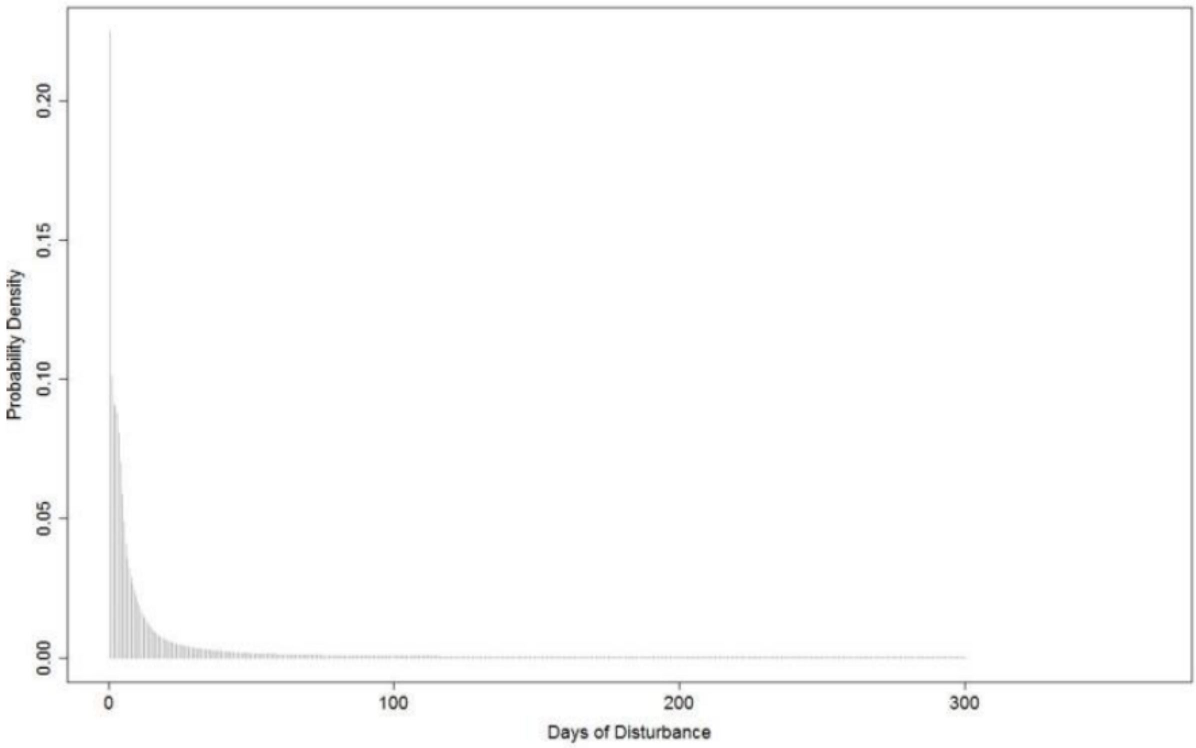

Figure 2 Probability distribution showing the consensus of the EE: the number of days of disturbance (of 6 hours zero energy intake) a porpoise mother:calf pair could 'tolerate' before it has any effect on survival.

2.1.1.2 Harbour and grey seals

The iPCoD model for harbour and grey seals was last updated following the expert elicitation in 2018.

Previous studies have shown that both harbour seals and grey seals are displaced from the vicinity of piling events (Russell *et al.*, 2016, Aarts *et al.*, 2018). The duration of the displacement was only short-term as seals returned to non-piling distributions within two hours after the end of a pile-driving event. Unlike harbour porpoise, both harbour and grey seals store energy in a thick layer of blubber, which means that they are more tolerant of periods of fasting when hauled out and resting between foraging trips, and when hauled out during the breeding and moulting periods. Therefore, they are unlikely to be particularly sensitive to short-term displacement from foraging grounds during periods of active piling.

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. The experts determined that the survival of 'weaned of the year' animals and fertility were the most sensitive life history parameters to disturbance.

- It was agreed that harbour seals were considered to have a reasonable ability to compensate for lost foraging opportunities due to their generalist diet, mobility, life history, and fat stores. It was thought that for an animal in bad condition, moderate levels of repeated disturbance might be sufficient to reduce fertility (Figure 3), however there was a large amount of uncertainty in this estimate.
- Grey seals were considered to have a reasonable ability to compensate for lost foraging opportunities due to their generalist diet, adaptable foraging tactics, ability to adjust their metabolic rates, wide ranging behaviour, life history and large body size with fat stores. Experts agreed that grey seals would be much more robust than harbour seals to the effects of disturbance and it was agreed that grey seals would require moderate-high levels of repeated disturbance before there was any effect on fertility rates (Figure 4).
- During nursing, a seal pup is given a lot of fat by its mother, which is followed by a post-weaning fast whilst on land (2-3 weeks in grey seals, 2-2.5 weeks in harbour seals). Following the fast there is a 2-3 month window in which animals will be particularly vulnerable to missed foraging opportunities as a result of disturbance. Experts felt it might take multiple days of repeated disturbance before there was expected to be any effect on the probability of survival (Figure 5), however, there was a lot of uncertainty surrounding this estimate.

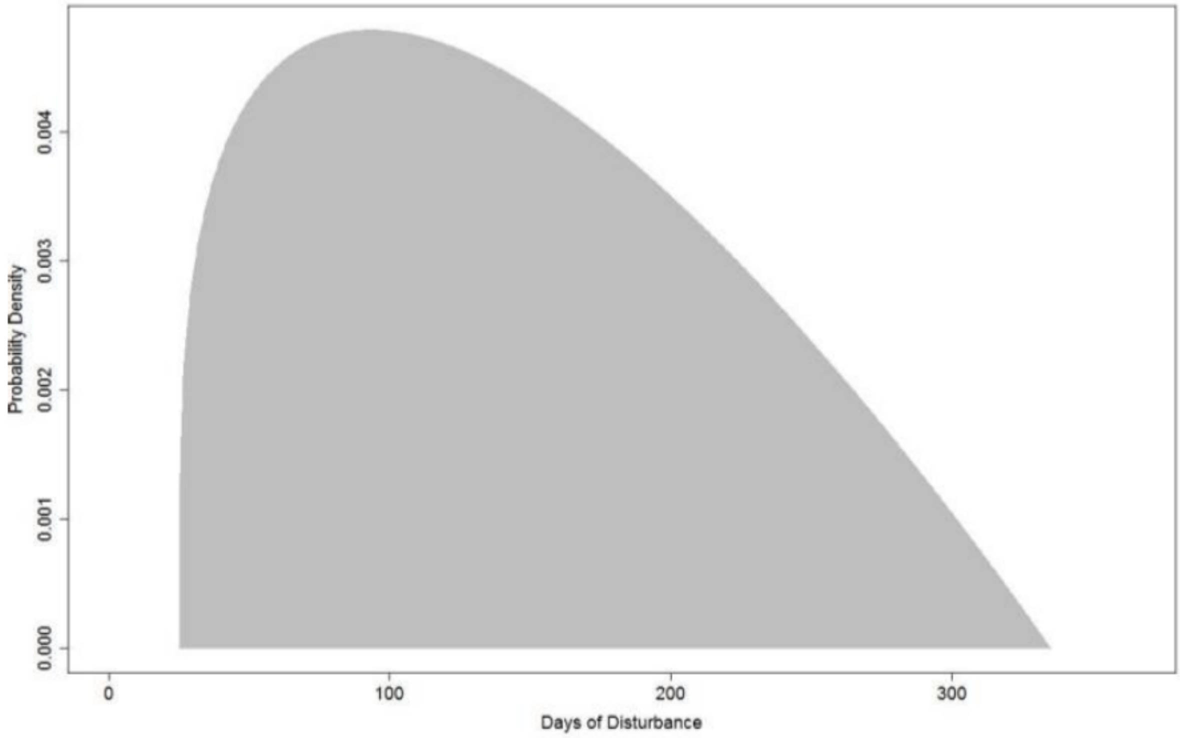

Figure 3 Probability distribution showing the consensus of the EE: the number of days of disturbance a pregnant female harbour seal could 'tolerate' before disturbance has any effect on fertility.

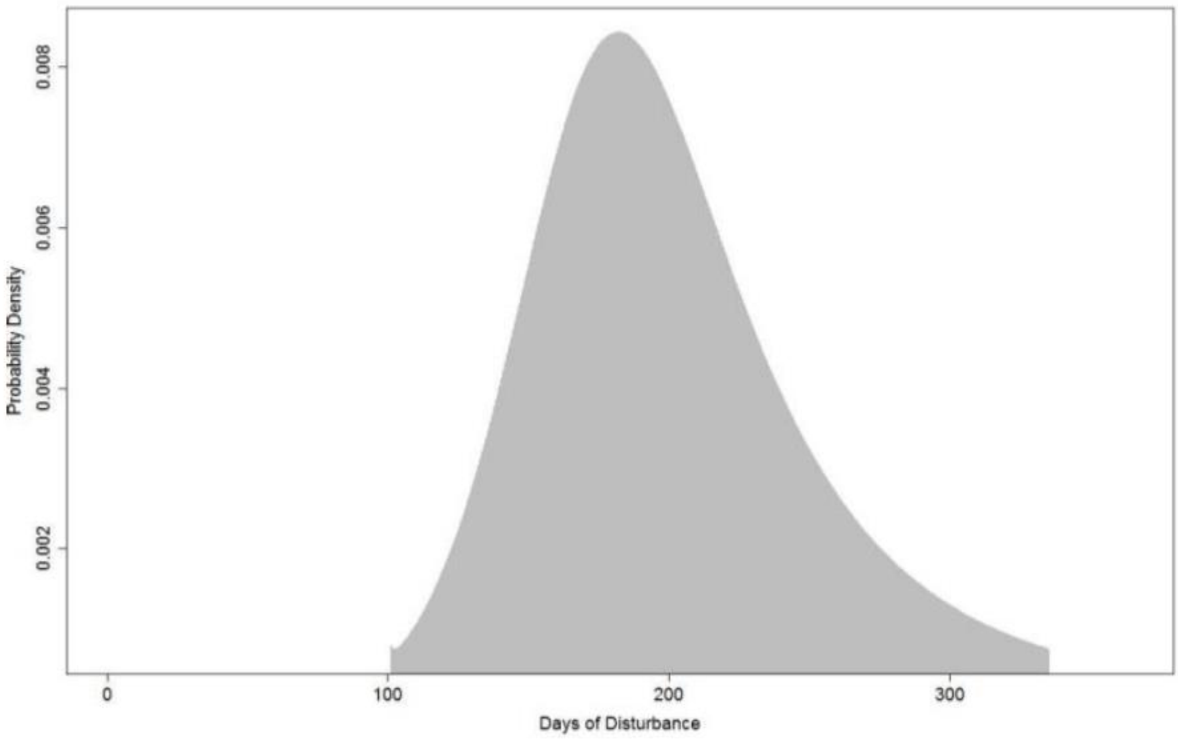

Figure 4 Probability distribution showing the consensus of the EE: the number of days of disturbance a pregnant grey seal female could 'tolerate' before disturbance has any effect on fertility.

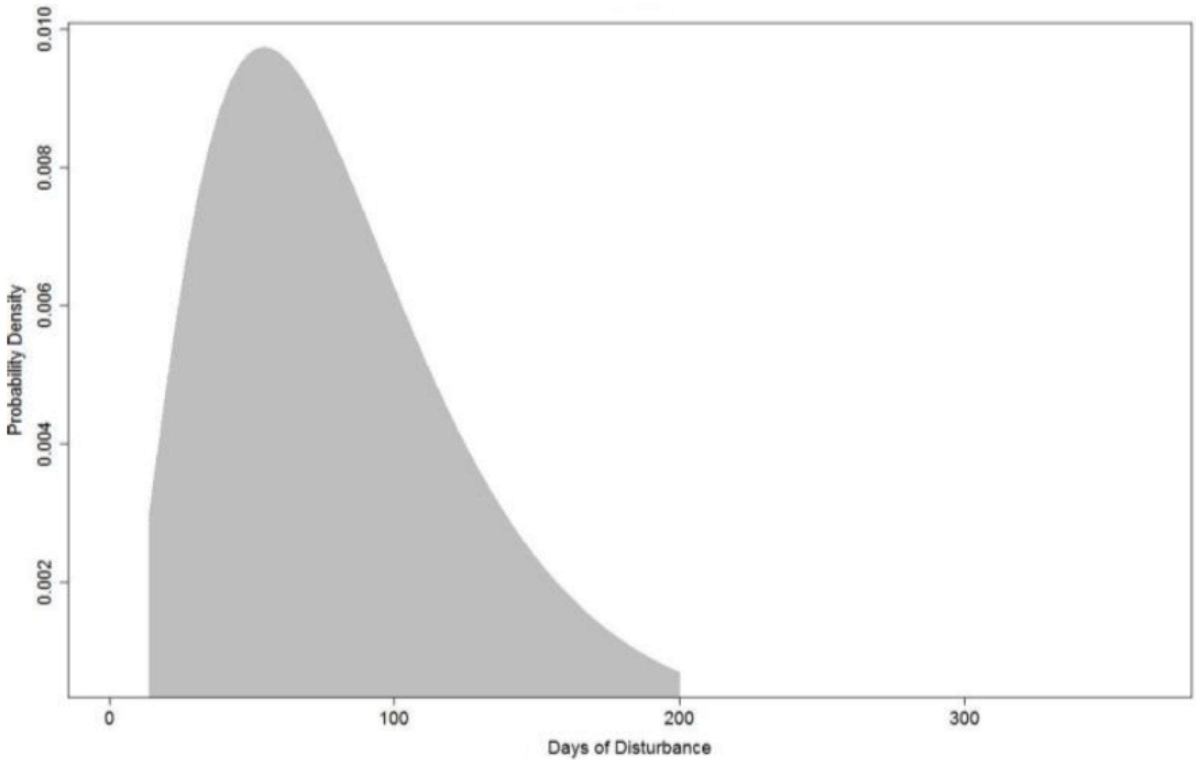

Figure 5 Probability distribution showing the consensus of the EE: the number of days of disturbance a 'weaned of the year' harbour or grey seal pup could 'tolerate' before it has any effect on survival.

2.1.1.3 Bottlenose dolphin

The iPCoD model for 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 (generally considered to be more responsive than bottlenose dolphins), and was amended to assume that disturbance resulted in 6 hours of non-foraging time (Booth *et al.*, 2019). Unfortunately, bottlenose dolphins were not included in the updated expert elicitation for disturbance, and thus the iPCoD model still assumes 24 hours of non-foraging time. This is unrealistic considering what we now know about marine mammal behavioural responses to pile driving. A recent study estimated energetic costs associated with disturbance from sonar, where it was assumed that 1 hour of feeding cessation was classified as a mild response, 2 hours of feeding cessation was classified as a strong response and 8 hours of feeding cessation was classified as an extreme response (Czapanskiy *et al.*, 2021). Assuming 24 hours of feeding cessation for bottlenose dolphins in the iPCoD model is significantly beyond that which is considered to be an extreme response, and will therefore over-estimate the true disturbance levels expected from the Offshore Development and is considered to be unrealistic.

2.1.2 Key limitations

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.

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 fact that the model assumes that bottlenose dolphins will not forage for 24 hours after being disturbed (detailed in section 2.1.1.3),
- The lack of density dependence in the model (meaning the population will not respond to any reduction in population size), and
- The level of environmental and demographic stochasticity in the model.

2.1.2.1 Lack of density dependence

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 model assumes no density dependence, 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. 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, which means that in reality, it would be expected that the impacted population would recover to carrying capacity (which 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) rather than continuing at a stable trajectory that is smaller than that of the un-impacted population.

2.1.2.2 Environmental and demographic stochasticity

The iPCoD model attempts to model some of the sources of uncertainty inherent in the calculation of the potential effects of disturbance on a 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).

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 3000 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).

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 Figure 6, after 25 years of simulation, the un-impacted population size varies between 176 (lower 2.5%) and 418 (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.

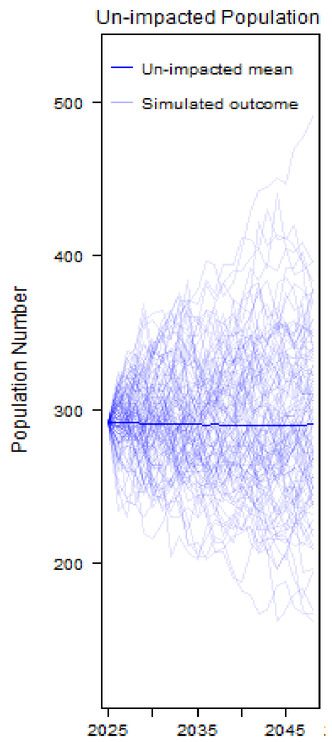

Figure 6 Simulated un-impacted (baseline) population size over the 25 years modelled.

2.1.2.3 Summary

All of the conservatisms built into the iPCoD model mean that the results are considered to be highly precautionary. Despite the limitations and uncertainties described above, this assessment has been carried out according to best practice, using the best available scientific information and is considered sufficient to carry out an adequate assessment. A level of caution should be taken into account when drawing conclusions.

2.2 Input parameters

2.2.1 Management Units

The following Management Units (MUs) were assumed in the assessment:

- Harbour porpoise: Celtic and Irish Sea MU, as advised in IAMMWG (2023): 62,517 porpoise
- Bottlenose dolphin: Irish Sea MU, total abundance obtained by summing the two SCANS IV blocks within the MU: 8,199 in CS-D + 127 in CS-E = 8,326 bottlenose dolphins
- Harbour seal: Southeast & East RoI & Northern Ireland MU: August haul-out counts from Morris and Duck (2019) and SCOS (2023) scaled to account for animals at sea: 1,365 seals
- Grey seal: Southeast & East RoI & Northern Ireland MU: August haul-out counts from Morris and Duck (2019) and SCOS (2023) scaled to account for animals at sea: 6,056 seals.

2.2.2 Demographic parameters

Demographic parameters were based on those presented in Sinclair *et al.* (2020) to obtain a stable population trajectory for harbour porpoise, bottlenose dolphins and harbour seals, and an increasing population trajectory for grey seals (Table 1).

Table 1 Demographic parameters used in the iPCoD modelling.

Parameter	Harbour porpoise	Bottlenose dolphin	Harbour seal	Grey seal
Population size	62,517	8,326	1,365	6,056
Calf/pup survival	0.8455	0.87	0.4	0.222
Juvenile survival	0.85	0.94	0.78	0.94
Adult survival	0.925	0.94	0.92	0.94
Fecundity rate	0.34	0.245	0.85	0.84
Age at which a calf/pup becomes independent of its mother	1	2	1	1
Age at which an average female gives birth to her first calf/pup	5	9	4	6
Proportion of animals in each vulnerable component of the population	Entire population is vulnerable (vulnmean = 1)			
Number of days of "residual" disturbance associated with each day of actual disturbance	Disturbance only lasts 1 single day (days = 0)			
Seasonal variation in disturbance	Disturbance numbers are the same throughout the year (seasons = 1)			

2.2.3 Piling schedules

Each of the five Projects provided indicative pile driving schedules. Where Projects had different piling schedules for monopiles and pin-piled jacket foundations, both were provided.

Piling schedule 1 (Figure 7):

- Monopiles at all five Projects
- Piling January 2027 to December 2029 inclusive

Piling schedule 2 (Figure 8):

- Monopiles at Arklow, Oriel and Codling
- Pin-pile jackets at NISA and Dublin
- Piling January 2027 to March 2031 inclusive.

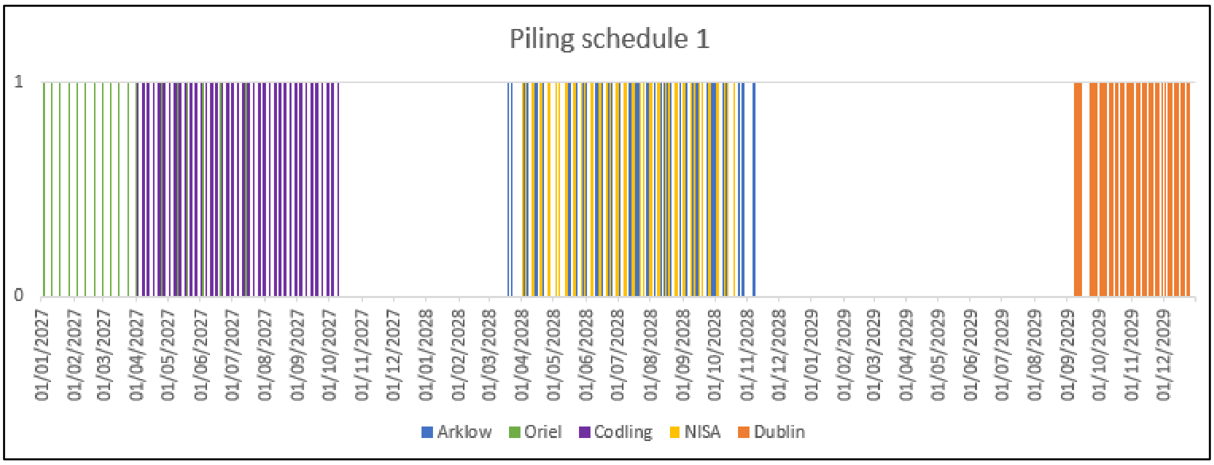

Figure 7 Piling schedule 1: Monopiles at all five Phase 1 Projects.

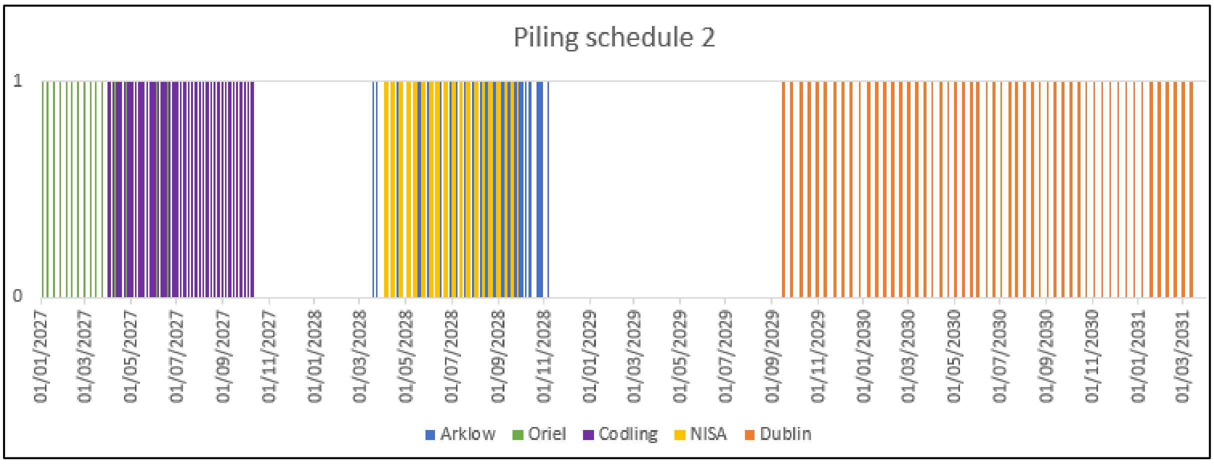

Figure 8 Piling schedule 2: Monopiles at Arklow, Oriel and Codling, pin-piled jackets at NISA and Dublin.

2.2.4 Disturbance

Each of the five Projects provided the maximum number of animals disturbed per day from pile driving activities, including for monopile and pin-piled scenarios where applicable. In order to make the results from each Project comparable, the same disturbance assessment approach was used for each species.

- For harbour porpoise, the dose-response function was used.
- For bottlenose dolphins, both the porpoise dose-response function and the Level B harassment threshold was used.
- For seals, the harbour seal dose-response function was used.

3 Results

3.1 Harbour porpoise

The iPCoD results show that the level of disturbance predicted under either piling schedule 1 or 2 is not sufficient to result in any changes at the population level, since the impacted population is predicted to continue at a stable trajectory at 99.6-99.7% of the size of the un-impacted population.

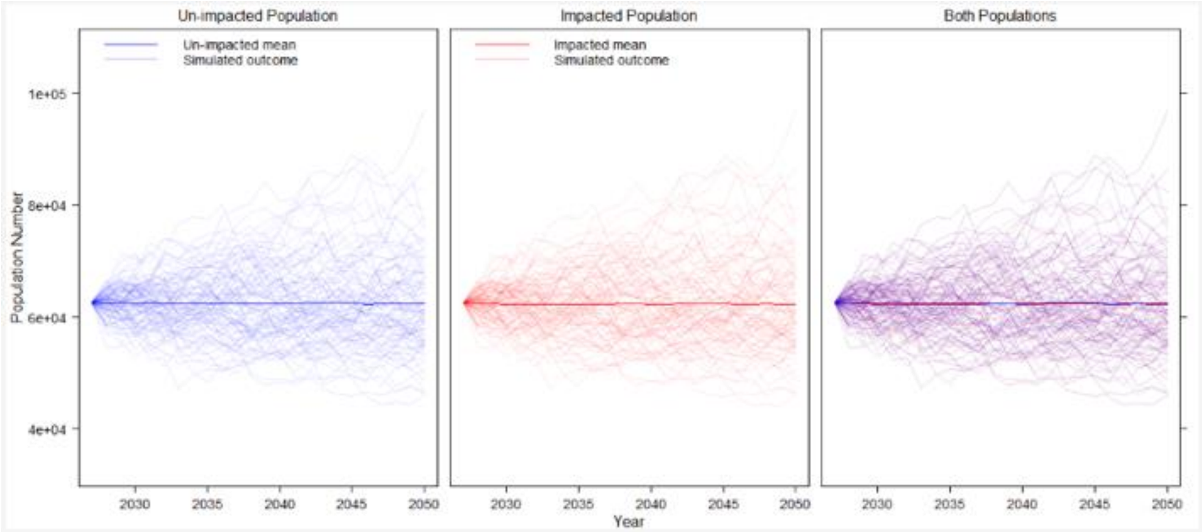

Figure 9 Predicted population trajectories for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations for piling schedule 1.

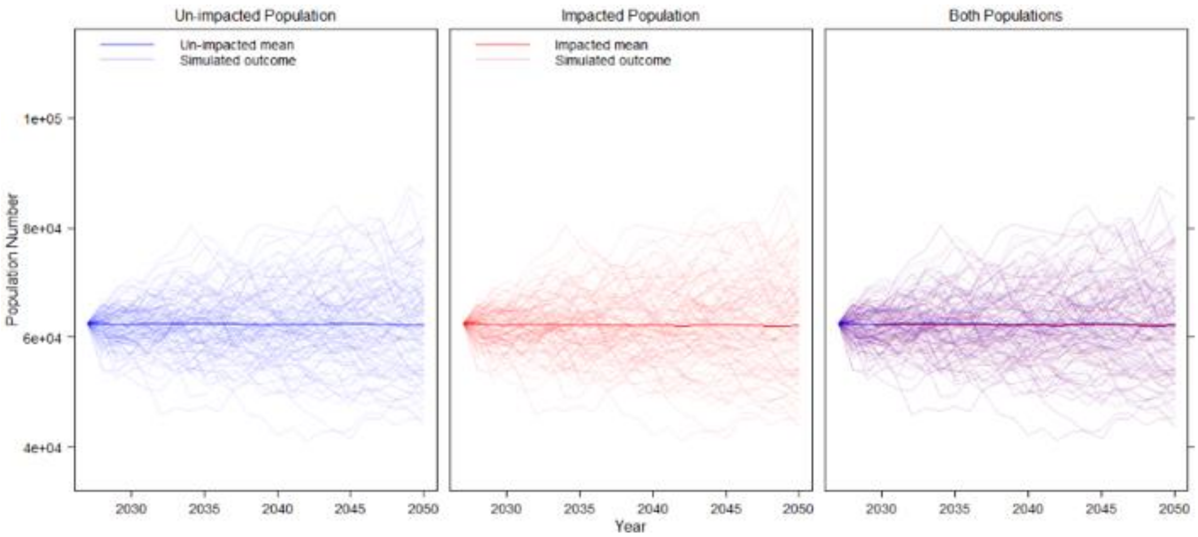

Figure 10 Predicted population trajectories for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations for piling schedule 2.

Table 2 Predicted mean population size for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations.

	Un-impacted population mean	Impacted population mean	Impacted as % of un-impacted
Piling schedule 1			
Before piling commences	62,516	62,516	100%
End 2027 – after 1 year piling	62,457	62,425	99.9%
End 2028 – after 2 years piling	62,526	62,415	99.8%
End 2029 – after 3 years piling	62,454	62,277	99.7%
End 2030 – 1 year after piling stops	62,491	62,297	99.7%
End 2035 – 6 years after piling stops	62,428	62,271	99.7%
End 2041 – 12 years after piling stops	62,476	62,319	99.7%
End 2047 – 18 years after piling stops	62,255	62,099	99.7%
Piling schedule 2			
Before piling commences	62,516	62,516	100.0%
End 2027 – after 1 year piling	62,565	62,530	99.9%
End 2028 – after 2 years piling	62,429	62,295	99.8%
End 2029 – after 3 years piling	62,423	62,199	99.6%
End 2030 – after 4 years piling	62,537	62,296	99.6%
End 2031 – after 5 years piling	62,562	62,297	99.6%
End 2032 – 1 year after piling stops	62,586	62,346	99.6%
End 2037 – 6 years after piling stops	62,440	62,204	99.6%
End 2043 – 12 years after piling stops	62,569	62,331	99.6%
End 2049 – 18 years after piling stops	62,346	62,110	99.6%

3.2 Bottlenose dolphin

3.2.1 Dose-response function

The results of the iPCoD modelling show a clear deviation from the baseline resulting from the pile driving disturbance across the five Phase 1 Projects. The mean impacted population size initially decreases very slightly from the mean un-impacted population size in response to piling, after which it continues on the same, stable trajectory at 95-96% of the mean un-impacted population size. As the iPCoD model does not currently allow for a density-dependent response (see Section 2.1.2.1), there is no way for the impacted population to increase in size after the piling disturbance. The impacted population does, however, continue on a stable trajectory in the long-term.

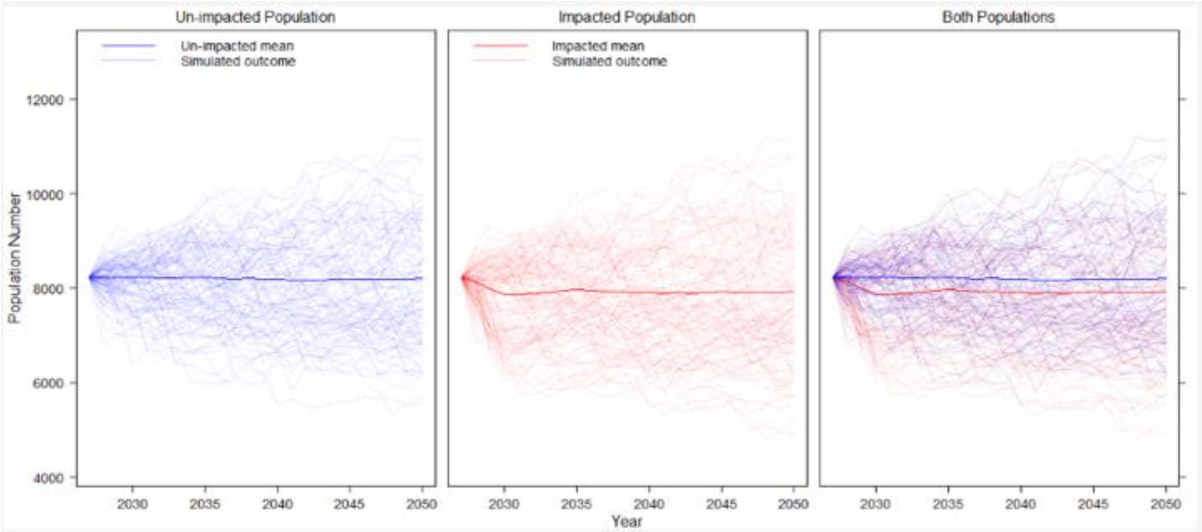

Figure 11 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for piling schedule 1 using the dose-response function.

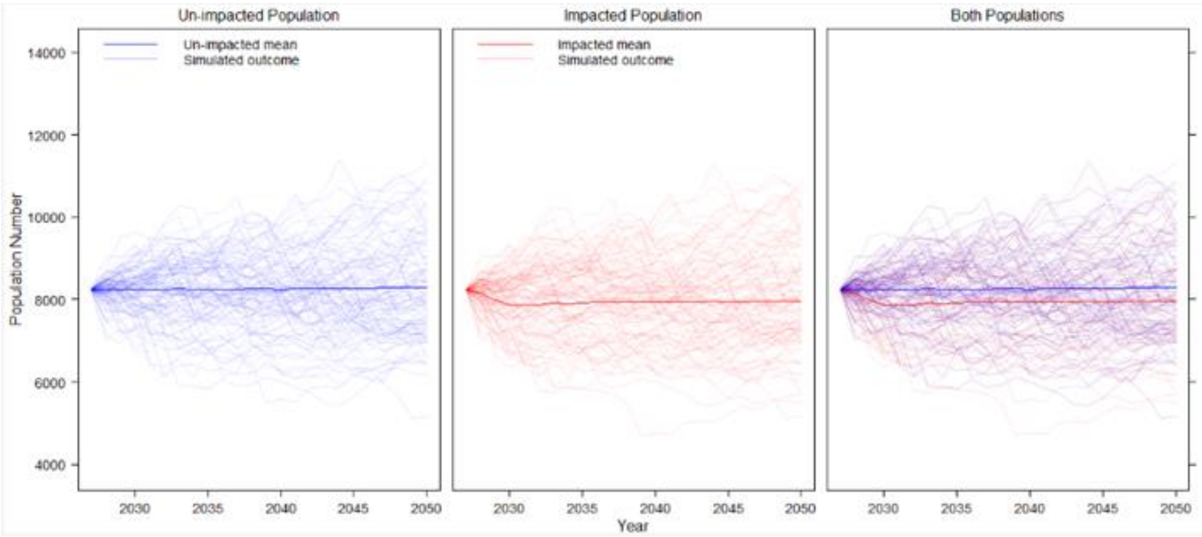

Figure 12 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for piling schedule 2 using the dose-response function.

Table 3 Predicted mean population size for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations using the dose-response function.

	Un-impacted population mean	Impacted population mean	Impacted as % of un-impacted
Piling schedule 1			
Before piling commences	8,236	8,236	100.0%
End 2027 – after 1 year piling	8,223	8,128	98.8%
End 2028 – after 2 years piling	8,235	7,991	97.0%
End 2029 – after 3 years piling	8,223	7,867	95.7%
End 2030 – 1 year after piling stops	8,231	7,878	95.7%
End 2035 – 6 years after piling stops	8,213	7,949	96.8%
End 2041 – 12 years after piling stops	8,180	7,899	96.6%
End 2047 – 18 years after piling stops	8,190	7,913	96.6%
Piling schedule 2			
Before piling commences	8,236	8,236	100.0%
End 2027 – after 1 year piling	8,233	8,144	98.9%
End 2028 – after 2 years piling	8,245	7,995	97.0%
End 2029 – after 3 years piling	8,249	7,875	95.5%
End 2030 – after 4 years piling	8,241	7,874	95.5%
End 2031 – after 5 years piling	8,251	7,872	95.4%
End 2032 – 1 year after piling stops	8,262	7,907	95.7%
End 2037 – 6 years after piling stops	8,259	7,949	96.2%
End 2043 – 12 years after piling stops	8,277	7,952	96.1%
End 2049 – 18 years after piling stops	8,291	7,968	96.1%

3.2.2 Level B harassment

The results of the iPCoD modelling show a clear deviation from the baseline resulting from the pile driving disturbance across the five Phase 1 Projects. The mean impacted population size initially decreases very slightly from the mean un-impacted population size in response to piling, after which it continues on the same, stable trajectory at 98% of the mean un-impacted population size. As the iPCoD model does not currently allow for a density-dependent response (see Section 2.1.2.1), there is no way for the impacted population to increase in size after the piling disturbance. The impacted population does, however, continue on a stable trajectory in the long-term.

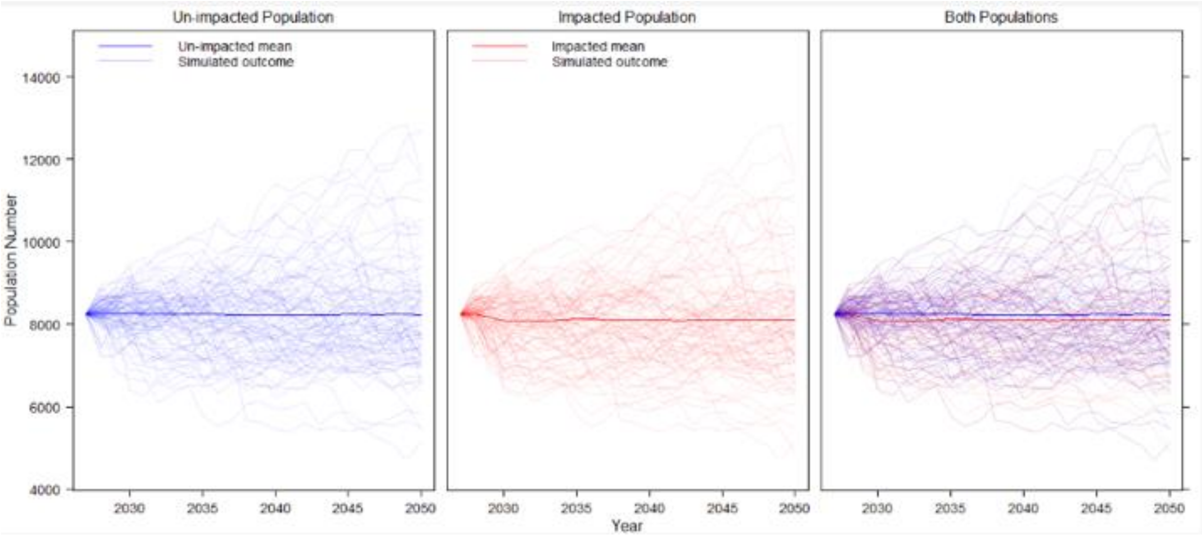

Figure 13 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for piling schedule 1 using the level B harassment threshold.

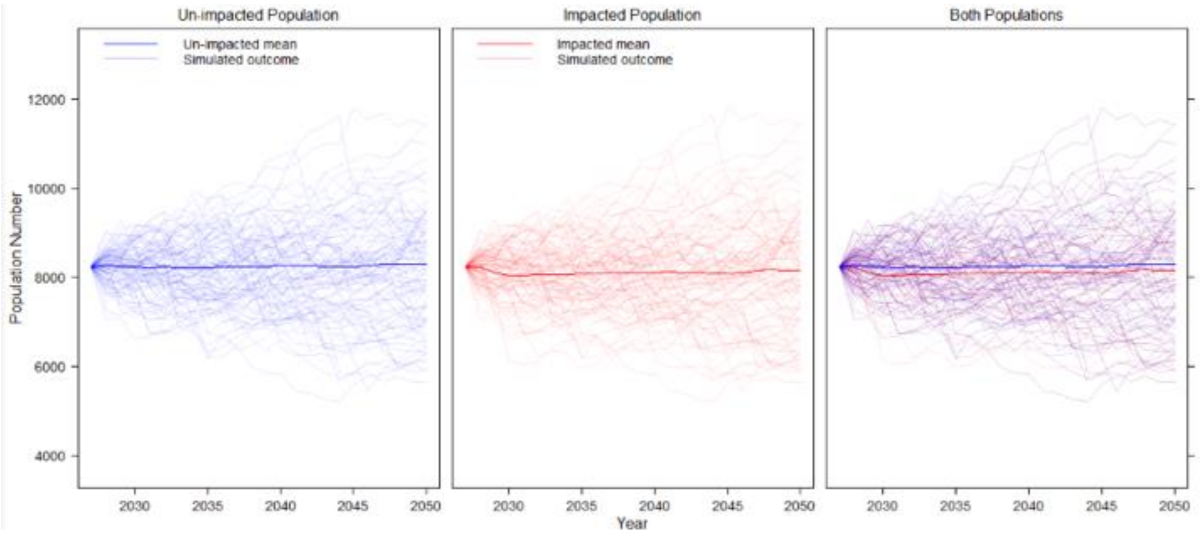

Figure 14 Predicted population trajectories for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations for piling schedule 2 using the level B harassment threshold.

Table 4 Predicted mean population size for the un-impacted (baseline) and impacted bottlenose dolphin iPCoD simulations using the level B harassment threshold.

	Un-impacted population mean	Impacted population mean	Impacted as % of un-impacted
Piling schedule 1			
Before piling commences	8,236	8,236	100.0%
End 2027 – after 1 year piling	8,260	8,246	99.8%
End 2028 – after 2 years piling	8,271	8,162	98.7%
End 2029 – after 3 years piling	8,265	8,081	97.8%
End 2030 – 1 year after piling stops	8,253	8,084	98.0%
End 2035 – 6 years after piling stops	8,241	8,117	98.5%
End 2041 – 12 years after piling stops	8,220	8,085	98.4%
End 2047 – 18 years after piling stops	8,246	8,113	98.4%
Piling schedule 2			
Before piling commences	8,236	8,236	100.0%
End 2027 – after 1 year piling	8,241	8,229	99.9%
End 2028 – after 2 years piling	8,225	8,110	98.6%
End 2029 – after 3 years piling	8,222	8,028	97.6%
End 2030 – after 4 years piling	8,211	8,033	97.8%
End 2031 – after 5 years piling	8,223	8,055	98.0%
End 2032 – 1 year after piling stops	8,215	8,057	98.1%
End 2037 – 6 years after piling stops	8,237	8,096	98.3%
End 2043 – 12 years after piling stops	8,233	8,087	98.2%
End 2049 – 18 years after piling stops	8,295	8,149	98.2%

3.3 Harbour seal

The iPCoD results show that the level of disturbance predicted under either piling schedule 1 or 2 is not sufficient to result in any changes at the population level, since the impacted population is predicted to continue at a stable trajectory at exactly the same size as the un-impacted population.

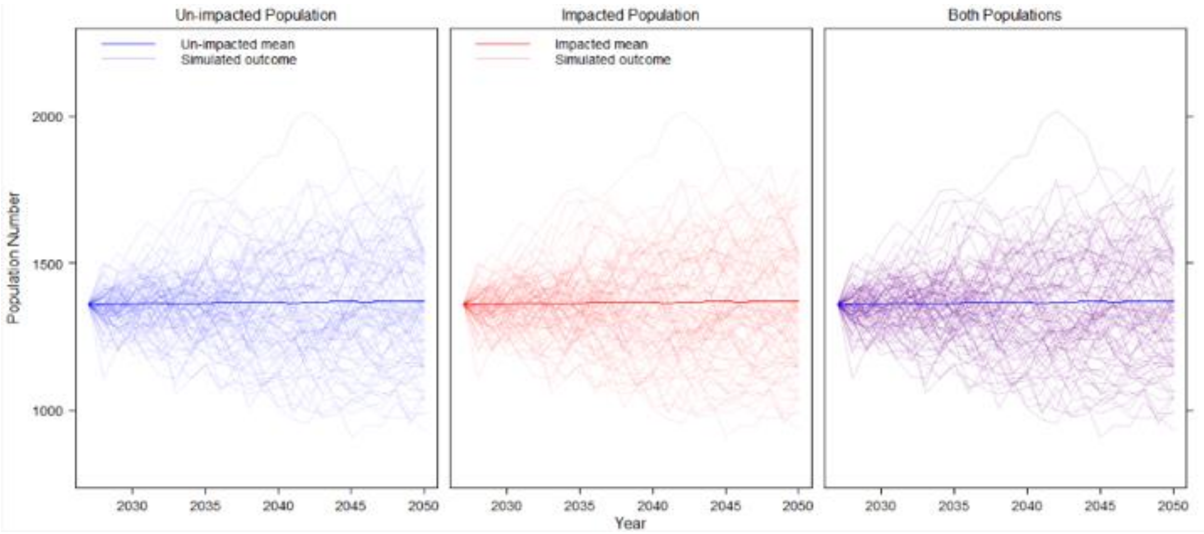

Figure 15 Predicted population trajectories for the un-impacted (baseline) and impacted harbour seal iPCoD simulations for piling schedule 1.

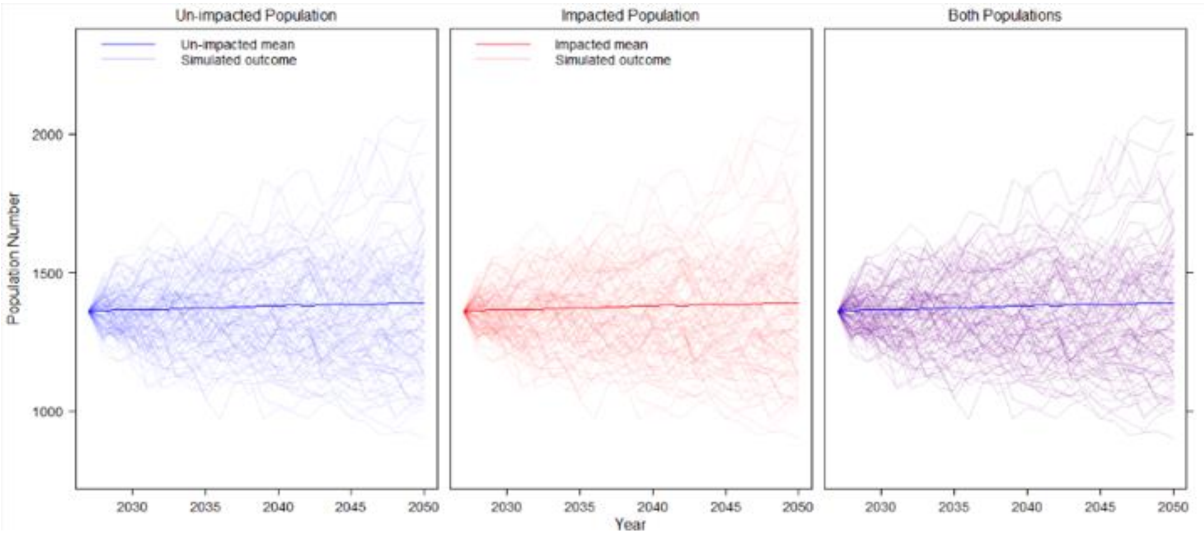

Figure 16 Predicted population trajectories for the un-impacted (baseline) and impacted harbour seal iPCoD simulations for piling schedule 2.

Table 5 Predicted mean population size for the un-impacted (baseline) and impacted harbour seal iPCoD simulations.

	Un-impacted population mean	Impacted population mean	Impacted as % of un-impacted
Piling schedule 1			
Before piling commences	1,360	1,360	100%
End 2027 – after 1 year piling	1,361	1,361	100%
End 2028 – after 2 years piling	1,360	1,360	100%
End 2029 – after 3 years piling	1,362	1,362	100%
End 2030 – 1 year after piling stops	1,364	1,364	100%
End 2035 – 6 years after piling stops	1,367	1,367	100%
End 2041 – 12 years after piling stops	1,368	1,368	100%
End 2047 – 18 years after piling stops	1,369	1,369	100%
Piling schedule 2			
Before piling commences	1,360	1,360	100%
End 2027 – after 1 year piling	1,363	1,363	100%
End 2028 – after 2 years piling	1,365	1,365	100%
End 2029 – after 3 years piling	1,366	1,366	100%
End 2030 – after 4 years piling	1,366	1,366	100%
End 2031 – after 5 years piling	1,367	1,367	100%
End 2032 – 1 year after piling stops	1,371	1,371	100%
End 2037 – 6 years after piling stops	1,376	1,376	100%
End 2043 – 12 years after piling stops	1,385	1,385	100%
End 2049 – 18 years after piling stops	1,389	1,389	100%

3.4 Grey seal

The iPCoD results show that the level of disturbance predicted under either piling schedule 1 or 2 is not sufficient to result in any changes at the population level, since the impacted population is predicted to continue at an increasing trajectory at exactly the same size as the un-impacted population.

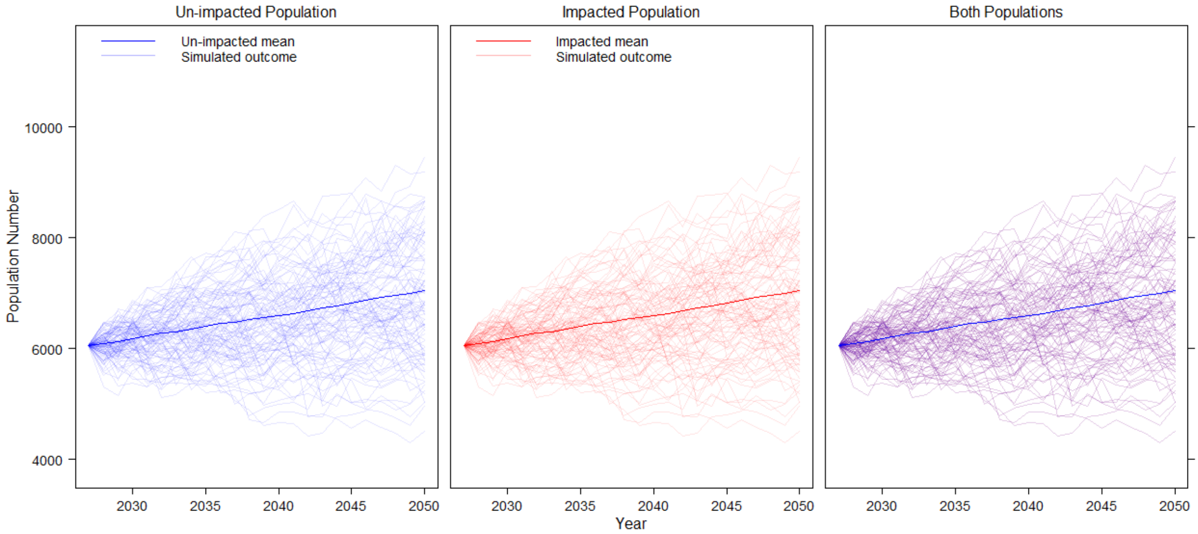

Figure 17 Predicted population trajectories for the un-impacted (baseline) and impacted grey seal iPCoD simulations for piling schedule 1.

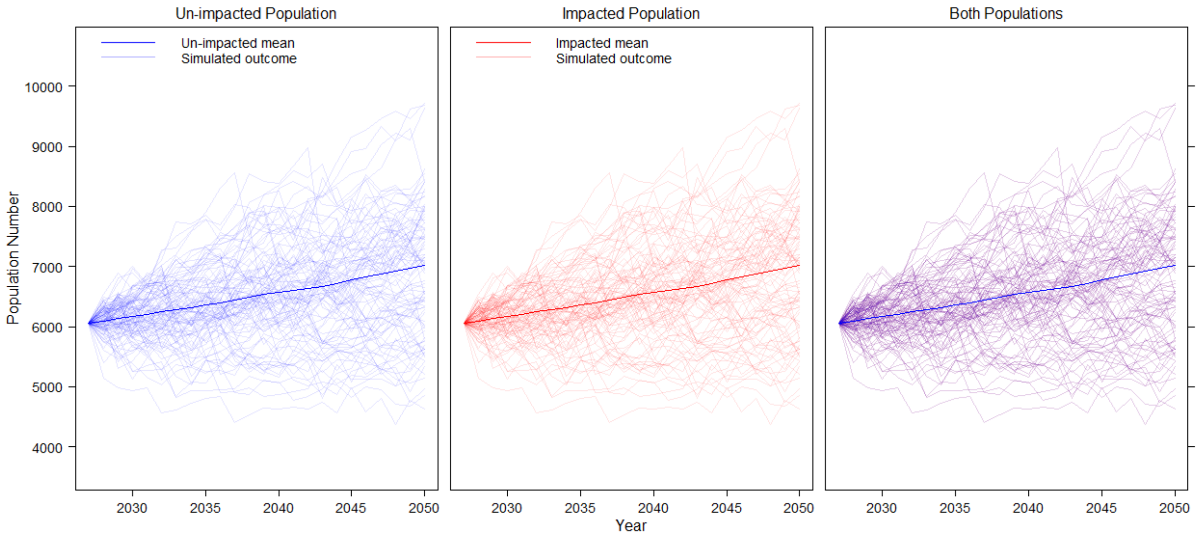

Figure 18 Predicted population trajectories for the un-impacted (baseline) and impacted grey seal iPCoD simulations for piling schedule 2.

Table 6 Predicted mean population size for the un-impacted (baseline) and impacted grey seal iPCoD simulations.

	Un-impacted population mean	Impacted population mean	Impacted as % of un-impacted
Piling schedule 1			
Before piling commences	6,060	6,060	100%
End 2027 – after 1 year piling	6,083	6,083	100%
End 2028 – after 2 years piling	6,127	6,127	100%
End 2029 – after 3 years piling	6,179	6,179	100%
End 2030 – 1 year after piling stops	6,223	6,223	100%
End 2035 – 6 years after piling stops	6,447	6,447	100%
End 2041 – 12 years after piling stops	6,682	6,682	100%
End 2047 – 18 years after piling stops	6,962	6,962	100%
Piling schedule 2			
Before piling commences	6,060	6,060	100%
End 2027 – after 1 year piling	6,090	6,090	100%
End 2028 – after 2 years piling	6,131	6,131	100%
End 2029 – after 3 years piling	6,170	6,170	100%
End 2030 – after 4 years piling	6,205	6,205	100%
End 2031 – after 5 years piling	6,255	6,255	100%
End 2032 – 1 year after piling stops	6,287	6,287	100%
End 2037 – 6 years after piling stops	6,498	6,498	100%
End 2043 – 12 years after piling stops	6,713	6,713	100%
End 2049 – 18 years after piling stops	7,013	7,013	100%

4 Conclusion

The cumulative population modelling has shown no significant impacts to any marine mammal species resulting from disturbance from pile driving at the five Irish Phase 1 Projects.

For harbour porpoise, the impacted population is predicted to continue at a stable trajectory at 99.6-99.7% of the size of the un-impacted population. As the iPCoD model does not currently allow for a density-dependent response (see Section 2.1.2.1), there is no way for the impacted population to increase in size after the piling disturbance. The impacted population does, however, continue on a stable trajectory in the long-term.

For bottlenose dolphins, the mean impacted population size initially decreases very slightly from the mean un-impacted population size in response to piling, after which it continues on the same, stable trajectory at 95-98% of the mean un-impacted population size. As the iPCoD model does not currently allow for a density-dependent response (see Section 2.1.2.1), there is no way for the impacted population to increase in size after the piling disturbance. The impacted population does, however, continue on a stable trajectory in the long-term.

For harbour and grey seals, the impacted population is predicted to continue at a stable trajectory at exactly the same size as the un-impacted population.

5 Literature Cited

Aarts, G., S. Brasseur, and R. Kirkwood. (2018). Behavioural response of grey seals to pile-driving. Wageningen Marine Research report C006/18.

Aspinall, W. (2010). A route to more tractable expert advice. Nature **463**:294.

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

Booth, C. G., F. Heinis, and H. J. (2019). Updating the Interim PCoD Model: Workshop Report - New transfer functions for the effects of disturbance on vital rates in marine mammal species. Report Code SMRUC-BEI-2018-011, submitted to the Department for Business, Energy and Industrial Strategy (BEIS), February 2019 (unpublished).

Brandt, M. J., A. Diederichs, K. Betke, and G. Nehls. (2011). Responses of harbour porpoises to pile driving at the Horns Rev II offshore wind farm in the Danish North Sea. Marine Ecology Progress Series **421**:205-216.

Brandt, M. J., A.-C. Dragon, A. Diederichs, M. A. Bellmann, V. Wahl, W. Piper, J. Nabe-Nielsen, and G. Nehls. (2018). Disturbance of harbour porpoises during construction of the first seven offshore wind farms in Germany. Marine Ecology Progress Series **596**:213-232.

Brandt, M. J., A. Dragon, A. Diederichs, A. Schubert, V. Kosarev, G. Nehls, V. Wahl, A. Michalik, A. Braasch, C. Hinz, C. Katzer, D. Todeskino, M. Gauger, M. Laczny, and W. Piper. (2016). Effects of offshore pile driving on harbour porpoise abundance in the German Bight. Report prepared for Offshore Forum Windenergie.

Brown, B. B. (1968). Delphi process: A methodology used for the elicitation of opinions of experts. Rand Corp Santa Monica CA.

Czapanskiy, M. F., M. S. Savoca, W. T. Gough, P. S. Segre, D. M. Wisniewska, D. E. Cade, and J. A. Goldbogen. (2021). Modelling short-term energetic costs of sonar disturbance to cetaceans using high-resolution foraging data. Journal of Applied Ecology **58**:1643-1657.

Dähne, M., A. Gilles, K. Lucke, V. Peschko, S. Adler, K. Krugel, J. Sundermeyer, and U. Siebert. (2013). Effects of pile-driving on harbour porpoises (*Phocoena phocoena*) at the first offshore wind farm in Germany. Environmental Research Letters **8**:025002.

Donovan, C., J. Harwood, S. King, C. Booth, B. Caneco, and C. Walker. (2016). Expert elicitation methods in quantifying the consequences of acoustic disturbance from offshore renewable energy developments. Advances in Experimental Medicine and Biology.

European Food Safety Authority. (2014). Guidance on Expert Knowledge Elicitation in Food and Feed Safety Risk Assessment.

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

Harwood, J., S. King, R. Schick, C. Donovan, and C. Booth. (2014). A protocol for Implementing the Interim Population Consequences of Disturbance (PCoD) approach: Quantifying and assessing the effects of UK offshore renewable energy developments on marine mammal populations. Report Number SMRUL-TCE-2013-014. Scottish Marine And Freshwater Science, 5(2).

Hoekendijk, J., J. Spitz, A. J. Read, M. F. Leopold, and M. C. Fontaine. (2018). Resilience of harbor porpoises to anthropogenic disturbance: Must they really feed continuously? Marine Mammal Science **34**:258-264.

IAMMWG. (2023). Review of Management Unit boundaries for cetaceans in UK waters (2023). JNCC Report 734, JNCC, Peterborough, ISSN 0963-8091.

Kahneman, D. (2011). Thinking, fast and slow. Macmillan.

King, S. L., R. S. Schick, C. Donovan, C. G. Booth, M. Burgman, L. Thomas, and J. Harwood. (2015). An interim framework for assessing the population consequences of disturbance. Pages 1150-1158 Methods in Ecology and Evolution.

Knol, A. B., P. Slottje, J. P. van der Sluijs, and E. Lebret. (2010). The use of expert elicitation in environmental health impact assessment: a seven step procedure. Environmental Health **9**:19.

Kynn, M. (2008). The 'heuristics and biases' bias in expert elicitation. Journal of the Royal Statistical Society: Series A (Statistics in Society) **171**:239-264.

MacMillan, D. C., and K. Marshall. (2006). The Delphi process–an expert-based approach to ecological modelling in data-poor environments. Animal Conservation **9**:11-19.

Martin, T. G., M. A. Burgman, F. Fidler, P. M. Kuhnert, S. Low-Choy, M. McBride, and K. Mengersen. (2012). Eliciting expert knowledge in conservation science. Conservation Biology **26**:29-38.

Morgan, M. G. (2014). Use (and abuse) of expert elicitation in support of decision making for public policy. Proceedings of the National Academy of Sciences **111**:7176-7184.

Morris, C., and C. Duck. (2019). Aerial thermal-imaging survey of seals in Ireland 2017 to 2018. National Parks and Wildlife Service. Department of Culture, Heritage and the Gaeltacht, 2019-10, Irish wildlife manuals, No.111, 2019.

O'Hagan, A., C. E. Buck, A. Daneshkhah, J. R. Eiser, P. H. Garthwaite, D. J. Jenkinson, J. E. Oakley, and T. Rakow. (2006). Uncertain judgements: eliciting experts' probabilities. John Wiley & Sons.

Rose, A., M. J. Brandt, R. Vilela, A. Diederichs, A. Schubert, V. Kosarev, G. Nehls, M. Volkenandt, V. Wahl, A. Michalik, H. Wendeln, A. Freund, C. Ketzer, B. Limmer, M. Laczny, and W. Piper. (2019). Effects of noise-mitigated offshore pile driving on harbour porpoise abundance in the German Bight 2014-2016 (Gescha 2). IBL Umweltplanung GmbH, Institut für Angewandte Ökosystemforschung Gmb, BioConsult SH GmbH & Co KG, Husum.

Runge, M. C., S. J. Converse, and J. E. Lyons. (2011). Which uncertainty? Using expert elicitation and expected value of information to design an adaptive program. Biological Conservation **144**:1214-1223.

Russell, D. J., G. D. Hastie, D. Thompson, V. M. Janik, P. S. Hammond, L. A. Scott-Hayward, J. Matthiopoulos, E. L. Jones, and B. J. McConnell. (2016). Avoidance of wind farms by harbour seals is limited to pile driving activities. Journal of Applied Ecology **53**:1642-1652.

Schwacke, L. H., T. A. Marques, L. Thomas, C. Booth, B. C. Balmer, A. Barratclough, K. Colegrove, S. De Guise, L. P. Garrison, and F. M. Gomez. (2021). Modeling population impacts of the Deepwater Horizon oil spill on a long-lived species with implications and recommendations for future environmental disasters. Conservation Biology.

SCOS. (2023). Scientific Advice on Matters Related to the Management of Seal Populations: 2022.

Sinclair, R., J. Harwood, and C. Sparling. (2020). Review of demographic parameters and sensitivity analysis to inform inputs and outputs of population consequences of disturbance assessments for marine mammals. **11**:74.

Sivle, L. D., P. H. Kvadsheim, C. Curé, S. Isojunno, P. J. Wensveen, F.-P. A. Lam, F. Visser, L. Kleivane, P. L. Tyack, and C. M. Harris. (2015). Severity of expert-identified behavioural responses of humpback whale, minke whale, and northern bottlenose whale to naval sonar. Aquatic Mammals **41**:469.

Wisniewska, D. M., M. Johnson, J. Teilmann, L. Rojano-Doñate, J. Shearer, S. Sveegaard, L. A. Miller, U. Siebert, and P. T. Madsen. (2016). Ultra-high foraging rates of harbor porpoises make them vulnerable to anthropogenic disturbance. Current Biology **26**:1441-1446.