Offshore Wind Power Limited

West of Orkney Offshore EIA Report

Volume 2, Supporting Study 10: Marine Mammal Underwater Noise Impact Assessment

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West of Orkney Wind Farm: Pre-construction and Construction Marine Mammal Underwater Noise Impact Assessment

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1 Executive summary

This report provides a quantitative impact assessment for underwater noise related impacts during pre-construction and construction related activities at the proposed West of Orkney Windfarm. This includes an assessment of the following impacts:

- Auditory injury and disturbance from pre-construction geophysical surveys,
- Auditory injury and disturbance from pre-construction UXO clearance,
- Auditory injury and disturbance from pile driving of foundations,
- Auditory injury and disturbance from other construction related activities (such as dredging and trenching etc),
- Disturbance from vessels, and
- Cumulative effects assessment of disturbance from underwater noise.

The underwater noise impact assessment has concluded **no significant impact** to any marine mammal species in EIA terms.

2 Introduction

2.1 The Project

Offshore Wind Power Limited (OWPL) (hereafter 'the Applicant') is proposing the development of the West of Orkney Windfarm (hereafter 'the offshore Project') within the ScotWind N1 Plan Option Area. SMRU Consulting were commissioned to undertake the quantitative underwater noise impact assessment for pre-construction and construction related activities, and the cumulative impact assessment to support the Offshore EIA Report marine mammal and megafauna impact assessment chapter (chapter 12: Marine mammals and megafauna). The results of this quantitative underwater noise impact assessment and cumulative impact assessment are summarised in chapter 12: Marine mammals and megafauna.

2.2 Baseline

The marine mammal baseline characterisation is detailed in full in chapter 12: Marine mammals and megafauna. **Table 2.1** identifies the Management Unit (MU) and density estimates taken forward in this quantitative impact assessment for each marine mammal species[1]. NatureScot requested that the UK portion of the MU is presented as the relevant reference population for each cetacean species. It is worth noting that while the IAMMWG (2022) report does give the portion of the MU within the UK Exclusive Economic Zone (EEZ), there is no explanation as to the biological basis of this division of the MU. Since, by definition, the entire MU is *'a geographical area in which the animals of a particular species are found to which management of human activities is applied'*, this is considered to be more appropriate to assess impacts against. This quantitative assessment provides results assuming both the UK portion of the MU (referred throughout as the "UK MU") and the full MU (referred throughout as the "full MU"). The densities used within the underwater noise assessment were agreed with NatureScot in a consultation meeting in May 2023.

[1] Note: this report includes species assessed quantitatively only. Other species that are less frequent in the area have been included qualitatively in chapter 12: Marine mammals and megafauna. This includes humpback whale, white-sided dolphin and killer whales.

Table 2.1 Species, management units and baseline density estimates for use in the impact assessment.

Species	MU	UK MU size	Full MU size	Density (#/km²)
Harbour porpoise	North Sea and West Scotland MUs	183,937	375,537	0.15
White beaked dolphin	CGNS MU	34,025	43,951	0.19
Common dolphin	CGNS MU	57,417	102,656	0.01
Risso's dolphin	CGNS MU	8,687	12,262	0.0135
Minke whale	CGNS MU	10,288	20,118	0.01
Harbour seal	North Coast and Orkney SMU	NA	1,951	Grid cell specific (average density across OAA + ECC = 0.009)
Grey seal	North Coast and Orkney SMU	NA	34,191	Grid cell specific (average density across OAA + ECC = 0.581)

3 Methods

3.1 Impact Assessment

The assessment process will consider the potential magnitude of the change to the baseline conditions arising from the Project and the sensitivity of the particular receptor under consideration, as well as any embedded mitigation measures. The sensitivity criteria used in the marine mammal assessment are defined in Table 3.1 and the impact magnitude criteria used for the marine mammal assessment are defined in Table 3.2. The matrix used to identify the consequence of effect is shown in Table 3.3 and the definitions of consequence of effect and associated significance are detailed in Table 3.4.

Table 3.1 Sensitivity criteria used for the marine mammal assessment

Sensitivity	Definition
High	Receptor has no ability to tolerate a particular effect causing a significant change in individual vital rates (survival and reproduction); Receptor has no ability to recover from any effect on vital rate (survival and reproduction); Receptor has no ability to adapt behaviour so that individual vital rates (survival and reproduction) are highly likely to be significantly affected; and/or Receptor of conservation / economic value to an extent that is international or nationally important.

Medium	Receptor has a limited ability to tolerate a particular effect which may cause a significant change in individual vital rates (survival and reproduction); Receptor has a limited ability to recover from any effect on vital rates (survival and reproduction); Receptor has a limited ability to adapt behaviour so that individual vital rates (survival and reproduction) may be significantly affected; and/or Receptor of conservation / economic value to an extent that is regionally important.
Low	Receptor has some tolerance to a particular effect with no significant change in individual vital rates (survival and reproduction); Receptor is able to recover from any effect on vital rates (survival and reproduction); Receptor has a limited ability to adapt behaviour so that individual vital rates (survival and reproduction) may be affected, but not at a significant level; and/or Receptor of conservation / economic value to an extent that is locally important.
Negligible	Receptor is able to tolerate a particular effect without any impact on individual vital rates (survival and reproduction); Receptor is able to return to previous behavioural states/activities once the impact has ceased; Receptor is able to adapt behaviour so that individual vital rates (survival and reproduction) are not affected; and/or Receptor is widespread / common and is of low conservation / economic value.

Table 3.2 Impact magnitude criteria used for the marine mammal assessment.

Magnitude	Definition
High	Total change or major alteration to the conservation status on integrity of the receptor or key elements / features of the baseline conditions; Impact occurs over a large scale or spatial geographical extent and/or is long-term (i.e. 15 years or more) or permanent in nature; and/or High frequency (occurring repeatedly or continuously for a long period of time) and/or at high intensity.
Medium	Partial change or alteration to the conservation status or integrity of the receptor or one or more key elements / features of the baseline conditions; Impact occurs over a medium scale/spatial extent and/or has a medium-term duration (i.e. 6 to 15 years); and/or Medium to high frequency (occurring repeatedly or continuously for a moderate length of time) and/or at moderate intensity or occurring occasionally/intermittently for short periods of time but at a moderate to high intensity.

Low	Minor shift away from the baseline conditions but unlikely to have a significant effect on the conservation status or integrity of the receptor; Impact occurs over a local to medium scale/spatial extent and/or has a short (i.e. 1 to 5 years) to medium-term duration; and/or Impact is unlikely to occur or at a low frequency (occurring occasionally / intermittently for short periods of time at a low intensity).
Negligible	Very slight change from baseline condition that will not affect the conservation status or integrity of the receptor; Impact of highly localised and short term with full rapid recovery expected to result in very slight or imperceptible changes to baseline conditions or receptor population; and/or The impact is very unlikely to occur and if it does will occur at very low frequency or intensity.

Table 3.3 Consequence of effect used in the marine mammal assessment.

Consequence		Magnitude			
		Negligible	**Low**	**Medium**	**High**
Sensitivity	**Negligible**	Negligible	Negligible	Negligible	Negligible
	Low	Negligible	Negligible	Minor	Minor
	Medium	Negligible	Minor	**Moderate**	**Moderate**
	High	Negligible	Minor	**Moderate**	**Major**

Table 3.4 Definitions of consequence of effect and associated significance.

Category	Definition
Major	A fundamental change to the environment or receptor, resulting in a significant effect.
Moderate	A material but non-fundamental change to the environment or receptor, resulting in a possible significant effect.
Minor	A detectable but non-material change to the environment or receptor resulting in no significant effect of small-scale temporary changes.
Negligible	No detectable change to the environment or receptor resulting in no significant effect.

3.2 Auditory injury (Permanent Threshold Shift)

Exposure to loud sounds can lead to a reduction in hearing sensitivity (a shift in hearing threshold), which is generally restricted to particular frequencies. This threshold shift results from physical injury to the auditory system and may be permanent (PTS). The PTS-onset thresholds used in this assessment are those presented in Southall *et al.,* (2019) (**Table 3.5**). The method used to calculate PTS-onset impact ranges for both 'instantaneous' PTS (SPL_{peak}), and 'cumulative' PTS (SEL_{cum}, over 24 hours) are detailed in see Supporting Study 11 (SS11): Underwater noise modelling report.

Table 3.5: PTS-onset thresholds for impulsive noise (from Southall et al 2019).

Hearing group	Species	Cumulative PTS (SEL_{cum} dB re 1 µPa²s weighted)	Instantaneous PTS (SPL_{peak} dB re 1 µPa unweighted)
Very High Frequency (VHF) Cetacean	Harbour porpoise	155	202
High Frequency (HF) Cetacean	White-beaked dolphin Common dolphin Risso's dolphin	185	230
Low Frequency (LF) Cetacean	Minke whale	183	219
Phocid (PCW)	Grey seal Harbour seal	185	218

In calculating the noise level that animals are likely to receive during the whole piling sequence, species-specific fleeing speeds were assumed. These are presented in Table 3.6 and are derived from recommendations from NatureScot (then SNH) for porpoise, minke whales, dolphins and seals (Scottish Natural Heritage, 2016). The calculated PTS-onset impact ranges therefore represent the minimum starting distances from the piling location for animals to escape and prevent them from receiving a dose higher than the threshold.

Table 3.6 Marine mammal swimming speed used in the cumulative PTS-onset assessment.

Hearing group	Species	Speed (m/s)
Very High Frequency (VHF) Cetacean	Harbour porpoise	1.4
High Frequency (HF) Cetacean	White-beaked dolphin Common dolphin Risso's dolphin	1.52
Low Frequency (LF) Cetacean	Minke whale	2.1
Phocid (PCW)	Grey seal Harbour seal	1.8

Southall *et al.,* (2019) propose the SPL_{z-p} (being either unweighted or flat weighted across the entire frequency band of a hearing group). This is because the direct mechanical damage to the auditory system that is associated with high peak sound pressures is not frequency dependent (i.e., restricted to the audible frequency range of a species). The physiological damage that sound energy can cause is mainly restricted to energy occurring in the frequency range of a species' hearing range. Therefore, for the cumulative sound exposure level (SEL_{cum}), sound was weighted based on species group specific weighting curves given in Southall *et al.,* (2019) (Figure 3.1).

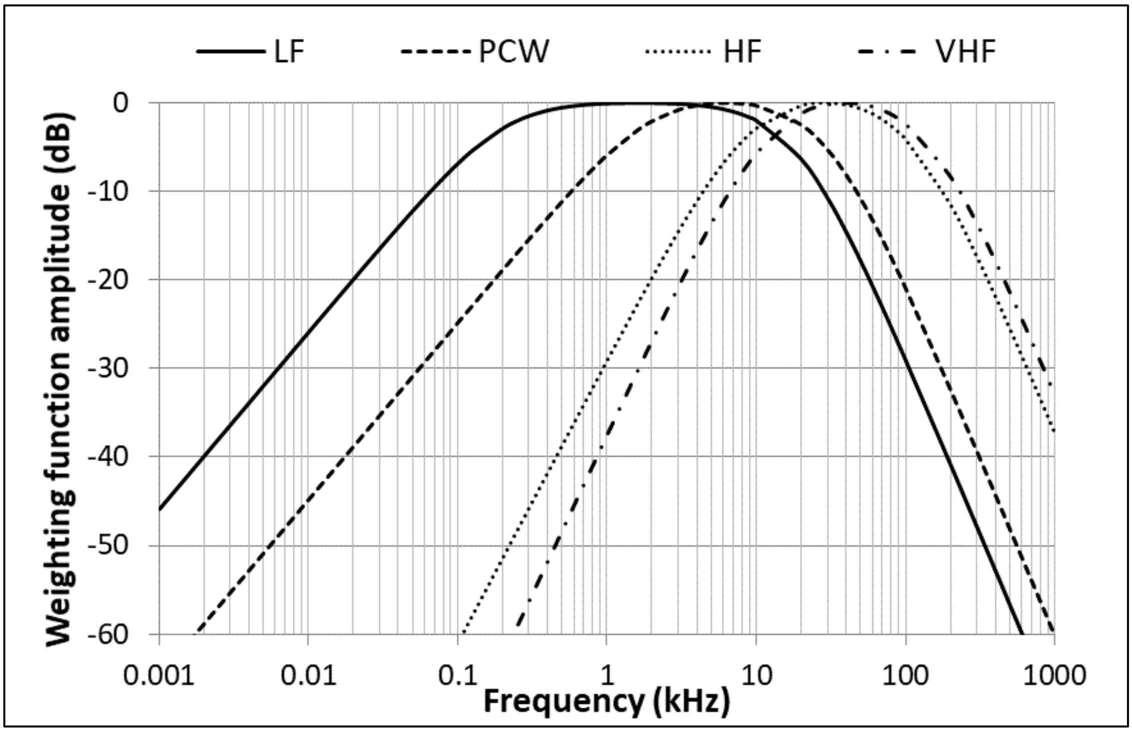

Figure 3.1 Auditory weighting functions for low frequency (LF), high frequency (HF) and very high frequency (VHF) cetaceans as well as phocid (PCW) pinnipeds in water according to Southall *et al.,* (2019).

3.3 PTS – pile driving

To quantify the impact of noise with regard to PTS, the PTS-onset impact range (the area around the piling location within which the noise levels exceed the PTS-onset threshold) was determined using the thresholds presented by Southall *et al.,* (2019) (Table 3.6). Based on agreed density estimates for each species presented in Supporting Study 9 (SS9): Marine mammal and megafauna baseline report, the number of animals expected within the PTS-onset impact range were calculated and presented as a proportion of the relevant (estimated) population size.

The SEL_{cum} threshold for PTS-onset considers the sound exposure level received by an animal and the duration of exposure, accounting for the accumulated exposure over the duration of an activity within a 24-hour period. Southall *et al.,* (2019) recommends the application of SEL_{cum} for the individual activity alone (i.e., not for multiple activities occurring within the same area or over the same time). To inform this impact assessment, sound modelling considered the SEL_{cum} over a piling event. For scenarios where more than one piling event is likely within 24 hours, additional modelling was conducted (e.g. 2 pin piles/day or 4 pin piles/day, see section 8.1).

3.4 PTS – UXO clearance

The Southall *et al.,* (2019) impulsive thresholds (Table 3.6) were used to assess the PTS-onset impact from UXO detonation from a range of charge sizes. The number of animals expected in the PTS-onset impact range were calculated and presented as a proportion of the relevant population size.

3.5 PTS – other construction activities

In the absence of specific guidance on the PTS-onset thresholds that should be used to assess the noise impacts from non-piling noise (including vessel activity, dredging, trenching and rock dumping) noise modelling was undertaken using the Southall *et al.,* (2019) continuous noise thresholds (non-impulsive). Full results are presented in SS11: Underwater noise modelling report to estimate the number and range of animals predicted to experience PTS from other construction activities.

3.6 Disturbance

Beyond the zone of PTS, noise levels are not anticipated to cause injury but can still cause disturbance. Unlike the thresholds for auditory injury, there are currently no established regulatory guidance documents and few published scientific articles providing clear advice on the approach to assessment of disturbance from underwater noise on marine mammal species.

In Environmental Impact Assessments, disturbance is considered to be the impact of anthropogenic noise on the behaviour of marine mammals and is typically considered to be impacts that result in the displacement of animals. Responses to disturbance are inherently variable and will consider a number of factors including prior exposure and learning.

3.7 Disturbance - pile driving

The assessment of disturbance from pile driven foundations was based on the current best practice methodology, making use of the best available scientific evidence. This incorporates the application of dose-response functions rather than fixed behavioural thresholds.

For example, the latest guidance provided in Southall *et al.,* (2019) is that "Apparent patterns in response as a function of received noise level (sound pressure level) highlighted a number of potential errors in using all-or-nothing "thresholds" to predict whether animals will respond. Tyack and Thomas (2019) subsequently and substantially expanded upon these observations. The clearly evident variability in response is likely attributable to a host of contextual factors, which emphasizes the importance of estimating not only a dose-response function but also characterizing response variability at any dosage".

Noise contours at 5 dB intervals were generated by noise modelling and were overlain on species density surfaces to predict the number of animals potentially disturbed. This allowed for the quantification of the number of animals that will potentially respond.

Compared with the EDR and fixed noise threshold approaches, the application of a dose-response curve allows for more realistic assumptions about animal responses varying with dose, which is supported by a growing number of studies. A dose-response function is used to quantify the probability of a response from an animal to a dose of a certain stimulus or stressor (Dunlop *et al.,* 2017) and is based on the assumption that not all animals in an impact zone will respond. The dose can either be determined using the distance from the sound source or the received weighted or unweighted sound level at the receiver (Sinclair *et al.,* 2021).

3.7.1 Harbour porpoise dose-response function

To estimate the number of harbour porpoise predicted to experience behavioural disturbance as a result of pile driving, this impact assessment uses the harbour porpoise dose-response function presented in Graham *et al.,* (2017a) (**Figure 3.2**). The Graham *et al.,* (2017a) dose-response function was developed using data on harbour porpoise collected during the first six weeks of piling during Phase 1 of the Beatrice Offshore Wind Farm monitoring program. Changes in harbour porpoise occurrence (detection positive hours per day) were estimated using 47 CPODs[2] placed around the wind farm site during piling and compared with baseline data from 12 sites outside of the wind farm area prior to the commencement of operations, to characterise this variation in occurrence. Harbour

[2] CPODs monitor the presence and activity of toothed cetaceans by the detection within the CPOD app of the trains of echolocation clicks that they make. See https://www.chelonia.co.uk/index.html

porpoise were considered to have exhibited a behavioural response to piling when the proportional decrease in occurrence was greater than 0.5. The probability that harbour porpoise occurrence did or did not show a response to piling was modelled along with the received single-pulse sound exposure levels piling source levels based on the received noise levels (Graham *et al.,* 2017a).

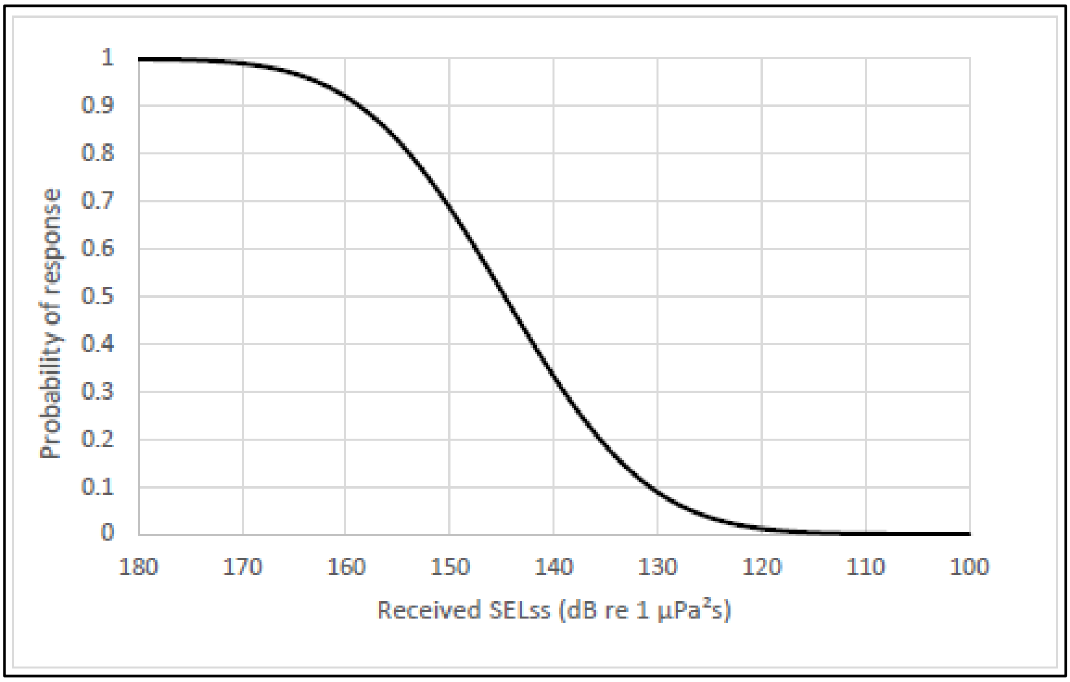

Figure 3.2: Relationship between the proportion of harbour porpoise responding and the received single strike SEL (SELss) (Graham *et al.,* 2017a).

Since the initial development of the dose-response function in 2017, additional data from the remaining pile driving events at Beatrice Offshore Windfarm have been processed, and are presented in Graham *et al.,* (2019). The passive acoustic monitoring showed a 50% probability of harbour porpoise response (a significant reduction in detection relative to baseline) within 7.4 km at the first location piled, with decreasing response levels over the construction period to a 50% probability of response within 1.3 km by the final piling location (**Figure 3.3**) (Graham *et al.,* 2019). Therefore, using the dose-response function derived from the initial piling events for all piling events in the impact assessment is precautionary, as evidence shows that harbour porpoise response is likely to diminish over the construction period.

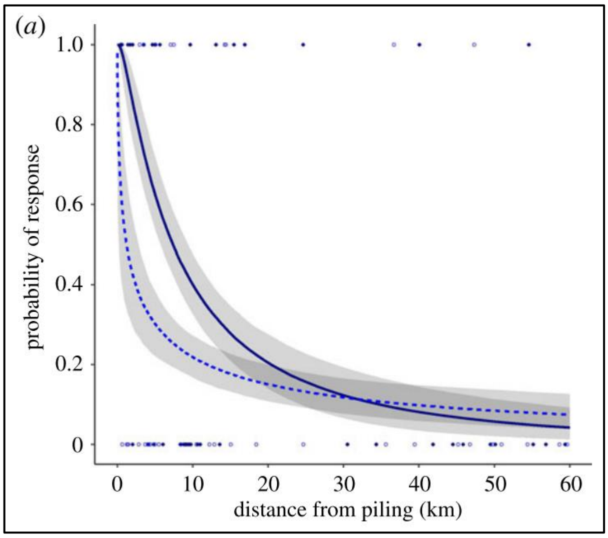

Figure 3.3 The probability of a harbour porpoise response (24 h) in relation to the partial contribution of distance from piling (solid navy line) and the final location piled (dashed blue line)[3]. Obtained from Graham *et al.,* (2019).

In the absence of species-specific data on white-beaked dolphins, common dolphins, Risso's dolphins or minke whales, this dose-response function has been adopted for all cetaceans; however, it is considered that the application of the harbour porpoise dose-response function to other cetacean species is highly precautionary. Harbour porpoise are considered to be particularly responsive to anthropogenic disturbance, with playback experiments showing avoidance reactions to very low levels of sound (Tyack, 2009) and multiple studies showing that harbour porpoise respond (avoidance and reduced vocalisation) to a variety of anthropogenic noise sources to distances of multiple kilometres (e.g., Brandt *et al.,* 2013, Thompson *et al.,* 2013, Tougaard *et al.,* 2013, Brandt *et al.,* 2018, Sarnocinska *et al.,* 2019, Thompson *et al.,* 2020, Benhemma-Le Gall *et al.,* 2021).

Various studies have shown that other cetacean species show comparatively less of a disturbance response from underwater noise compared with harbour porpoise. For example, through an analysis of 16 years of marine mammal observer data from seismic survey vessels, Stone *et al.,* (2017) found a significant reduction in harbour porpoise detection rates when large seismic airgun arrays were actively firing, but not for bottlenose dolphins. While the strength and significance of responses varied between harbour porpoise and other dolphin species for different measures of effect, the study emphasised the sensitivity of the harbour porpoise (Stone *et al.,* 2017). In the Moray Firth, bottlenose dolphins have been shown to remain in the impacted area during both seismic activities and pile installation activities (Fernandez-Betelu *et al.,* 2021) which highlights a lack of complete displacement response. Likewise, other high-frequency cetacean species, such as striped and common dolphins, have been shown to display less of a response to underwater noise signals and construction-related activities compared with harbour porpoise (e.g. Kastelein *et al.,* 2006, Culloch *et al.,* 2016).

3.7.2 Seal dose-response function

For harbour seals, the dose-response function adopted was based on the data presented in (Whyte *et al.,* 2020) (**Figure 3.4**). Whyte *et al.,* (2020) uses the same telemetry data as that presented in Russell

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[3] Predicted assuming the number of AIS vessel locations within 1 km; confidence intervals (shaded areas) estimated for uncertainty in fixed effects only. Harbour porpoise occurrence was considered to have responded to piling when the proportional decrease in occurrence (DPH) exceeded a threshold of 0.5. Points show actual response data for the first location piled (filled navy circles) and the final location piled (open blue circles).

et al., (2016b) and Russell and Hastie (2017) (harbour seals tagged in the Wash to assess how seal usage changed in relation to the pile driving activities at the Lincs Offshore Wind farm in 2011-2012). In the Whyte *et al.,* (2020) dose-response function it has been assumed that all seals are displaced at sound exposure levels above 180 dB re 1 µPa^{2}s. This is a conservative assumption since there were no data presented in the study for harbour seal responses at this level. It is also important to note that the percentage decrease in response in the categories 170≤175 and 175≤180 dB re 1 µPa^{2}s is slightly anomalous (higher response at a lower sound exposure level) due to the small number of spatial cells included in the analysis for these categories (n= 2 and 3 respectively). Given the large confidence intervals on the data, this assessment presents the mean number of seals predicted to be disturbed alongside the 95% confidence intervals, for context.

There are no corresponding data for grey seals and, as such, the harbour seal dose-response function is applied to the grey seal disturbance assessment. This is considered to be an appropriate proxy for grey seals, since both species are categorised within the same functional hearing group. However, it is likely that this over estimates the grey seal response, since grey seals are considered to be less sensitive to behavioural disturbance than harbour seals and could tolerate more days of disturbance before there is likely to be an effect on vital rates (Booth *et al.,* 2019). Recent studies of tagged grey seals have shown that there is vast individual variation is responses to pile driving, with some animals not showing any evidence of a behavioural response (Aarts *et al.,* 2018). Likewise, if the impacted area is considered to be a high quality foraging patch, it is likely that some grey seals may show no behavioural response at all, given their motivation to remain in the area for foraging (Hastie *et al.,* 2021). Therefore, the adoption of the harbour seal dose-response function for grey seals is considered to be precautionary as it will likely over-estimate the potential for impact on grey seals.

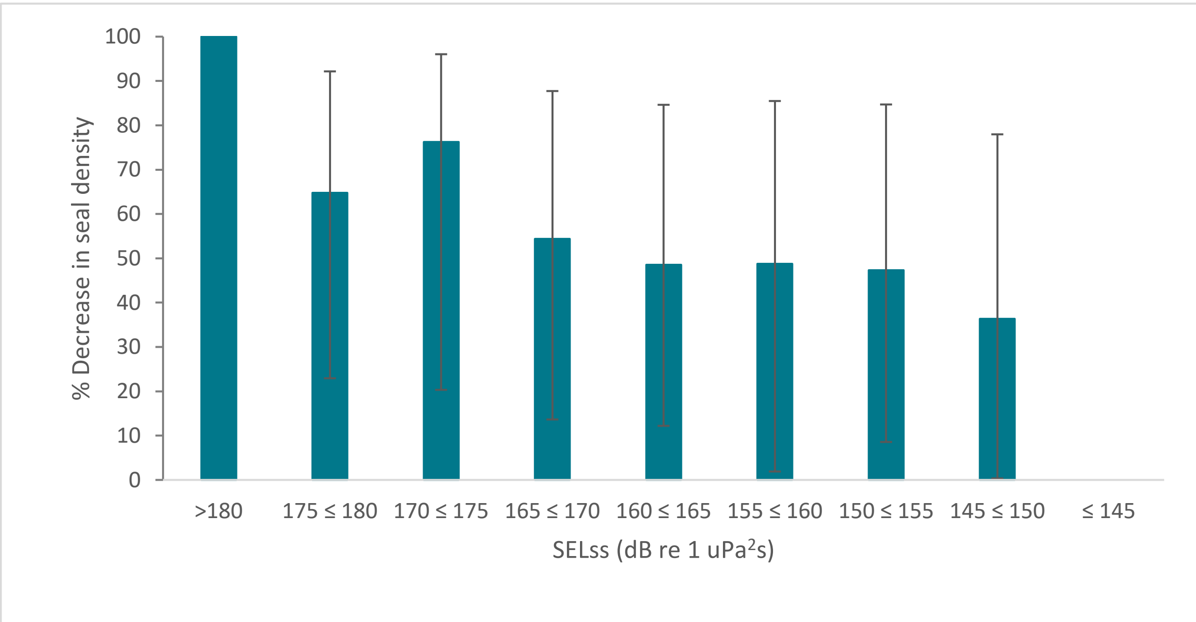

Figure 3.4: Predicted decrease in seal density as a function of estimated sound exposure level, error bars show 95% CI (Whyte *et al.,* 2020).

3.8 Disturbance - UXO clearance

While there are empirically derived dose-response relationships for pile driving, these are not directly applicable to the assessment of UXO detonation due to the very different nature of the sound emission. While both sound sources (piling and explosives) are categorised as "impulsive", they differ drastically in the number of pulses and the overall duration of the noise emission, both of which will ultimately drive the behavioural response. While one UXO-detonation is anticipated to result in a one-off startle-response or aversive behaviour, the series of pulses emitted during pile driving will more or less continuously drive animals out of the impacted area, giving rise to a measurable and quantifiable dose-response relationship. For UXO clearance, there are no dose-response functions available that describe the magnitude and transient nature of the behavioural impact of UXO detonation on marine mammals.

Recent assessments of UXO clearance activities have used the TTS-onset threshold to indicate the level at which a 'fleeing' response may be expected to occur in marine mammals (e.g. Seagreen, Neart na Gaoithe and Awel y Mor). This is a result of discussion in Southall *et al.,* (2007) which states that in the absence of empirical data on responses, the use of the TTS-onset threshold may be appropriate for single pulses (like UXO detonation):

"Even strong behavioral responses to single pulses, other than those that may secondarily result in injury or death (e.g., stampeding), are expected to dissipate rapidly enough as to have limited long-term consequence. Consequently, upon exposure to a single pulse, the onset of significant behavioral disturbance is proposed to occur at the lowest level of noise exposure that has a measurable transient effect on hearing (i.e., TTS-onset). We recognize that this is not a behavioral effect per se, but we use this auditory effect as a de facto behavioral threshold until better measures are identified. Lesser exposures to a single pulse are not expected to cause significant disturbance, whereas any compromise, even temporarily, to hearing functions has the potential to affect vital rates through altered behavior." (Southall et al., 2007).

"Due to the transient nature of a single pulse, the most severe behavioral reactions will usually be temporary responses, such as startle, rather than prolonged effects, such as modified habitat utilization. A transient behavioral response to a single pulse is unlikely to result in demonstrable effects on individual growth, survival, or reproduction. Consequently, for the unique condition of a single pulse, an auditory effect is used as a de facto disturbance criterion. It is assumed that significant behavioral disturbance might occur if noise exposure is sufficient to have a measurable transient effect on hearing (i.e., TTS-onset). Although TTS is not a behavioral effect per se, this approach is used because any compromise, even temporarily, to hearing functions has the potential to affect vital rates by interfering with essential communication and/or detection capabilities. This approach is expected to be precautionary because TTS at onset levels is unlikely to last a full diel cycle or to have serious biological consequences during the time TTS persists." (Southall et al., 2007).

Therefore, an estimation of the extent of behavioural disturbance can be based on the sound levels at which the onset of TTS is predicted to occur from impulsive sounds. TTS-onset thresholds are taken as those proposed for different functional hearing groups by Southall *et al.,* (2019).

It is important for the impact assessment to acknowledge that our understanding of the effect of disturbance from UXO detonation is very limited, and as such the assessment can only provide an indication of the number of animals potentially at risk of disturbance given the limited evidence available.

3.9 Disturbance – other construction activities

There is currently no guidance on the thresholds to be used to assess disturbance of marine mammals from other construction activity. Therefore, this impact assessment provides a qualitative assessment for these impacts. The assessment is based on the limited evidence that is available in the existing literature for that impact pathway and species combination. The majority of available evidence on the impact of disturbance of marine mammals from other construction activities focuses on the impact of vessel activity and dredging. Both these activities will be of relevance during the construction period, with dredging techniques potentially being required for seabed preparation work for foundations as well as potentially for export cable, array cable and interconnector cable installations, due to lack of geotechnical data.

3.10 Population modelling

The iPCoD framework (Harwood *et al.,* 2014b, King *et al.,* 2015) was used to predict the potential population consequences of the predicted amount of PTS and 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 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.

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.

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.

The scenario run for the iPCoD modelling for disturbance from pile driving activities for the Project alone was for piled jacket foundations, since this represented the worst-case scenario in terms of number of piling days. It was assumed that 290 piling days would be required (500 pin piles for WTGs + 80 pin piles for OSPs = total 580 pin piles, assuming 2 pin piles are installed per day = 290 days), spread across the three-year construction window (97 piling days per year) with piling days randomly spread across the indicative 6-month piling window in each year (May-Oct inclusive). For each scenario, the maximum number of animals predicted to be disturbed was assumed for every pile location which will be conservative. The demographic parameters used in the iPCoD modelling were obtained from (Sinclair *et al.,* 2020) and are summarised in **Table 3.7**.

Table 3.7 Demographic parameters used in the iPCoD modelling

Species	Harbour porpoise	Harbour seal	Grey seal
MU	183,937	1,951	34,191
Calf/pup survival	0.8455	0.24	0.222
Juvenile survival	0.85	0.86	0.94
Adult survival	0.925	0.8	0.94
Fertility	0.34	0.9	0.84

Age at independence	1	1	1
Age at first birth	5	4	6

4 Uncertainties and Limitations

There are several uncertainties relating to the underwater noise modelling and impact assessment. Broadly, these relate to predicting exposure of animals to underwater noise, predicting the response of animals to underwater noise and predicting potential population consequences of disturbance from underwater noise, which altogether result in an extremely precautionary impact assessment. These uncertainties and limitations are explained in detail in Appendix 1: Uncertainties and limitations, and a short summary is provided here.

The main uncertainties and limitations include:

- **Cumulative PTS:** The assessment assumes assumptions that a) the amount of sound energy an animal is exposed to within 24 hours will have the same effect on its auditory system, regardless of whether it is received all at once or in several smaller doses spread over a longer period; and, b) the sound keeps its impulsive character, regardless of the distance to the sound source. However, both assumptions are invalid since a) there is a recovery of a threshold shift between pulses during pile driving or in piling breaks leading to an onset of PTS at a higher energy level than assumed with the given SEL_{cum} threshold; and, b) pulsed sound loses its impulsive characteristics while propagating away from the sound source, resulting in a slower shift of an animal's hearing threshold than would be predicted for an impulsive sound.
- **Proportion impacted**: The assessment assumes that all animals within the PTS-onset threshold contour experience PTS-onset. In reality only 18-19% of animals are predicted to experience PTS at the PTS-onset threshold level.
- **Density:** All methods for determining at-sea abundance and distribution of marine mammals suffer from a range of biases and uncertainties. This is described in further detail in the baseline characterisation SS9: Marine mammal and megafauna baseline report.
- **Predicting response:** The current methods for prediction of behavioural responses are based on received sound levels, but it is likely that factors other than noise levels alone will also influence the probability of response and the strength of response (e.g., previous experience, behavioural and physiological context, proximity to activities, characteristics of the sound other than level, such as duty cycle and pulse characteristics).
- **Population modelling:** 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 to predict the effects of disturbance and PTS on survival and reproductive rate.

5 Overall construction period

The offshore construction period of WOW is scheduled over a four year period (**Table 5.1**) with an additional year of pre-construction activities. For the purposes of the cumulative effects assessment, it has been assumed that pre-construction will occur the year before construction equating to 2027 and that piling will occur between 2028-2030 (year 1-3).

Table 5.1 Expected offshore construction activity at WOW

Activity	Pre-construction	Year 1	Year 2	Year 3	Year 4
Pre-construction activities	Feb - Oct				
Site preparation		Mar - Sep	Mar - Sep	Mar - Sep	
Piling		Apr - Oct	Apr - Oct	Apr - Oct	
OSS		Apr - May	Apr - May	Apr - May	
Array Cables		Jun - Sep	Jun - Sep	Jun - Sep	
Export cables		May - Jun	May - Jun	May - Jun	
WTGs		Jun - Oct	Apr - Oct	Apr - Sep	Apr - Sep

6 Pre-Construction Geophysical Surveys

6.1 Project Description

Pre-construction geophysical equipment could include any or all of the following: multibeam echosounder (MBES); Side Scan Sonar (SSS) with piggybacked magnetometer. The SSS/magnetometer would be towed behind the vessel (tow fish), to avoid disturbance from the vessel, and could use ultra-short baseline (USBL) positioning systems.

- **MBES:** MBES is used to acquire detailed seabed topography and water depth by emitting a fan shaped swath of acoustic energy (sound waves) along a survey transect. The sound waves are reflected from the seabed to enable high resolution seafloor mapping. The MBES can be either hull mounted or ROV mounted.
- **SSS:** SSS utilises conical or fan shaped pulses of sounds directed at the seafloor to provide information on the surface of the seabed through analysis of reflected sound.
- **Magnetometer:** A magnetometer is used to measure the variation in the earth's total magnetic field to detect and map ferromagnetic objects on or near the sea floor along the survey's vessel tracks. Often, two magnetometers are mounted in a gradiometer format to measure the magnetic gradient between the two sensors. The magnetometer is a passive system and, therefore, does not emit any noise.
- **USBL system:** A USBL system is used to obtain accurate equipment positioning during sampling activities. This system consists of a transceiver mounted under the vessel, and a transponder on deployed equipment. The transceiver transmits an acoustic pulse which is detected by the transponder, followed by a reply of an acoustic pulse from the transponder. This pulse is detected by the transceiver and the time from transmission of the initial pulse is measured by the USBL system and converted into a range.

6.2 Screening for potential effects

An essential step in assessing the potential for effects on relevant species is a consideration of their auditory sensitivities. Marine mammal hearing groups and auditory injury criteria from Southall *et al.,* (2019), and corresponding species of relevance to this assessment, are summarised in Table 6.1. There are no audiogram data available for low-frequency cetaceans; therefore, predictions are based on the hearing anatomy for each species and considerations of the frequency range of vocalisations.

Table 6.1 Marine mammal hearing groups, estimated hearing range and sensitivity and injury criteria and corresponding species relevant to this assessment (Southall *et al.,* 2019)

Hearing Group	Species	Estimated hearing range	Estimated region of greatest sensitivity†	Estimated peak sensitivity†
Low-frequency (LF) cetaceans	Minke whale	7 Hz –35 kHz	200 Hz –19 kHz	-
High-frequency (HF) cetaceans	White-beaked dolphin Risso's dolphin Common dolphin	150 Hz –160 kHz	8.8 –110 kHz	58 kHz
Very high-frequency (VHF) cetacean	Harbour porpoise	275 Hz –160 kHz	12 –140 kHz	105 kHz
Phocid carnivores in water (PCW)	Harbour seal Grey seal	50 Hz –86 kHz	1.9 –30 kHz	13 kHz

†Region of greatest sensitivity represents low-frequency(F1) and high-frequency(F2) inflection points, while peak sensitivity is the frequency at which the lowest threshold was measured (T0) (Southall *et al.,* 2019).

Prior to an evaluation in relation to each item of equipment, the overlap between typical survey equipment operating characteristics and marine mammal functional hearing capability is considered in **Table 6.2**. **Table 6.2** presents typical values for geophysical surveys for large offshore wind farms, but equipment specific values will vary between different survey contractors. Where there is no overlap between hearing capability and functional hearing, there is no potential for disturbance effects to occur; however, the potential for injury will still need to be considered if animals could be exposed to sound pressure of sufficient magnitude to cause hearing damage or other harm.

Table 6.2 Comparison of typical noise emitting survey equipment operating characteristics and overlap with the most sensitive region of marine mammal hearing capabilities

Equipment	Estimated source pressure level	Expected Sound Frequency	Functional hearing group			
			LF	HF	VHF	PCW
MBES	218 (peak), 213 dB rms	200 - 400 kHz	Above all hearing ranges			
SSS	210 (peak), 242 dB rms	300 kHz & 900 kHz	Above all hearing ranges			
USBL	194 (peak), 188 (rms)	20 – 35 kHz	No	Yes	Yes	Yes

6.3 Injury

While the indicative source levels for MBES and SSS exceed the unweighted injury threshold for harbour porpoise and seals, peak energy is far above that of greatest hearing sensitivity and the frequency of the source is sufficiently high that sound pressure levels would be rapidly attenuated to below thresholds for PTS-onset for porpoise within a few metres of the source. JNCC (2017) do not advise that mitigation to avoid injury from use of MBES is necessary in shallow (<200 m) waters where the MBES used are of high frequencies (as they are planned to be here). EPS Guidance (JNCC *et al.,* 2010) for use of SSS states that *"this type of survey is of a short-term nature and results in a negligible risk of an injury or disturbance offence (under the Regulations)."* An equivalent conclusion was reached by DECC (2011). Therefore, **the risk of injury from MBES and SSS is concluded to be of Negligible magnitude.**

The source levels of USBL equipment are below the PTS-onset thresholds for all marine mammal species and therefore **it is concluded that there would be no risk of PTS-onset to any marine mammals from the use of USBL equipment.**

6.4 Disturbance

As indicated in **Table 6.2**, there is no potential for disturbance effects to occur through use of MBES or SSS, as the sound levels emitted are above 200 kHz and therefore above the hearing frequency range of the marine mammals likely to be present in the region.

As indicated in **Table 6.2**, disturbance effects to minke whales (low frequency cetaceans) through use of USBL are highly unlikely, as the sound levels emitted are above 20 kHz and therefore above the expected hearing frequency range with greatest sensitivity for minke whales. However, the expected sound frequency for the USBL falls within the function hearing range for all other relevant species and, therefore, has the potential to result in disturbance effects.

Considering the characteristics of the noise emitted, the risk of disturbance from USBL is considered to be less than that of sub-bottom profilers (SBPs). JNCC *et al.,* (2010) EPS Guidance concludes that the use of SBPs in geophysical surveys, *"Could, in a few cases, cause localised short-term impacts on behaviour such as avoidance. However, it is unlikely that this would be considered as disturbance in the terms of the Regulations. It is unlikely that injury would occur as an animal would need to locate in the very small zone of ensonification and stay in that zone associated with the vessel for a period of time, which is also unlikely."*

Therefore, considering the nature of the USBL source, disturbance is likely to be of a very localised spatial extent which is unlikely to extend much beyond that of temporary avoidance associated with the concurrent presence of the survey vessel(s). For example, support and supply vessels of 50-100 m (which encompasses the indicative survey vessels of 70-80 m length) are expected to have broadband source levels in the range 165-180 dB re 1µPa, with the majority of energy below 1 kHz (OSPAR 2009). When using thrusters for DP to hold station during sampling activities, increased sound generation in the order of c. 10 dB over levels when in transit may be expected (Rutenko and Ushchipovskii, 2015). Therefore, the noise generated by the survey vessel while holding station on DP is likely to be approaching a similar amplitude to that of the USBL system, albeit with dominant energy at lower frequencies.

Therefore, for a disturbance effect to occur, the animals would have to be in very close proximity to the USBL. Should the short-term operations result in a response by an animal, this would not be likely to impair the ability of an animal to survive or reproduce, or result in any effects to the local populations or distribution. Any response will likely be temporary; for example, evidence from Thompson *et al.,* (2013) suggests that short-term disturbance caused by a commercial two-dimensional seismic survey (a much louder noise source than USBL) does not lead to long-term displacement of harbour porpoises.

6.4.1 Assessment of disturbance at any one time (static source)

An EPS risk assessment was conducted for offshore geophysical and benthic surveys at the Offshore Project in the summer of 2022 (Xodus, 2022), which assessed the potential for disturbance to marine mammals from a USBL. The benthic survey assessment used the Level B harassment threshold of 160 SPL RMS dB re 1µPa which resulted in a predicted disturbance range of 1.08 km and an impact area of 3.66 km^2. Using this static vessel approach, the number of animals predicted to be disturbed at any one time from USBL equipment is 2 grey seals or <1 individual of each other species assessed (Table 6.3).

This static vessel approach will underestimate the true number of animals impacted per survey day as it does not take into account vessel movement and thus the true impacted area. Therefore, alternative assessment approaches have been included below.

Table 6.3 Number of animals predicted to be disturbed by USBL at any one time (assuming a static sound source)[4]

Species	Density (#/km^2)	Area impacted (km^2)	# Impacted	% MU	% UK MU
Harbour porpoise	0.15	3.66	<1	0.00%	0.00%
White-beaked dolphin	0.19	3.66	<1	0.00%	0.00%
Common dolphin	0.01	3.66	<1	0.00%	0.00%
Risso's dolphin	0.0135	3.66	<1	<0.01%	<0.01%
Minke whale	0.01	3.66	<1	0.00%	<0.01%
Harbour seal	0.009	3.66	<1	<0.05%	NA
Grey seal	0.581	3.66	2	0.01%	NA

6.4.2 Assessment of disturbance over a survey day (moving source)

In order to account for a moving survey vessel, the impact area is calculated as a moving impact radius (1.08 km) over the entire survey trackline (109.8 km – average distance travelled by the survey vessel in the 2022 geophysical surveys). This results in a total impacted area of 240.8 km^2 over a survey day. The total number of animals predicted to be disturbed per survey day represents a very low proportion of the UK MU/Full MU (<1% for all species) (Table 6.4). Disturbance effects to marine mammals are expected to be restricted to isolated, temporary and short-lived effects upon low numbers of animals and, overall, to be **Negligible** in magnitude.

Table 6.4 Number of animals predicted to be disturbed by USBL over a survey day (moving sound source)

Species	Density (#/km^2)	Area impacted (km^2)	# Impacted	% UK MU	% Full MU
Harbour porpoise	0.15	240.8	36	0.02%	0.01%
White-beaked dolphin	0.19	240.8	46	0.13%	0.10%
Common dolphin	0.01	240.8	2	0.00%	0.00%
Risso's dolphin	0.0135	240.8	3	0.04%	0.03%
Minke whale	0.01	240.8	2	0.02%	0.01%
Harbour seal	0.009	240.8	2	NA	0.11%
Grey seal	0.581	240.8	140	NA	0.41%

6.5 Conclusion

The sensitivity of all species to PTS-onset from geophysical and UXO surveys has been assessed as **Low**. Overall, the magnitude of PTS-onset to all species of marine mammal from pre-construction geophysical surveys (using MBES, SSS and USBL) is concluded to be **Negligible**, noting that the

[4] Note: the marine mammal densities used in this assessment differ slightly to those presented in the previous offshore geophysical and benthic survey EPS risk assessments. The density data here are informed by site-specific surveys not just SCANS III densities.

characteristics of USBL are such that there is no risk of PTS-onset. **Therefore, effects of this activity are considered to be of Negligible significance, which is Not Significant in EIA terms.**

Potential disturbance impacts to marine mammals resulting from the planned survey activities are expected to be restricted to the use of USBL, and result in isolated, temporary and short-lived effects upon low numbers of animals and, overall, to be **Negligible** in magnitude. The sensitivity of all species to disturbance from USBL has been assessed as **Low**. **Therefore, effects of this activity are considered to be of Negligible significance, which is Not Significant in EIA terms.**

7 UXO clearance

7.1 Project Description

If found, a risk assessment will be undertaken and items of UXO will either be avoided, removed or detonated in situ. Recent advancements in the available methods for UXO clearance mean that high-order detonation may be avoided, and as such, all efforts will be made to avoid high order detonation. Because the detailed pre-construction surveys have not yet been completed, it is not possible at this time to determine how many items of UXO will require clearance. As a result, a separate Marine Licence and EPS assessment will be applied for post-consent for the clearance (where required) of any UXO identified.

The number of UXOs that may require clearance will depend on a number of factors including the size of the OWF and export cable area and the historical military activity. It has been estimated that 222 potential pUXO targets will require investigation and that between 3-10% of these will be classified as confirmed cUXO (6 Alpha Associates Ltd, 2022a). Therefore, it is expected that between 6 and 22 cUXO may require clearance. These estimates have been derived from both desk-top study and review of Project site-specific data. The expected size of the UXO is unknown; however, it is estimated that the maximum charge weight for the potential UXO devices that could be present within the offshore Project site boundary is 247 kg (6 Alpha Associates Ltd, 2022b).

It is expected that 1 UXO will be cleared per day (in daylight hours only), resulting in between 6 and 22 days of UXO clearance to remove all 6-22 cUXOs. In line with the recommendations outlined within the recent position statement on UXO clearance (DEFRA *et al.,* 2021) this impact assessment includes an assessment for high-order detonations, though this is considered unlikely to occur in practice.

The methods under consideration of UXO clearance include:

- **High-order detonation:** A bulk high explosive disposal charge (normally not exceeding 5 kg NEQ), is deployed and placed on, or in very close proximity to the cUXO. The disposal charge will detonate the high explosive contents within the UXO.
- **Low-order deflagration:** A shaped charge is placed in very close proximity to the cUXO, to deliberately deflagrate it. Deflagration is a very high temperature rapid burning event that causes the UXO to break open exposing its high explosive contents. The amount of high explosives required to initiate the shape charge is significantly less (and typically up to 85% less) than that associated with the higher-order method. There is always a risk (albeit low) of a high-order event when attempting to employ any low-order technique.
- **Low-order burning:** An Explosively Formed Magnesium Projectile (or similar) is used to penetrate the UXO case and to immediately burn-out its main high explosive charge. The amount of high explosives required to initiate the shape charge is significantly less (and typically up to 90% less) than that associated with the higher-order method. There is always a risk (albeit low) of a high-order event when attempting to employ any low-order technique.

Note: the noise levels from low-order burning are expected to be less than that of low-order deflagration, and therefore was not included in the underwater noise modelling.

7.2 Auditory injury from UXO clearance

An estimation of the source level and predicted PTS-onset impact ranges were calculated for a range of expected UXO sizes. The maximum charge weight for the potential UXO devices that could be present within the WOW site boundary has been estimated as 247 kg. In line with the recommendations outlined within the recent position statement on UXO clearance (DEFRA *et al.,* 2021) this impact assessment includes an assessment for high-order detonations, though this is considered unlikely to occur in practice.

High order clearance: This has been modelled for the maximum expected charge size of 247 kg alongside potential smaller high-order charges at 3.1, 25 and 130 kg. In each case, a donor weight of 5 kg has been included to initiate detonation.

Low-order deflagration: This assumes that the donor or shaped-charge (charge weight 0.05 kg) detonates fully but without the follow-up detonation of the UXO.

No mitigation measures have been considered for this modelling.

Full details of the underwater noise modelling and the resulting PTS-onset impact areas and ranges are detailed in SS11: Underwater noise modelling report. The source level of each UXO charge weight was calculated in accordance with Soloway and Dahl (2014), which follows Arons (1954) and Barett (1996), and using conservative calculation parameters that result in the upper estimate of the source level for each charge size. This is therefore considered to be an indication of the potential maximum noise output from each charge size and, as such, likely results in an overestimate of PTS-onset impact ranges, especially for larger charge sizes. More recent models developed by Robinson *et al.,* (2022) were found to agree reasonably well with the experimental characterisation of explosive noise sources in shallow water environments used by Soloway and Dahl (2014).

7.2.1 Magnitude

The largest PTS-onset impact range for the high order clearance of a 247 kg UXO and 5 kg donor is 9.9 km for harbour porpoise. This is predicted to injure 46 harbour porpoise which equates to 0.03% of the UK MU, or 0.01% of the Full MU (**Table 7.1**). The largest impact to seals is predicted to injure 6 individual grey seals which equates to 0.22% MU. For all other species, <1 individual is predicted to be injured. It is noted that high-order detonations are unlikely to occur, since less impactful, low-order clearance methods are preferred where possible.

For low-order clearance methods, the largest PTS-onset impact range is 580 m for harbour porpoise. Across all marine mammal species, the low-order clearance method is predicted to injure <1 individual (**Table 7.1**).

While auditory injury (PTS) is a permanent impact, the occurrence of UXO clearance is expected to be intermittent (maximum 22 days) over a 9-month window in the year prior to the start of piling activities. The very low number of animals predicted to be potentially injured is not expected to result in any change to the baseline condition of the population, and there is expected to be no effect on the conservation status or integrity of any marine mammal receptor. **The magnitude of injury (PTS-onset) to all species of marine mammals from UXO clearance activities is assessed as Negligible.**

Table 7.1 Predicted PTS-onset impact ranges and number of animals impacted for low-order and a range of high-order UXO clearance activities.

Threshold & Species		Metric	Low-order	High order			
			0.05 kg donor	3.1 + 5 kg donor	25 + 5 kg donor	130 + 5 kg donor	247 + 5 kg donor
Unweighted SPL_{peak}							
202 dB (VHF)	Harbour porpoise	Range (km)	0.58	2.5	4.9	8.1	9.9
		# animals	<1	3	11	31	46
		% UK MU	<0.01	<0.01	<0.01	0.02	0.03
		% Full MU	<0.01	<0.01	<0.01	<0.01	0.01
230 dB (HF)	Dolphins (all species)	Range (km)	0.03	0.14	0.28	0.46	0.57
		# animals	<1	<1	<1	<1	<1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
219 dB (LF)	Minke whale	Range (km)	0.10	0.44	0.84	1.4	1.7
		# animals	<1	<1	<1	<1	<1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
218 dB (PCW)	Harbour seal	Range (km)	0.11	0.49	0.96	1.5	1.9
		# animals	<1	<1	<1	<1	<1
		% MU	<0.05	<0.05	<0.05	<0.05	<0.05
	Grey seals	# animals	<1	<1	2	4	6
		% MU	0.00	0.00	0.00	0.01	0.022
Weighted SEL_{ss}							
155 dB (VHF)	Harbour porpoise	Range (km)	<0.05	0.28	0.60	0.99	1.1
		# animals	<1	<1	<1	<1	1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
185 dB (HF)	Dolphins (all species)	Range (km)	<0.05	<0.05	<0.05	<0.05	<0.05
		# animals	<1	<1	<1	<1	<1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
183 (dB LF)	Minke whale	Range (km)	0.10	0.90	2.3	4.9	6.7
		# animals	<1	<1	<1	1	1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
185 dB (PCW)	Harbour seal	Range (km)	<0.05	0.16	0.42	0.88	1.1
		# animals	<1	<1	<1	<1	<1
		% MU	<0.05	<0.05	<0.05	<0.05	<0.05
	Grey seals	# animals	<1	<1	<1	1	2
		% MU	0.00	0.00	0.00	0.00	0.01

7.2.2 Sensitivity

Most of the acoustic energy produced by a high-order detonation is below a few hundred Hz, decreasing on average by about SEL 10 dB per decade above 100 Hz, and there is a pronounced drop-off in energy levels above ~5-10 kHz (von Benda-Beckmann *et al.,* 2015, Salomons *et al.,* 2021). Therefore, the primary acoustic energy from a high-order UXO detonation is below the region of greatest sensitivity for most marine mammal species considered here (porpoise, dolphins and seals) (Southall *et al.,* 2019). If PTS were to occur within this low frequency range, it would be unlikely to result in any significant impact to vital rates of porpoise, dolphins and seals. Therefore, **porpoise, dolphins and seals have been assessed as having a Low sensitivity to PTS from UXO clearance.**

Recent acoustic characterisation of UXO clearance noise has shown that there is more energy at lower frequencies (<100 Hz) then previously assumed (Robinson *et al.,* 2022). Given the lower frequency components of the sound produced by UXO clearance, it is more **precautionary to assess minke whales as having a Medium sensitivity to PTS from UXO clearance.**

7.2.3 Impact significance

The magnitude of auditory injury (PTS-onset) to all marine mammal species from UXO clearance has been assessed as **Negligible**.

The sensitivity of harbour porpoise, dolphin species and both seal species to auditory injury (PTS-onset) from UXO clearance has been assessed as **Low**.

The sensitivity of minke whales to auditory injury (PTS-onset) from UXO clearance has been assessed as **Medium**.

Therefore, the effect significance of auditory injury (PTS-onset) from UXO clearance to all marine mammal species is Negligible, which is not significant in EIA terms.

7.3 Disturbance from UXO clearance

It is acknowledged that our understanding of the effect of disturbance from UXO detonation is very limited, and as such the assessment can only provide an indication of the number of animals potentially at risk of disturbance given the limited evidence available.

7.3.1 Magnitude

With the exception of minke whales and grey seals, the maximum TTS-onset (proxy for disturbance) range for the clearance of a single high-order 247 kg UXO + 5 kg donor equates to <0.1% MU being impacted (**Table 7.2**). For minke whales, the maximum high-order charge size is predicted to disturb 1.81% of the UK MU, or 0.92% of the Full MU; for grey seals, the same charge size is predicted to disturb 1.00% of the MU (Table 7.2). It is noted that high-order detonations are unlikely to occur, since less impactful, low-order clearance methods are preferred where possible.

To assess the potential for disturbance from low-order methods, it has been assumed that a donor/shaped charge of 0.05 kg is used to deflagrate the UXO. The donor/shaped charge is expected to detonate fully, without causing the detonation of the UXO. The impact range and the number of animals predicted to be disturbed by low-order clearance is very low for all species (maximum 2 animals, and <0.01% MU for each species, **Table 7.2**).

The occurrence of UXO clearance is expected to be intermittent (maximum 22 days) over a 9 month window in the year prior to the start of piling activities. The very low number of animals predicted to be potentially disturbed is not expected to result in any change to the baseline condition of the population, and there is expected to be no effect on the conservation status or integrity of any marine mammal receptor. **The magnitude of disturbance to all species of marine mammals from UXO clearance activities is assessed as Negligible.**

Table 7.2 Predicted TTS-onset (as a proxy for disturbance) impact ranges and number of animals impacted for low-order and a range of high-order UXO clearance activities.

Threshold & Species		Metric	Low-order	High-order			
			0.05 kg donor	3.1 + 5 kg donor	25 + 5 kg donor	130 + 5 kg donor	247 + 5 kg donor
Unweighted SPL_{peak}							
196 dB (VHF)	Harbour porpoise	Range (km)	1	4.6	9	14	18
		# animals	2	10	38	92	153
		% MU	<0.01	<0.01	0.01	0.02	0.04
		% UK MU	<0.01	<0.01	0.02	0.05	0.08
224 dB (HF)	Dolphins (all species)	Range (km)	0.06	0.26	0.52	0.86	1
		# animals	<1	<1	<1	<1	<1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01

			Low-order	High-order			
213 dB (LF)	Minke whale	Range (km)	0.19	0.82	1.6	2.6	3.2
		# animals	<1	<1	<1	<1	<1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
218 dB (PCW)	Harbour seal	Range (km)	0.21	0.91	1.7	2.9	3.6
		# animals	<1	<1	<1	<1	<1
		% MU	<0.05	<0.05	<0.05	<0.05	<0.05
	Grey seals	# animals	<1	1	5	15	23
		% MU	0.00	0.00	0.01	0.04	0.07
Weighted SEL_{ss}							
155 dB (VHF)	Harbour porpoise	Range (km)	0.42	1.6	2.5	3.2	3.6
		# animals	<1	1	3	5	6
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
185 dB (HF)	Dolphins (all species)	Range (km)	0.05	0.07	0.16	0.31	0.40
		# animals	<1	<1	<1	<1	<1
		% UK/Full MU	<0.01	<0.01	<0.01	<0.01	<0.01
183 dB (LF)	Minke whale	Range (km)	1.4	12	31	60	77
		# animals	<1	5	30	113	186
		% UK MU	<0.01	0.05	0.29	1.10	1.81
		% Full MU	<0.01	0.02	0.15	0.56	0.92
185 dB (PCW)	Harbour seal	Range (km)	0.26	2.2	5.6	11	14
		# animals	<1	<1	1	3	6
		% MU	<0.05	<0.05	0.05	0.18	0.28
	Grey seals	# animals	<1	8	55	212	343
		% MU	0.00	0.02	0.16	0.62	1.00

7.3.2 Sensitivity

It is noted in the JNCC (2020) guidance that *"...a one-off explosion would probably only elicit a startle response and would not cause widespread and prolonged displacement..".* Therefore, it is not expected that disturbance from a single low-order UXO detonation would result in any significant impacts, and that disturbance would not be sufficient to result in any changes to the vital rates of individuals. Therefore, **the sensitivity of marine mammals to disturbance from UXO clearance is expected to be Negligible.**

7.3.3 Significance

The magnitude of disturbance to all marine mammal species from UXO clearance has been assessed as **Negligible**.

The sensitivity of all marine mammal species to disturbance from UXO clearance has been assessed as **Negligible**.

Therefore, the effect significance of disturbance from UXO clearance to all marine mammal species is Negligible, which is not significant in EIA terms.

8 Pile Driving

8.1 Project Description

The full maximum design scenario for marine mammals is outlined in Offshore EIA Report, chapter 11: Marine mammals and megafauna. The worst case WTG installation method for marine mammals is pile driving due to the underwater noise levels it will produce. At this stage, it is unknown if WTGs will be installed on suction bucket jackets, monopile or pin-pile jacket foundations, and therefore both pile driven monopiles and pile driven jackets have been assessed here. For monopile scenarios, two different hammer energies have been assumed; where there is expected to be hard sediment, a higher maximum hammer energy of 5,000 kJ has been assumed, whereas for softer sediment locations a higher maximum hammer energy of 3,000 kJ has been assumed. A summary of the project design parameters for pile driving is provided in **Table 8.1**. The piling profiles used to assess the potential for auditory injury and disturbance to marine mammals is provided in **Table 8.2**.

Table 8.1 Project design parameters relevant to piling underwater noise impacts

Substructure types	Monopile WTG	Piled Jacket WTG	Piled Jacket OSP
# WTGs/OSPs	125	125	5
# piles required	1	4	16 (8 legs/OSP, 2 piles/leg)
# piles total	125	500	80
Hammer energy (kJ)	Hard sediment: 5,000 Soft sediment: 3,000	3,000	3,000
Duration to pile 1 pile	Hard sediment: 16 hr Soft sediment: 8 hr	4 hr	4 hr
# Piles per 24 hours	1	2 or 4	2 or 4
Total days piling	125 days (1 pile/day)	250 days (2 pin piles/day) 125 days (4 pin piles/day)	40 days (2 pin pile/day) 20 days (4 pin piles/day)
Concurrent piling	None	2 pin piles concurrently	None

Table 8.2 Piling parameters used to assess auditory injury and disturbance to marine mammals

	Soft start	Ramp up				Full	TOTAL
Monopile – hard sediment (1 pile/day)							
Hammer Energy (kJ)	750	750	1,250	2,500	3,750	5,000	-
No. of strikes	60	400	400	400	400	45,500	**47,160**
Blow rate (bpm)	6	40	40	40	40	50	**-**
Duration (mins)	10	10	10	10	10	910	**16 hours**
Monopile – soft sediment (1 pile/day)							
Hammer Energy (kJ)	450	450	750	1,500	2,250	3,000	-
No. of strikes	60	400	400	400	400	21,500	**23,160**
Blow rate (bpm)	6	40	40	40	40	50	**-**
Duration (mins)	10	10	10	10	10	430	**8 hours**
Jacket – hard sediment (2 piles/day)							
Hammer Energy (kJ)	450	450	750	1,500	2,250	3,000	-
No. of strikes	60	400	400	400	400	9,500	**11,160/pile**
Blow rate (bpm)	6	40	40	40	40	50	**-**
Duration (mins)	10	10	10	10	10	190	**4 hr/pile 8 hr/day**
Jacket – soft sediment (4 piles/day)							
Hammer Energy (kJ)	450	450	750	1,500	2,250	3,000	-
No. of strikes	60	400	400	400	400	9,500	**11,160/pile**
Blow rate (bpm)	6	40	40	40	40	50	**-**
Duration (mins)	10	10	10	10	10	190	**4 hr/pile 16 hr/day**

Underwater noise modelling was conducted at three separate locations within the OAA (**Figure 8.1**). The north west location was selected as it represented a shallower location (54 m depth) that was furthest from shore, the south west location was selected as it represented a deep water location (70 m depth) and the south east location was selected as it represented a site closer to Orkney where densities of seals are higher. For concurrent piling of pin-pile jackets, the southwest and southeast locations were selected as they were furthest away from each other and closest to the coastal waters of Orkney.

8.2 Auditory injury from pile driving

The following section provides the quantitative assessment of the impact of auditory injury (PTS) from pile driving on marine mammal species.

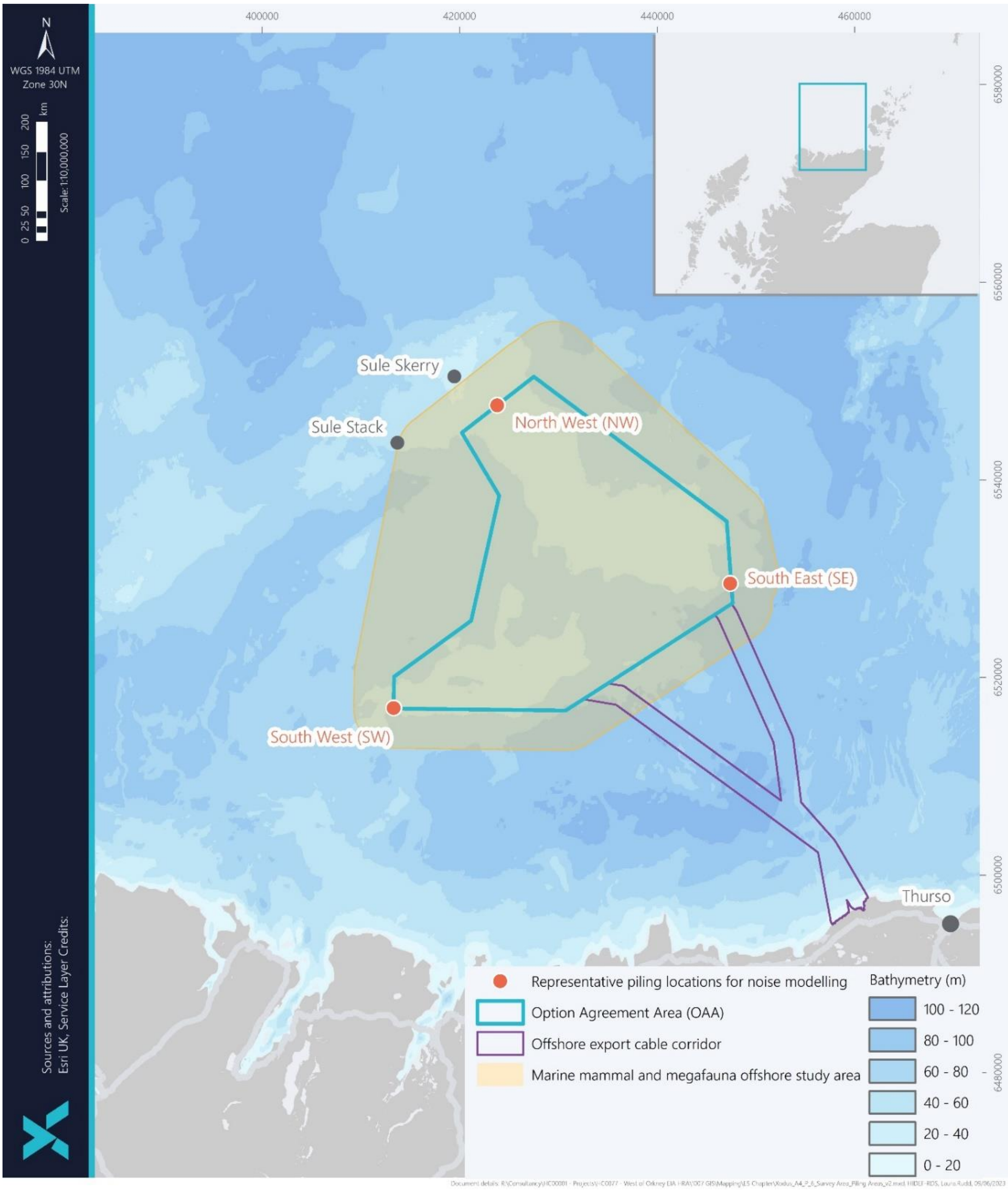

Figure 8.1 Underwater noise modelling locations at the West of Orkney Windfarm.

8.2.1 Harbour porpoise

8.2.1.1 Magnitude

Across all potential piling parameter configurations, the maximum instantaneous PTS-onset range from pile driving at full hammer energy is 720 m. The maximum cumulative PTS-onset range from pile driving at a single location is 17 km for harbour porpoise. This is predicted to impact 93 harbour porpoise, which equates to 0.05% of the UK MU or 0.02% of the Full MU (**Table 8.3**).

For concurrent piling of pin-piles (3,000 kJ) at the SE and SW locations, the maximum number of harbour porpoise expected to experience PTS is 255 which equates to 0.14% of the UK MU or 0.07% of the Full MU (Table 8.3).

It should be noted that the predictions for PTS-onset assume that all animals within the PTS-onset range are impacted, which will overestimate the true number of impacted animals as only 18-19% of the animals are predicted to actually experience PTS at the PTS-onset threshold level (Finneran *et al.,* 2005). In addition, the sound is modelled as being fully impulsive irrespective of the distance to the pile which is highly precautionary, resulting in predictions that are unlikely to be realised. While it is acknowledged that the pile diameters proposed are larger and the water depths deeper than in the Hastie *et al.,* (2019) study, it is still expected that the likelihood of the pile driving sound retaining its impulsive characteristics at distances above 10 km is extremely unlikely.

Overall, **the impact of auditory injury from pile driving is considered to be a Negligible magnitude** as there is expected to be no change to the conservation status or integrity of the harbour porpoise receptor given the very low proportion of the MU (UK or Full) impacted.

Table 8.3 Impact area, maximum range, number of harbour porpoise predicted to experience auditory injury (PTS-onset) from piling

	Instantaneous PTS (SPL_{peak})			Cumulative PTS (SEL_{cum})			
	NW	SE	SW	NW	SE	SW	SE+SW
Monopile (hard sediment)							
Area (km^2)	1.5	1.6	1.5	490	620	490	No concurrent monopiles
Range (km)	0.7	0.72	0.7	16	17	14	
# porpoise	<1	<1	<1	74	93	74	
% UK MU	0.00	0.00	0.00	0.04	0.05	0.04	
% Full MU	0.00	0.00	0.00	0.02	0.02	0.02	
Monopile (soft sediment)							
Area (km^2)	1.2	1.2	1.2	340	450	360	No concurrent monopiles
Range (km)	0.61	0.63	0.61	13	14	12	
# porpoise	<1	<1	<1	51	68	54	
% UK MU	0.00	0.00	0.00	0.03	0.04	0.03	
% Full MU	0.00	0.00	0.00	0.01	0.02	0.01	
Jacket (hard sediment – 2 piles/day)							
Area (km^2)	1	1.1	1	320	430	340	1,700
Range (km)	0.58	0.6	0.58	13	13	12	-
# porpoise	<1	<1	<1	48	65	51	255
% UK MU	0.00	0.00	0.00	0.03	0.04	0.03	0.14
% Full MU	0.00	0.00	0.00	0.01	0.02	0.01	0.07
Jacket (soft sediment – 4 piles/day)							
Area (km^2)	1	1.1	1	330	440	350	1,700
Range (km)	0.58	0.6	0.58	13	14	12	-
# porpoise	<1	<1	<1	50	66	53	255
% UK MU	0.00	0.00	0.00	0.03	0.04	0.03	0.14
% Full MU	0.00	0.00	0.00	0.01	0.02	0.01	0.07

8.2.1.2 Sensitivity

The ecological consequences of PTS for marine mammals are uncertain. At an expert elicitation workshop (March 2018), experts in marine mammal hearing discussed the nature, extent and potential consequence of PTS to UK marine mammal species (Booth and Heinis, 2018). This workshop outlined and collated the best and most recent empirical data available on the effects of PTS on marine mammals. A number of general points came out in discussions as part of the elicitation. These included that PTS did not mean animals were deaf, that the limitations of the ambient noise environment should be considered and that the magnitude and frequency band in which PTS occurs are critical to assessing the effect on vital rates.

For piling noise, most energy is between ~30 - 500 Hz, with a peak usually between 100 – 300 Hz and energy extending above 2 kHz (Kastelein *et al.,* 2015, Kastelein *et al.,* 2016). Studies have shown that exposure to impulsive pile driving noise induces TTS in a relatively narrow frequency band in harbour porpoise and harbour seals (reviewed in Finneran, 2015), with statistically significant TTS occurring at 4 and 8 kHz (Kastelein *et al.,* 2016) and centred at 4 kHz (Kastelein *et al.,* 2012a, Kastelein *et al.,* 2012b, Kastelein *et al.,* 2013b, Kastelein *et al.,* 2017). Therefore, during the expert elicitation, the experts agreed that any threshold shifts as a result of pile driving would manifest themselves in the 2 - 10 kHz range (Kastelein *et al.,* 2017) and that a PTS 'notch' of 6 – 18 dB in a narrow frequency band in the 2 - 10 kHz region is unlikely to significantly affect the fitness of individuals (ability to survive and reproduce). The expert elicitation concluded that:

"… the effects of a 6 dB PTS in the 2-10 kHz band was unlikely to have a large effect on survival or fertility of the species of interest.

"… for all species experts indicated that the most likely predicted effect on survival or fertility as a result of 6 dB PTS was likely to be very small (i.e. <5 % reduction in survival or fertility).

"… the defined PTS was likely to have a slightly larger effect on calves/pups and juveniles than on mature females survival or fertility."

For harbour porpoise, the predicted decline in vital rates from the impact of a 6 dB PTS in the 2-10 kHz band for different percentiles of the elicited probability distribution are provided in **Table 8.4** and displayed graphically in **Figure 8.2**, **Figure 8.3** and **Figure 8.4**. The data provided in **Table 8.4** should be interpreted as:

- Experts estimated that the median decline in an individual mature female harbour porpoise's survival was 0.01% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz).
- Experts estimated that the median decline in an individual mature female harbour porpoise's fertility was 0.09% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz).
- Experts estimated that the median decline in an individual harbour porpoise juvenile or dependent calf survival was 0.18% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz).

Table 8.4: Predicted decline in harbour porpoise vital rates for different percentiles of the elicited probability distribution.

	Percentiles of the elicited probability distribution								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Adult survival	0	0	0	0.01	0.01	0.03	0.05	0.1	0.23
Fertility	0	0	0.02	0.05	0.09	0.16	0.3	0.7	1.35
Calf/Juvenile survival	0	0	0.02	0.09	0.18	0.31	0.49	0.8	1.46

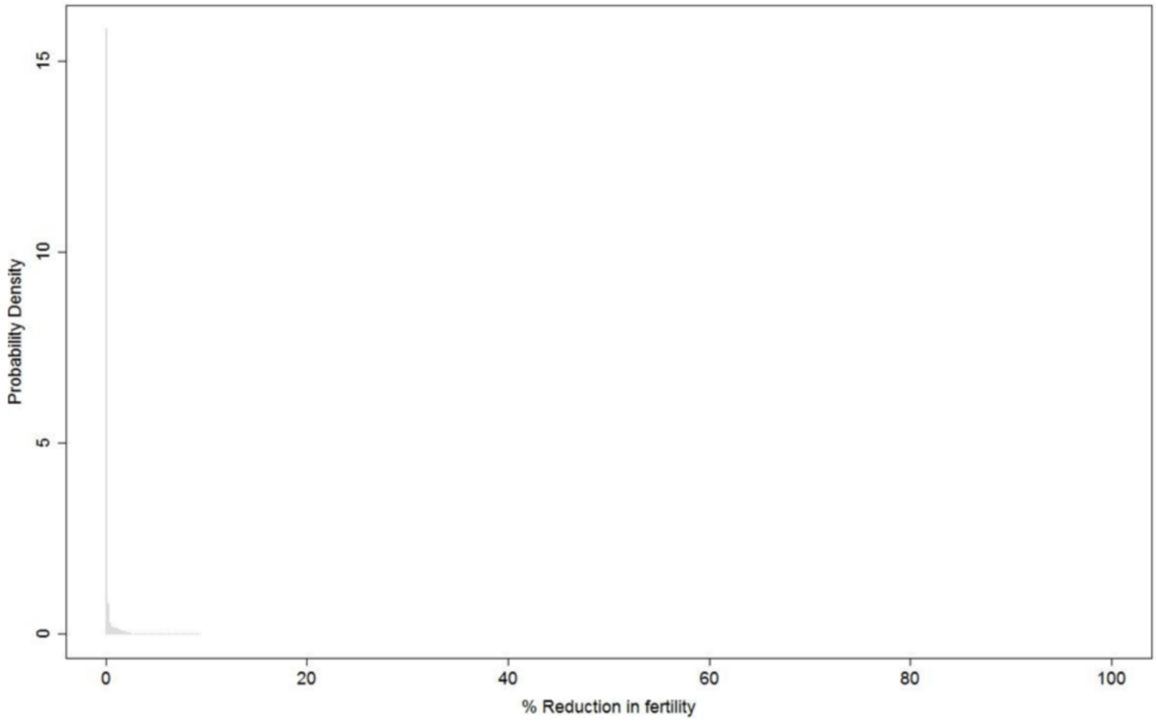

Figure 8.2: Probability distribution showing the consensus distribution for the effects on fertility of a mature female harbour porpoise as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

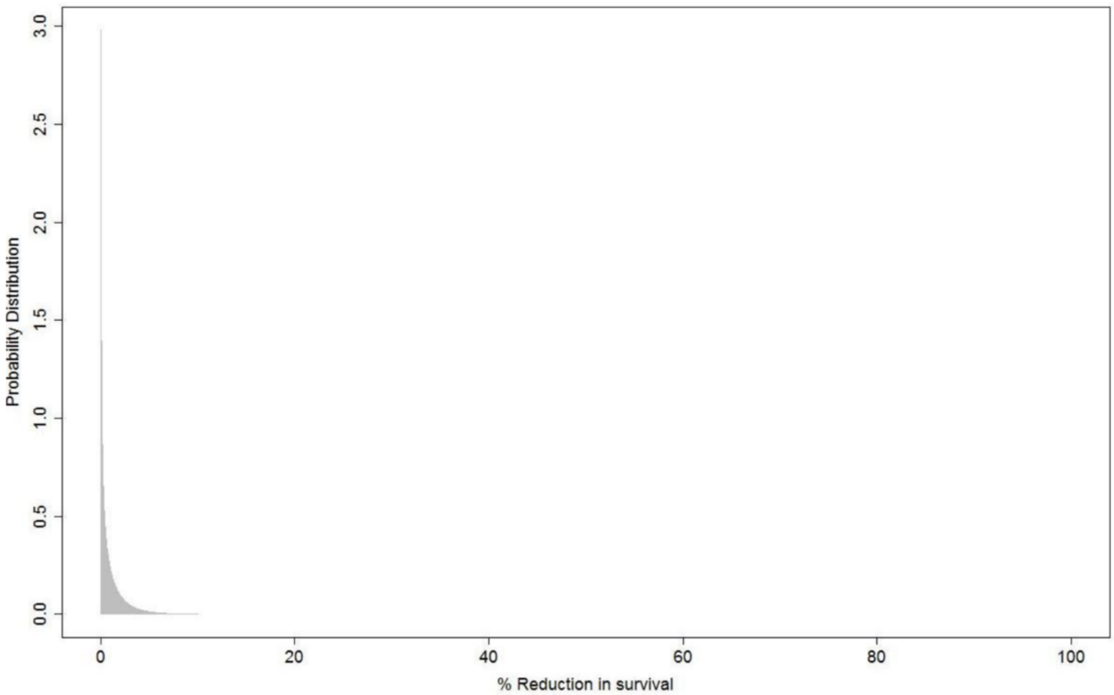

Figure 8.3: Probability distribution showing the consensus distribution for the effects on survival of a mature female harbour porpoise as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

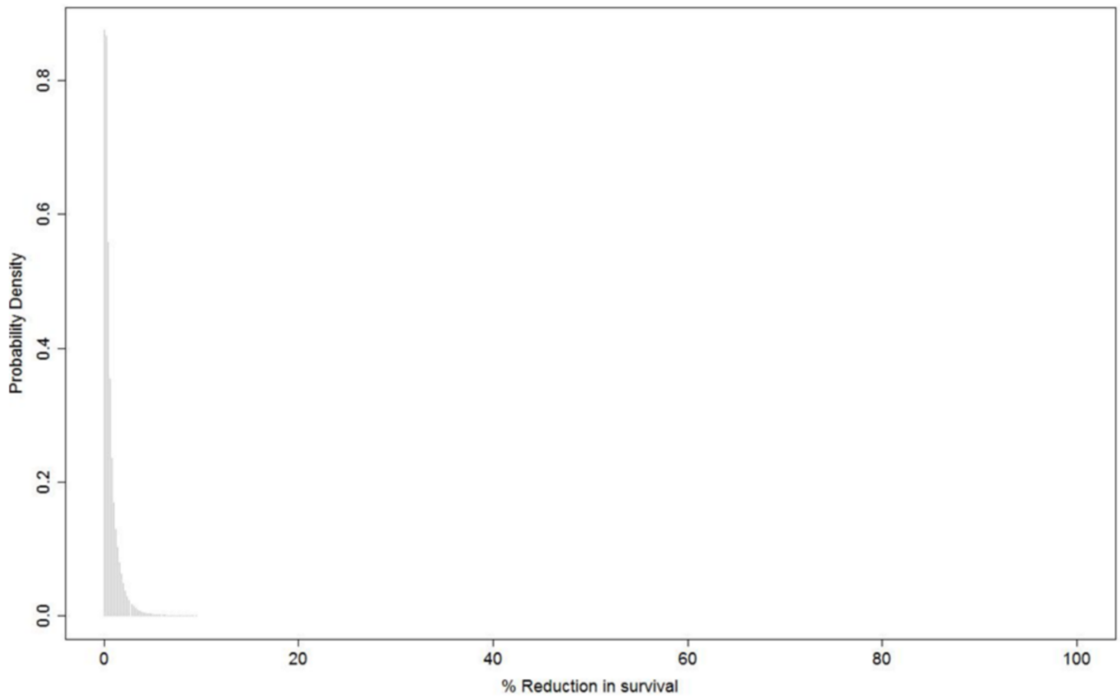

Figure 8.4: Probability distribution showing the consensus distribution for the effects on survival of juvenile or dependent calf harbour porpoise as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

Furthermore, data collected during wind farm construction have demonstrated that porpoise detections around the pile driving site decline several hours prior to the start of pile driving. It is assumed that this is due to the increase in other construction related activities and vessel presence in advance of the actual pile driving (Brandt *et al.,* 2018, Graham *et al.,* 2019, Benhemma-Le Gall *et al.,* 2021). Therefore, the presence of construction related vessels prior to the start of piling can act as a local scale deterrent for harbour porpoise and therefore reduce the risk of auditory injury. Assumptions that harbour porpoise are present in the vicinity of the pile driving at the start of the soft start are therefore likely to be overly conservative.

Whilst PTS is a permanent effect which cannot be recovered from, the evidence does not suggest that PTS from piling will cause a significant impact on either survival or reproductive rates; therefore, **harbour porpoise have been assessed as having a Low sensitivity to PTS from pile driving.**

8.2.1.3 Significance

The magnitude of auditory injury (PTS-onset) to harbour porpoise from piling has been assessed as **Negligible**.

The sensitivity of harbour porpoise to auditory injury from piling has been assessed as **Low**.

Therefore, the consequence of auditory injury from piling to harbour porpoise is Negligible, which is not significant in EIA terms.

NOTE: although the numbers and percentage of harbour porpoise predicted to be at risk from PTS-onset are low and are not considered to be significant in EIA terms, harbour porpoise are EPS and under EPS legislation it is an offence to injure a single individual (this includes PTS auditory injury). Further mitigation measures will be considered, as required, in relation to future EPS Licence applications, once all the appropriate information is collated to inform the Piling Strategy.

8.2.2 Dolphin species

8.2.2.1 Magnitude

Across all scenarios considered, the predicted auditory injury (PTS-onset) range for all dolphin species is <0.1 km and thus no dolphin species are expected to be injured (Table 8.5). Due to the lack of predicted impact, **the magnitude of auditory injury (PTS-onset) to all dolphin species from piling has been assessed as Negligible**.

Table 8.5 Impact area, maximum range, number of dolphin sp. (white-beaked, common and Risso's) predicted to experience auditory injury (PTS-onset) from piling

	Instantaneous PTS (SPL_{peak})			Cumulative PTS (SEL_{cum})			
	NW	SE	SW	NW	SE	SW	SE+SW
Monopile (hard sediment)							
Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	No concurrent monopiles
Range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
# dolphins	<1	<1	<1	<1	<1	<1	
% UK/Full MU	0.00	0.00	0.00	0.00	0.00	0.00	
Monopile (soft sediment)							
Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	No concurrent monopiles
Range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
# dolphins	<1	<1	<1	<1	<1	<1	
% UK/Full MU	0.00	0.00	0.00	0.00	0.00	0.00	
Jacket (hard sediment – 2 piles/day)							
Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	No in-combination effect
Range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
# dolphins	<1	<1	<1	<1	<1	<1	
% UK/Full MU	0.00	0.00	0.00	0.00	0.00	0.00	
Jacket (soft sediment – 4 piles/day)							
Area (km^2)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	No in-combination effect
Range (km)	<0.1	<0.1	<0.1	<0.1	<0.1	<0.1	
# dolphins	<1	<1	<1	<1	<1	<1	
% UK/Full MU	0.00	0.00	0.00	0.00	0.00	0.00	

8.2.2.2 Sensitivity

There are no data available on the sensitivity of white beaked dolphins, common dolphins or Risso's dolphins to PTS from pile driving.

There is, however, information from the expert elicitation on PTS for bottlenose dolphins (Booth and Heinis, 2018) which can be used as a proxy for other dolphin species since they belong to the same hearing group and are therefore expected to have similar sensitivities. The predicted decline in bottlenose dolphin vital rates from the impact of a 6 dB PTS in the 2-10 kHz band for different percentiles of the elicited probability distribution are provided in Table 8.6 and displayed graphically in Figure 8.5, Figure 8.6, Figure 8.7. The data provided in Table 8.6 should be interpreted as:

- Experts estimated that the median decline in an individual mature female bottlenose dolphin's survival was 1.6% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz);

- Experts estimated that the median decline in an individual mature female bottlenose dolphin's fertility was 0.43% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz);
- Experts estimated that the median decline in an individual bottlenose dolphin juvenile survival was 1.32% (due to a 6 dB PTS (a notch a few kHz wide and 6dB high) occurring somewhere in the hearing between 2-10 kHz); and
- Experts estimated that the median decline in an individual bottlenose dolphin dependent calf survival was 2.96% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz).

Whilst PTS is a permanent effect which cannot be recovered from, the evidence does not suggest that PTS from piling will cause a significant impact on either survival or reproductive rates. It is noted however, that the likely effect of PTS from pile driving on bottlenose dolphins was considerably less certain than expert judgements for harbour porpoise. Therefore, **dolphins have been conservatively assessed as having a Medium sensitivity to PTS from pile driving**.

Table 8.6: Predicted decline in bottlenose dolphin vital rates for different percentiles of the elicited probability distribution.

	Percentiles of the elicited probability distribution								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Adult survival	0	0.18	0.57	1.04	1.6	2.34	3.39	5.18	10.99
Fertility	0	0.04	0.13	0.26	0.43	0.85	1.66	3.49	6.22
Juvenile survival	0.01	0.11	0.35	0.75	1.32	2.14	3.3	5.19	11.24
Calf survival	0	0.29	0.93	1.77	2.96	4.96	7.81	10.69	14.79

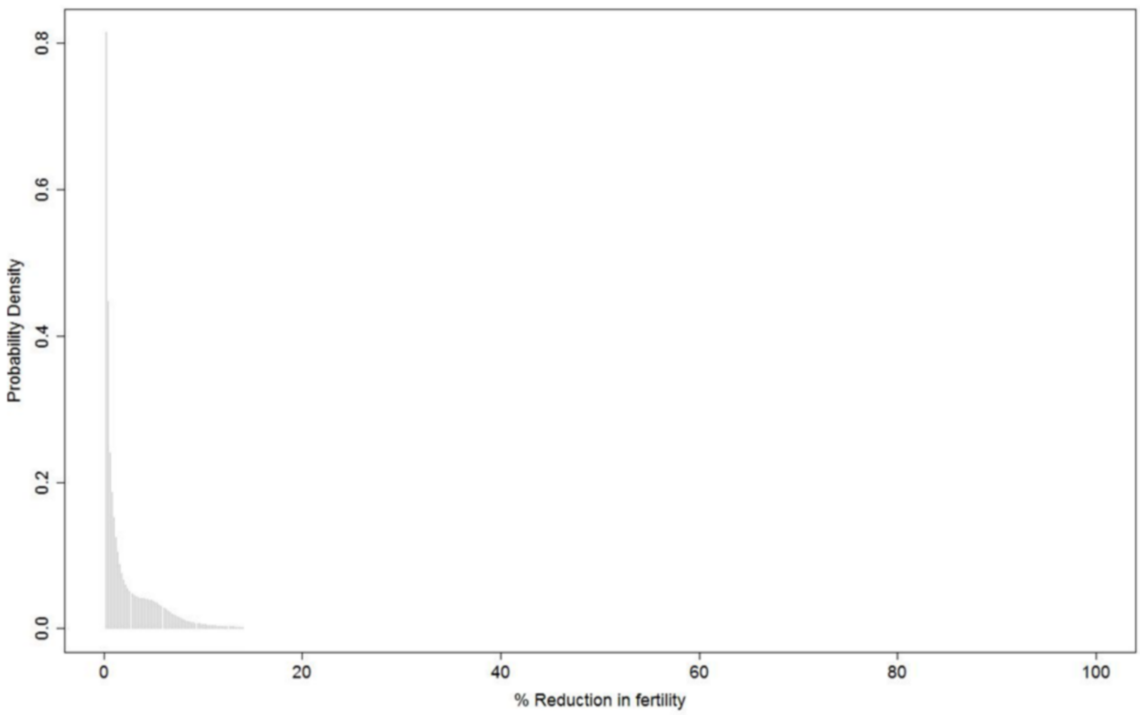

Figure 8.5: Probability distribution showing the consensus distribution for the effects on fertility of mature female bottlenose dolphin as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

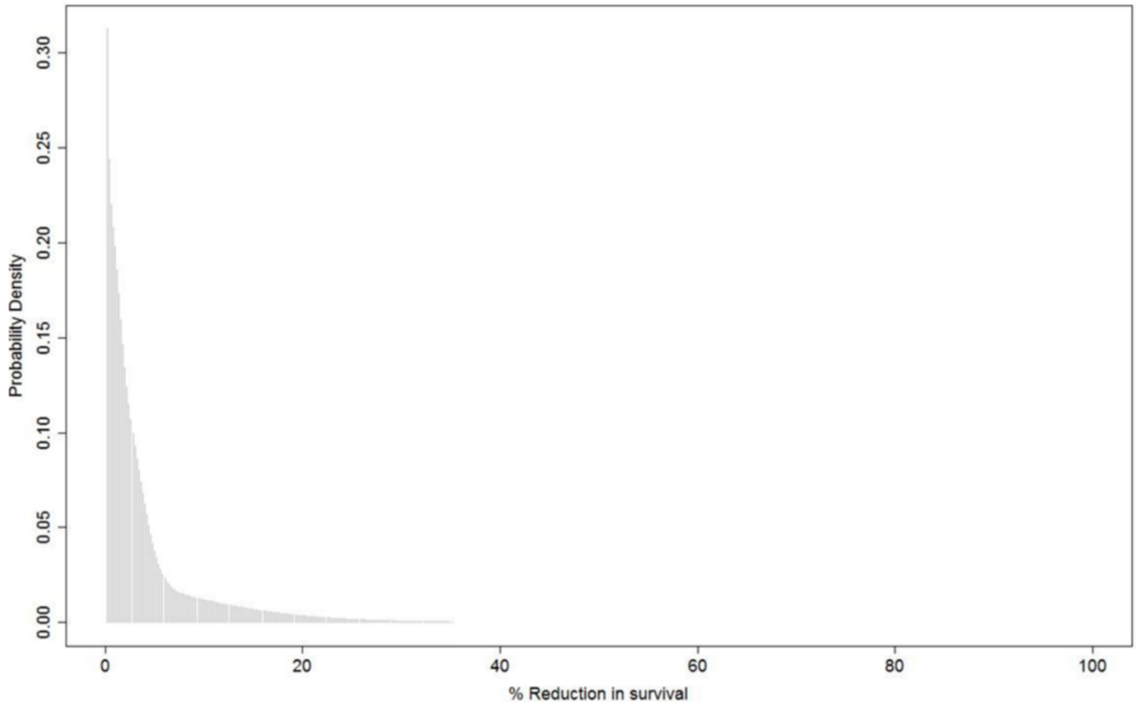

Figure 8.6: Probability distribution showing the consensus distribution for the effects on survival of mature female bottlenose dolphin as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

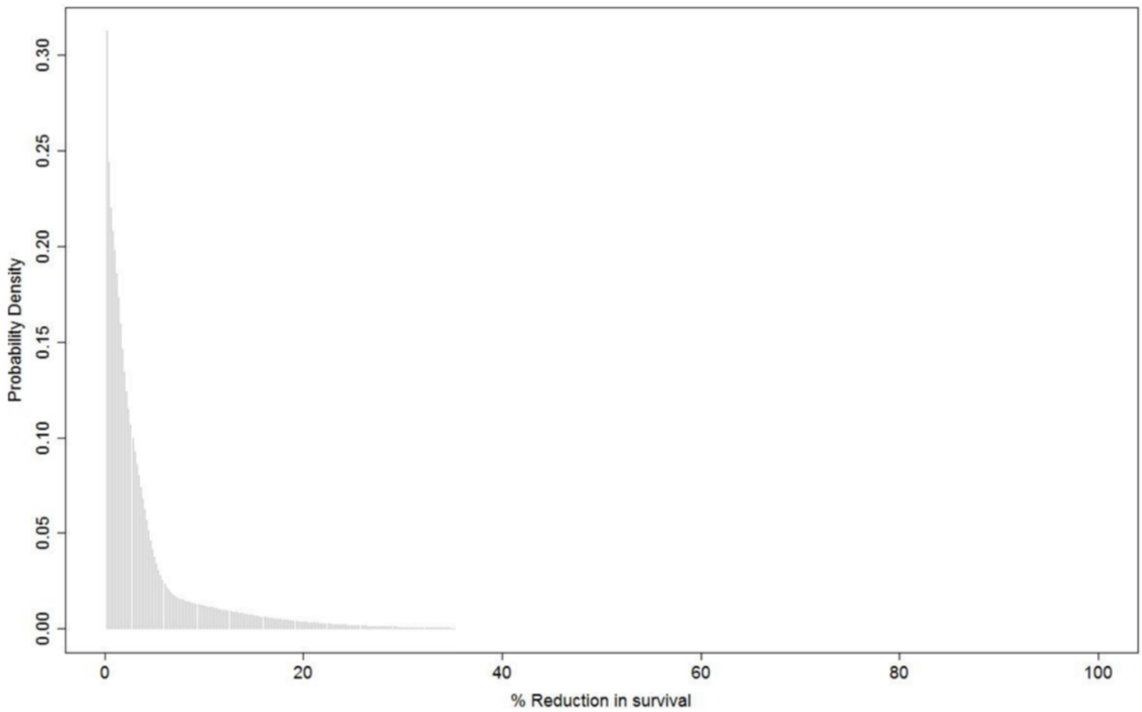

Figure 8.7: Probability distribution showing the consensus distribution for the effects on survival of juvenile or dependent calf bottlenose dolphin as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

8.2.2.3 Significance

The magnitude of auditory injury (PTS-onset) to dolphin species from piling has been assessed as **Negligible**.

The sensitivity of dolphin species to auditory injury from piling has been conservatively assessed as **Medium**.

Therefore, the consequence of auditory injury from piling to dolphin species is Negligible, which is not significant in EIA terms.

8.2.3 Minke whale

8.2.3.1 Magnitude

The maximum instantaneous PTS-onset range from pile driving at full hammer energy is <50 m. The maximum cumulative PTS-onset range from pile driving at a single location is 47 km for minke whales. This is predicted to impact 27 whales, which equates to 0.26% of the UK MU, or 0.15% of the Full MU (**Table 8.7**).

For concurrent piling of pin-piles (3,000 kJ) at the SE and SW locations, the maximum number of minke whales expected to experience PTS is 45 which equates to 0.44% of the UK MU, or 0.22% of the Full MU (**Table 8.7**).

It should be noted that the predictions for PTS-onset assume that all animals within the PTS-onset range are impacted, which will overestimate the true number of impacted animals as only 18-19% of the animals are predicted to actually experience PTS at the PTS-onset threshold level (Finneran, 2015). In addition, the sound is modelled as being fully impulsive irrespective of the distance to the pile which is highly precautionary, resulting in predictions that are unlikely to be realised. While it is acknowledged that the pile diameters proposed within the project design envelope are larger and the water depths deeper than in the Hastie *et al.,* (2019) study, it is still expected that the likelihood of the sound retaining its impulsive characteristics at distances above 10 km is extremely unlikely and thus the 47 km impact ranges predicted here are beyond what is reasonably expected.

Overall, **the impact of auditory injury from pile driving is considered to be a Negligible magnitude** as there is expected to be no change to the conservation status or integrity of the receptor given the very low proportion of the MU impacted.

Table 8.7 Impact area, maximum range, number of minke whales predicted to experience injury (PTS-onset) from piling.

	Instantaneous PTS (SPL_{peak})			Cumulative PTS (SEL_{cum})			
	NW	SE	SW	NW	SE	SW	SE+SW
Monopile (hard sediment)							
Area (km²)	0.01	0.01	0.01	3,000	2,700	2,100	No concurrent monopiles
Range (km)	<0.05	<0.05	<0.05	44	47	34	
# whales	<1	<1	<1	30	27	21	
% UK MU	0.00	0.00	0.00	0.29	0.26	0.20	
% Full MU	0.00	0.00	0.00	0.15	0.13	0.10	
Monopile (soft sediment)							
Area (km²)	0.01	0.01	0.01	2,400	2,300	1,800	No concurrent monopiles
Range (km)	<0.05	<0.05	<0.05	40	42	30	
# whales	<1	<1	<1	24	23	18	
% UK MU	0.00	0.00	0.00	0.23	0.22	0.17	
% Full MU	0.00	0.00	0.00	0.12	0.11	0.09	
Jacket (hard sediment – 2 piles/day)							
Area (km²)	0.01	0.01	0.01	2,200	2,200	1,700	4,500
Range (km)	<0.05	<0.05	<0.05	38	40	30	-
# whales	<1	<1	<1	22	22	17	45
% UK MU	0.00	0.00	0.00	0.21	0.21	0.17	0.44
% Full MU	0.00	0.00	0.00	0.11	0.11	0.08	0.22
Jacket (soft sediment – 4 piles/day)							
Area (km²)	0.01	0.01	0.01	2,200	2,200	1,700	4,500
Range (km)	<0.05	<0.05	<0.05	38	40	30	-
# whales	<1	<1	<1	22	22	17	45
% UK MU	0.00	0.00	0.00	0.21	0.21	0.17	0.44
% Full MU	0.00	0.00	0.00	0.11	0.11	0.08	0.22

8.2.3.2 Sensitivity

The low frequency noise produced during piling may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Minke whale communication signals have been demonstrated to be below 2 kHz (Edds-Walton, 2000, Mellinger *et al.,* 2000, Gedamke *et al.,* 2001, Risch *et al.,* 2013, Risch *et al.,* 2014). Tubelli *et al.,* (2012) estimated the most sensitive hearing range (the region with thresholds within 40 dB of best sensitivity) to extend from 30 to 100 Hz up to 7.5 to 25 kHz, depending on the specific model used. Whilst PTS is a permanent effect which cannot be recovered from, a 2-10 kHz notch of 6 dB will affect only a small region of minke whale hearing, which is unlikely to cause a significant impact on either survival or reproductive rates. Given the lack of data, and acknowledging their lower-frequency hearing abilities, **minke whales have been conservatively assessed as having a Medium sensitivity to PTS from pile driving**.

8.2.3.3 Significance

The magnitude of auditory injury (PTS-onset) to minke whales from piling has been assessed as **Negligible**.

The sensitivity of minke whales to auditory injury from piling has been assessed as **Medium**.

Therefore, the consequence of auditory injury from piling to minke whales is Negligible, which is not significant in EIA terms.

NOTE: although the numbers and percentage of minke whales predicted to be at risk from PTS-onset are low and not considered to be significant in EIA terms, minke whales are EPS and under EPS legislation it is an offence to injure a single individual (this includes PTS auditory injury). Further mitigation measures will be considered, as required, in relation to future EPS Licence applications, once all the appropriate information is collated to inform the Piling Strategy.

8.2.4 Seal species

8.2.4.1 Magnitude

Across all scenarios considered, the predicted auditory injury (PTS-onset) range for both seal species is <0.1 km and no individual seals are expected to be injured (**Table 8.8**). Due to the lack of predicted impact, **the magnitude of auditory injury (PTS-onset) to both seal species from piling has been assessed as Negligible**.

Table 8.8 Impact area, maximum range, number of seals (both harbour and grey seals) predicted to experience auditory injury (PTS-onset) from piling.

	Instantaneous PTS (SPL_{peak})			Cumulative PTS (SEL_{cum})			
	NW	SE	SW	NW	SE	SW	SE+SW
Monopile (hard sediment)							
Area (km^2)	0.01	0.01	0.01	0.01	0.2	< 0.1	No concurrent monopiles
Range (km)	<0.05	<0.05	<0.05	<0.05	0.35	0.13	
# seals	<1	<1	<1	<1	<1	<1	
% MU	0.00	0.00	0.00	0.00	0.00	0.00	
Monopile (soft sediment)							
Area (km^2)	0.01	0.01	0.01	0.01	< 0.1	< 0.1	No concurrent monopiles
Range (km)	<0.05	<0.05	<0.05	<0.05	< 0.1	< 0.1	
# seals	<1	<1	<1	<1	<1	<1	
% MU	0.00	0.00	0.00	0.00	0.00	0.00	
Jacket (hard sediment – 2 piles/day)							
Area (km^2)	0.01	0.01	0.01	<0.1	<0.1	<0.1	No in-combination effect
Range (km)	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1	
# seals	<1	<1	<1	<1	<1	<1	
% MU	0.00	0.00	0.00	0.00	0.00	0.00	
Jacket (soft sediment – 4 piles/day)							
Area (km^2)	0.01	0.01	0.01	<0.1	<0.1	<0.1	No in-combination effect
Range (km)	<0.05	<0.05	<0.05	<0.1	<0.1	<0.1	
# seals	<1	<1	<1	<1	<1	<1	
% MU	0.00	0.00	0.00	0.00	0.00	0.00	

8.2.4.2 Sensitivity

At the expert elicitation workshop held at the University of St Andrews (March 2018), experts in marine mammal hearing discussed the nature, extent and potential consequence of PTS to UK marine mammal species (Booth and Heinis, 2018). This workshop outlined and collated the best and most recent empirical data available on the effects of PTS on marine mammals.

The predicted decline in harbour and grey seals vital rates from the impact of a 6 dB PTS in the 2-10 kHz band for different percentiles of the elicited probability distribution are provided in **Table 8.9** and displayed graphically in **Figure 8.8**, **Figure 8.9** and **Figure 8.10**. The data provided in **Table 8.9** should be interpreted as:

- Experts estimated that the median decline in an individual mature female seal's survival was 0.39% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz).
- Experts estimated that the median decline in an individual mature female seal's fertility was 0.27% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz).
- Experts estimated that the median decline in an individual seal pup/juvenile survival was 0.52% (due to a 6 dB PTS (a notch a few kHz wide and 6 dB high) occurring somewhere in the hearing between 2-10 kHz).

Whilst PTS is a permanent effect which cannot be recovered from, the evidence does not suggest that PTS from piling will cause a significant impact on either survival or reproductive rates; therefore, **both seal species have been assessed as having a Low sensitivity to PTS from piling**.

Table 8.9: Predicted decline in harbour and grey seal vital rates for different percentiles of the elicited probability distribution.

	Percentiles of the elicited probability distribution								
	10%	20%	30%	40%	50%	60%	70%	80%	90%
Adult survival	0.02	0.1	0.18	0.27	0.39	0.55	0.78	1.14	1.89
Fertility	0.01	0.02	0.05	0.14	0.27	0.48	0.88	1.48	4.34
Calf survival	0	0.04	0.15	0.32	0.52	0.8	1.21	1.88	3

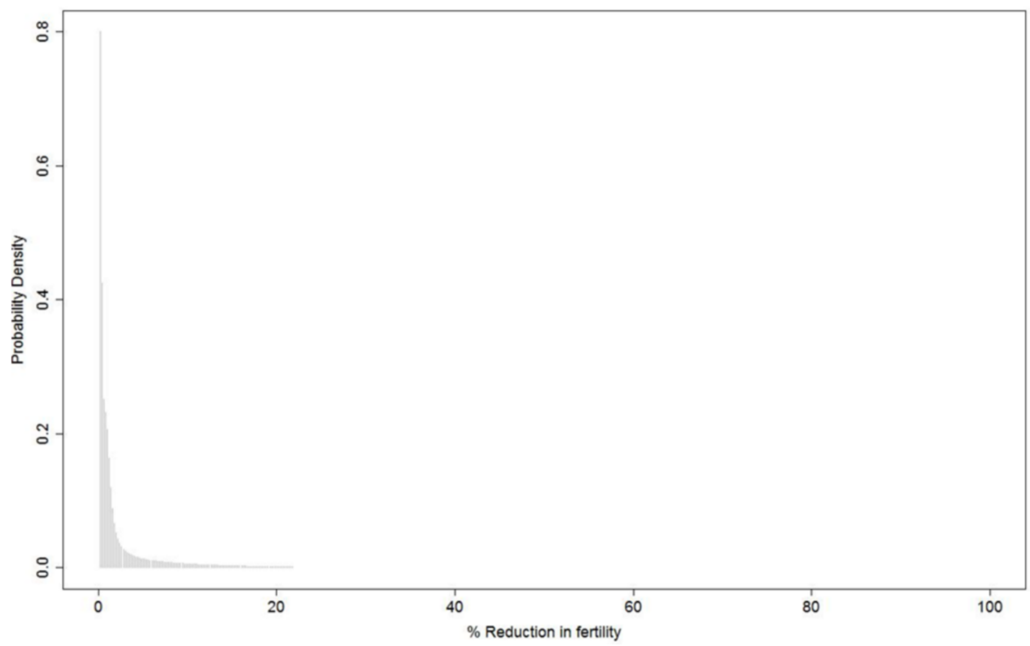

Figure 8.8: Probability distribution showing the consensus distribution for the effects on fertility of a mature female (harbour or grey) seal as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

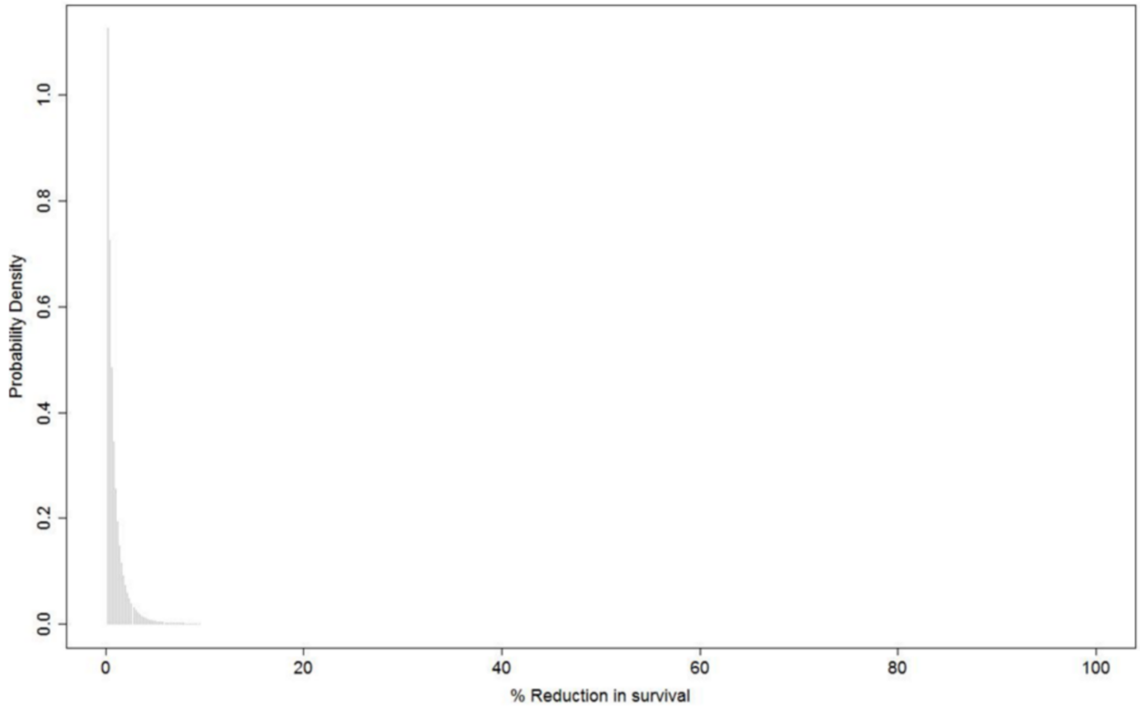

Figure 8.9: Probability distribution showing the consensus distribution for the effects on survival of a mature female (harbour or grey) seal as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

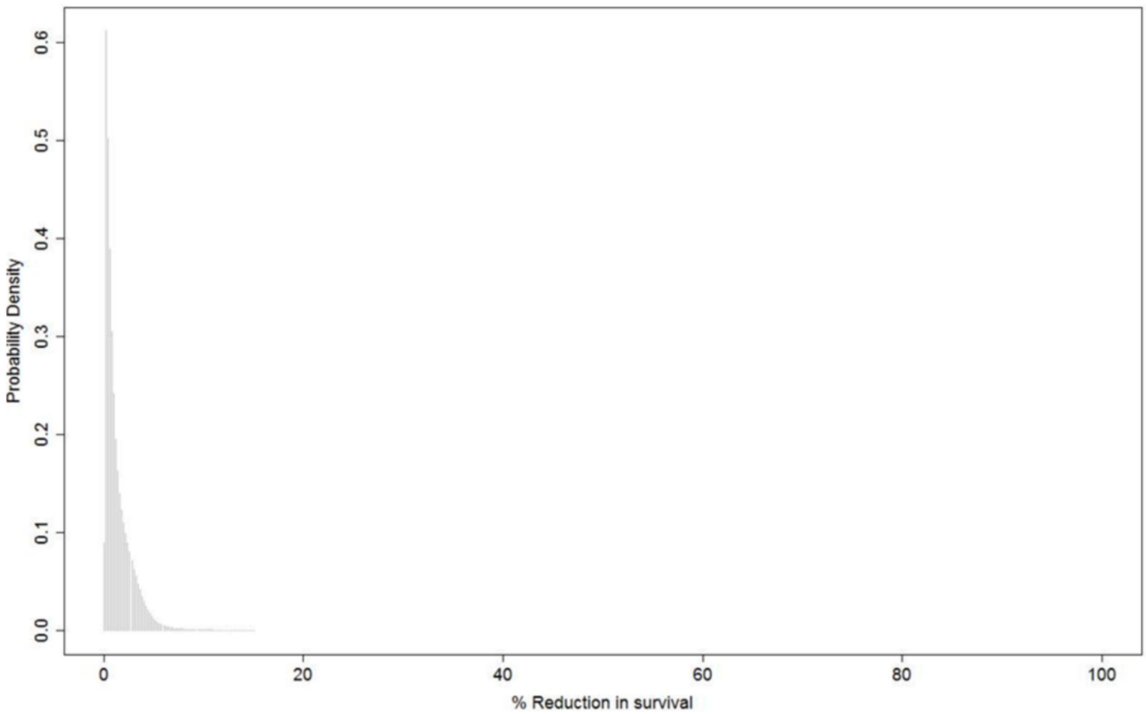

Figure 8.10: Probability distribution showing the consensus distribution for the effects on survival of juvenile or dependent pup (harbour or grey) seal as a consequence of a maximum 6 dB of PTS within a 2-10 kHz band. Figure taken from Booth and Heinis (2018).

8.2.4.3 Significance

The magnitude of auditory injury (PTS-onset) to both seal species from piling has been assessed as **Negligible**.

The sensitivity of both seal species to auditory injury from piling has been assessed as **Low**.

Therefore, the consequence of auditory injury from piling to both seal species is Negligible, which is not significant in EIA terms.

8.2.5 Summary

For all marine mammal species, the very low proportion of the MU predicted to experience auditory injury (PTS) from pile driving activity resulted in a **Negligible** impact significance for each species, which is **not significant** in EIA terms (**Table 8.10**).

However, a non-zero number of individual porpoise and minke whales (EPS) are predicted to be injured. Further mitigation measures will be considered, as required, in relation to future EPS Licence applications, once all the appropriate information is collated to inform the Piling Strategy.

Table 8.10 Summary of the effect of auditory injury (PTS-onset) to marine mammals resulting from single and concurrent pile driving activities.

Species	Max % UK MU injured	Max % Full MU injured	Magnitude	Sensitivity	Consequence	Significance in EIA terms
Harbour porpoise	Single: 0.05 Conc: 0.14	Single: 0.02 Conc: 0.07	Negligible	Low	Negligible	Not significant
Minke whale	Single: 0.29 Conc: 0.44	Single: 0.15 Conc: 0.22	Negligible	Medium	Negligible	Not significant
White-beaked dolphin	0.00	0.00	Negligible	Medium	Negligible	Not significant
Common dolphin	0.00	0.00	Negligible	Medium	Negligible	Not significant
Risso’s dolphin	0.00	0.00	Negligible	Medium	Negligible	Not significant
Harbour seal	0.00	0.00	Negligible	Low	Negligible	Not significant
Grey seal	0.00	0.00	Negligible	Low	Negligible	Not significant

8.3 Disturbance from pile driving

8.3.1 Harbour porpoise

8.3.1.1 Magnitude

Given the low expected density of harbour porpoise in the area, the number of animals predicted to be disturbed by pile driving on any given day is low (maximum 1,349 individuals), representing a low proportion of both the UK MU (0.73%) and the Full MU (0.36%) (**Table 8.11** and **Figure 8.11**). To determine whether this level of disturbance is expected to result in population level impacts, iPCoD modelling was conducted. As detailed in **Section 3.10**, modelling assumed the installation of pin piled jackets over three construction years, resulting in a total of 290 piling days throughout this period. The disturbance value used in the modelling was 1,149 harbour porpoise per day since this was the highest number of animals predicted to be impacted by a single pin pile jacket location. This is considered to be conservative since modelling has shown lesser impact at other model locations within the OAA.

The results of the iPCoD modelling show that there is no effect of disturbance resulting from the Project on the size and trajectory of the harbour porpoise population (Table 8.12 and Figure 8.12). Therefore, it is expected that the level of disturbance predicted is not sufficient to result in any changes at the population level since the impacted population is predicted to continue at a stable trajectory, the same as the un-impacted population. **Therefore, the magnitude of impact of disturbance from pile driving is considered to be Negligible.**

Table 8.11 Predicted impact of disturbance from pile driving activities on harbour porpoise.

Location	# Impacted	% UK MU	% Full MU	Magnitude (informed by iPCoD)
Monopile (hard sediment – 5,000 kJ)				
NW	1,349	0.73	0.36	Negligible
SE	1,026	0.56	0.27	Negligible
SW	1,005	0.55	0.27	Negligible
Monopile (soft sediment – 3,000 kJ)				
NW	1,217	0.66	0.32	Negligible
SE	941	0.51	0.25	Negligible
SW	901	0.49	0.24	Negligible
Jacket (hard/soft sediment – 3,000 kJ)				
NW	1,149	0.62	0.31	Negligible
SE	903	0.49	0.24	Negligible
SW	856	0.47	0.23	Negligible
SE+SW	1,268	0.69	0.34	Negligible

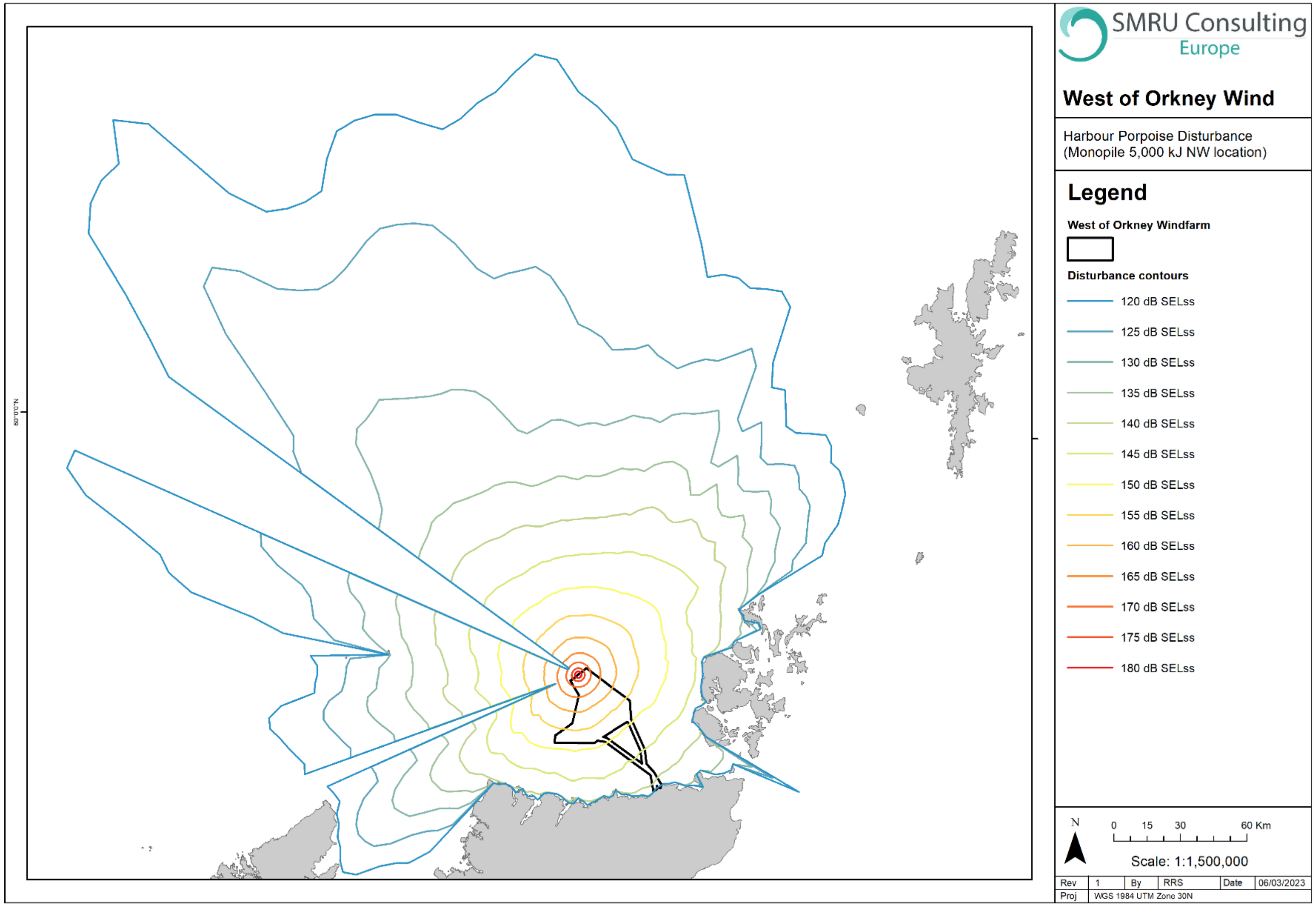

Figure 8.11 Harbour porpoise disturbance contours for the installation of a monopile at 5,000 kJ at the NW location

Table 8.12 Results of iPCoD modelling for harbour porpoise.

Simulation year	Un-impacted mean population size	Impacted mean population size	Impacted as % of un-impacted population size	Median ratio impacted:un-impacted growth rate
End 2027 (before piling commences)	184,351	184,346	100	1.00
End 2030 (after piling stops)	183,567	183,504	100	1.00
End 2036 (6 years after piling stops)	183,241	183,191	100	1.00
End 2042 (12 years after piling stops)	182,892	182,842	100	1.00

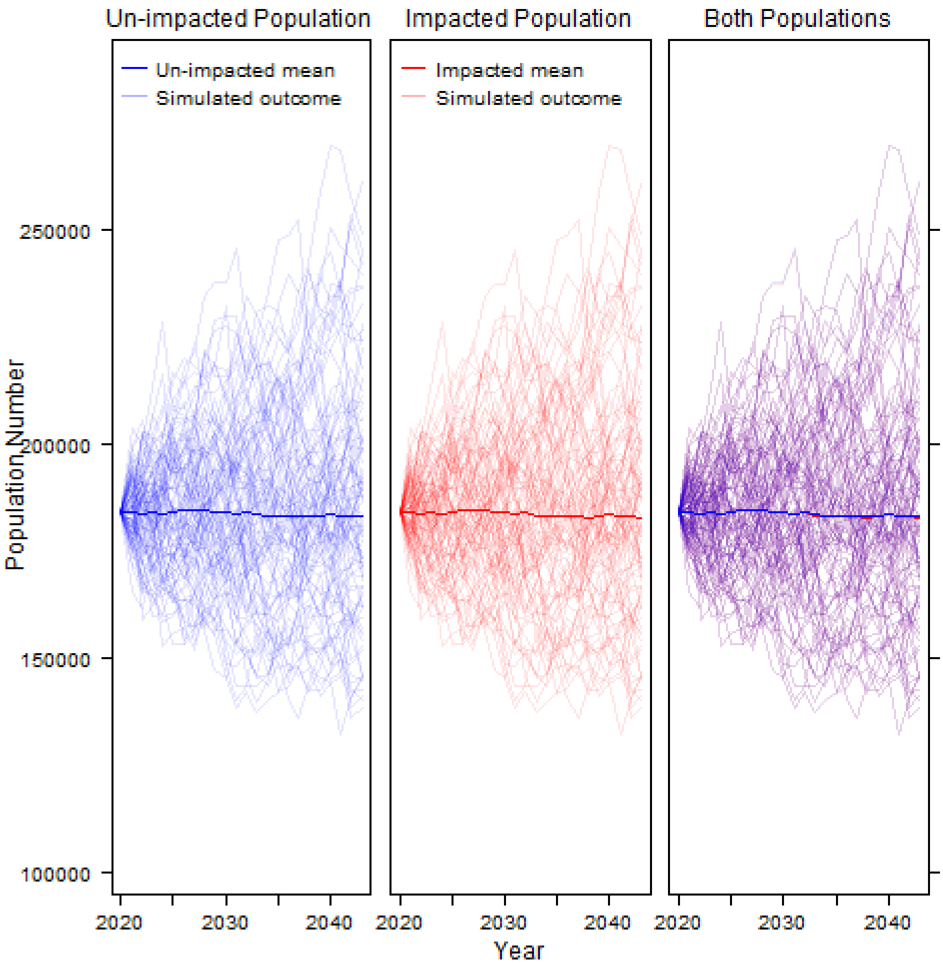

Figure 8.12 Predicted population trajectories for the un-impacted (baseline) and impacted harbour porpoise iPCoD simulations (simulation starting in 2020 and piling occurring in 2028, 2029 and 2030).

8.3.1.2 Sensitivity

Previous studies have shown that harbour porpoises are displaced from the vicinity of piling events. For example, studies at wind farms in the German North Sea have recorded large declines in harbour porpoise detections close to the piling (>90% decline at noise levels above 170 dB) with decreasing effect with increasing distance from the pile (25% decline at noise levels between 145 and 150 dB) (Brandt *et al.,* 2016). The detection rates revealed that harbour porpoise were only displaced from the piling area in the short term (1 to 3 days) (Brandt *et al.,* 2011, Dähne *et al.,* 2013, Brandt *et al.,* 2016, Brandt *et al.,* 2018). 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 (e.g. Rojano-Doñate *et al.,* 2018). This makes them vulnerable to starvation if they are unable to obtain sufficient levels of prey intake.

Studies using Digital Acoustic Recording Tags (DTAGs) have shown that harbour porpoise tagged after capture in pound nets foraged on small prey nearly continuously during both the day and the night on their release (Wisniewska *et al.,* 2016). However, Hoekendijk *et al.,* (2018) point out that this could be an extreme short-term response to capture in nets, and may not reflect natural harbour porpoise behaviour. Nevertheless, if the foraging efficiency of harbour porpoise is disturbed or if they are displaced from a high-quality foraging ground, and are unable to find suitable alternative feeding grounds, they could potentially be at risk of changes to their overall fitness if they are not able to compensate and obtain sufficient food intake in order to meet their metabolic demands.

However, the results from Wisniewska *et al.,* (2016) could also suggest that harbour porpoises have an ability to respond to short term reductions in food intake, implying a resilience to disturbance. As Hoekendijk *et al.,* (2018) and Booth (2020) argue, this could help explain why harbour porpoises are such an abundant and successful species. It is important to note that the studies providing evidence for the responsiveness of harbour porpoises to piling noise have not provided any evidence for subsequent individual consequences. In this way, responsiveness to disturbance cannot reliably be equated to sensitivity to disturbance and harbour porpoises may well be able to compensate by moving quickly to alternative areas to feed, while at the same time increasing their feeding rates.

Monitoring of harbour porpoise activity at the Beatrice Offshore Wind Farm during pile driving activity has indicated that harbour porpoises were displaced from the immediate vicinity of the pile driving activity – with a 50% probability of response occurring at approximately 7 km (Graham *et al.,* 2019). This monitoring also indicated that the response diminished over the construction period, so that eight months into the construction stage, the range at which there was a 50% probability of response was only 1.3 km. In addition, the study indicated that harbour porpoise activity recovered between pile driving days.

A study of tagged harbour porpoises has shown large variability between individual responses to a seismic survey airgun stimulus (van Beest *et al.,* 2018). Of the five harbour porpoises tagged and exposed to airgun pulses at ranges of 420–690 m (SEL 135–147 dB re 1 µPa^{2}s), one individual showed rapid and directed movements away from the source. Two individuals displayed shorter and shallower dives immediately after exposure and the remaining two animals did not show any quantifiable response. Therefore, there is expected to be a high level of variability in responses from individual harbour porpoises exposed to low frequency broadband pulsed noise (including both airguns and pile-driving).

At a BEIS-funded expert elicitation workshop held in Amsterdam in June 2018, experts in marine mammal physiology, behaviour and energetics discussed the nature, extent and potential consequences of disturbance to harbour porpoise from exposure to low frequency broadband pulsed noise (e.g. pile-driving, airgun pulses) (Booth *et al.,* 2019). Experts were asked to estimate the potential consequences of a six-hour period of zero energy intake, assuming that disturbance from a pile driving event resulted in missed foraging opportunities for this duration. A Dynamic Energy Budget

(DEB) model for harbour porpoise (based on the DEB model in Hin *et al.,* (2019)) was used to aid discussions regarding the potential effects of missed foraging opportunities on survival and reproduction. The model described the way in which the life history processes (growth, reproduction and survival) of a female and her calf depend on the way in which assimilated energy is allocated between different processes and was used during the elicitation to model the effects of energy intake and reserves following simulated 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 that the final third of the year was the most critical for harbour porpoises as they reach the end of the current lactation period and the start of new pregnancies, therefore it was thought that significant impacts on fertility would only occur when animals received repeated exposure throughout the whole year. 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 8.13 left**), and that it was very unlikely an animal would terminate a pregnancy early. The experts agreed that calf survival could be reduced by only a few days of repeated disturbance to a mother/calf pair during early lactation (**Figure 8.13 right**); however, it is highly unlikely that the same mother-calf pair would repeatedly return to the area in order to receive these levels of repeated disturbance.

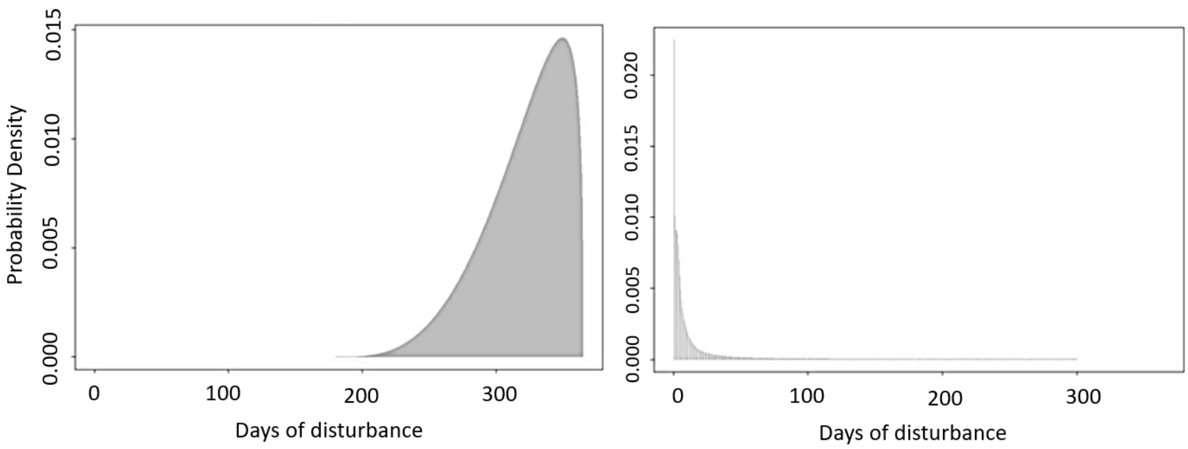

Figure 8.13: Probability distributions showing the consensus of the expert elicitation for harbour porpoise disturbance from piling (Booth *et al.,* 2019). Left: the number of days of disturbance (i.e. days on which an animal does not feed for six hours) a pregnant female could 'tolerate' before it has any effect on fertility. Right: the number of days of disturbance (of six hours zero energy intake) a mother/ calf pair could 'tolerate' before it has any effect on survival.

A recent study by Benhemma-Le Gall *et al.,* (2021) provided two key findings in relation to harbour porpoise response to pile driving. Harbour porpoise were not completely displaced from the piling site: detections of clicks (echolocation) and buzzing (associated with prey capture) in the short-range (2 km) did not cease in response to pile driving, and harbour porpoise appeared to compensate: detections of both clicks (echolocation) and buzzing (associated with prey capture) increased above baseline levels with increasing distance from the pile, which suggests that those harbour porpoise that are displaced from the near-field resume foraging at a greater distance from the piling location and may compensate for missed foraging activity by increasing foraging activities beyond the impact range (**Figure 8.14**). Therefore, harbour porpoise that experience displacement are expected to be able to compensate for the lost foraging opportunities and increased energy expenditure of fleeing.

Due to observed responsiveness to piling, their income breeder life history, and the low numbers of days of disturbance expected to affect calf survival, **harbour porpoises have been assessed as having a Low sensitivity to disturbance from pile driving.**

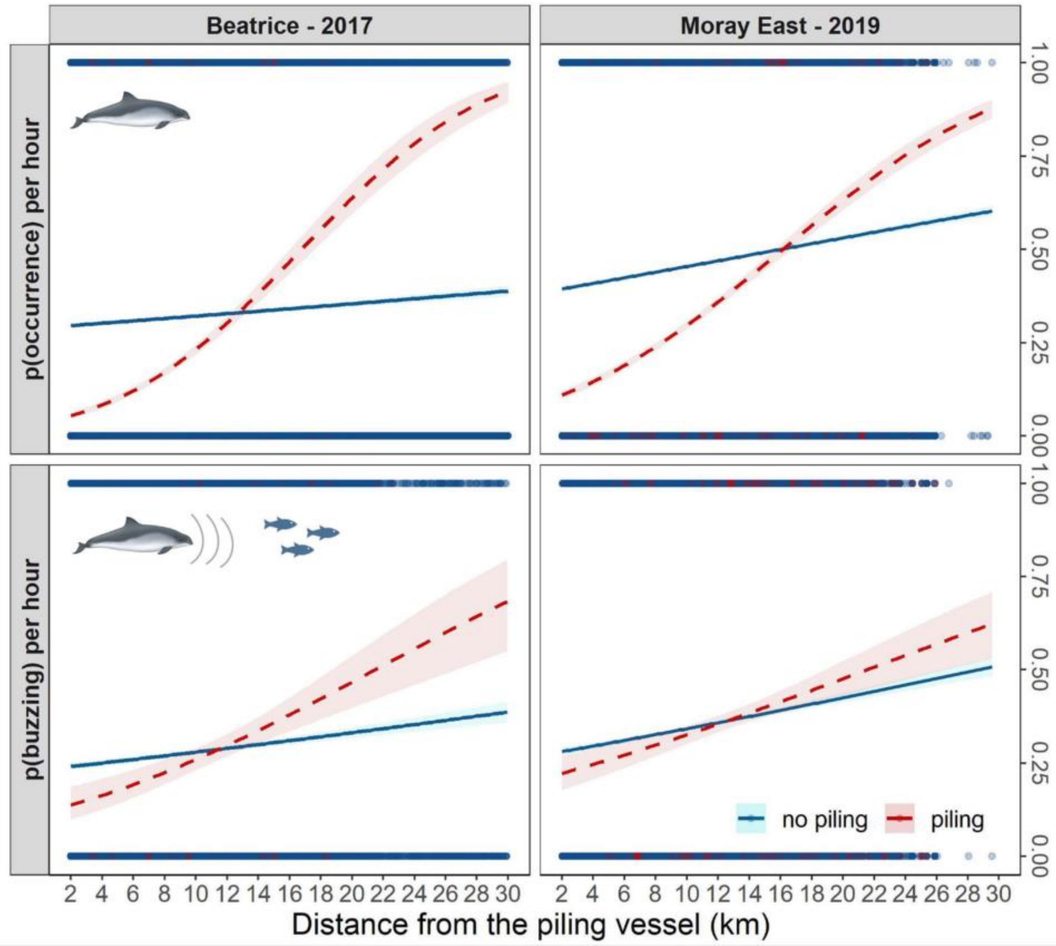

Figure 8.14: The probability of harbour porpoise occurrence and buzzing activity per hour during (dashed red line) and out with (blue line) pile-driving hours, in relation to distance from the pile-driving vessel at Beatrice (left) and Moray East (right). Obtained from Benhemma-Le Gall *et al.,* (2021).

8.3.1.3 Significance

The magnitude of disturbance to harbour porpoise from piling has been assessed as **Negligible**.

The sensitivity of harbour porpoise to disturbance from piling has been assessed as **Low**.

Therefore, the consequence of disturbance from piling to harbour porpoise is Negligible, which is not significant in EIA terms.

8.3.2 White-beaked dolphin

8.3.2.1 Magnitude

Given the relatively high density estimate for white-beaked dolphins in the area, the number of animals predicted to experience disturbance from the installation of a monopile in hard sediment is 1,709 dolphins which represents 5.02% of the UK MU, or 3.89% of the Full MU (Table 8.13).

The harbour porpoise dose-response function has been used as a proxy for all dolphin species response in the absence of similar empirical data. However, this makes the assumption that the same disturbance relationship is observed in white-beaked dolphins. It is anticipated that this approach will be overly precautionary as evidence suggests that dolphin species are less sensitive to disturbance compared to harbour porpoise. A literature review of recent (post Southall *et al.,* (2007)) behavioural responses by harbour porpoises and bottlenose dolphins to noise was conducted by Moray Offshore

Renewables Limited (2012). Several studies have reported a moderate to high level of behavioural response at a wide range of received SPLs (100 and 180 dB re 1µPa) (Lucke *et al.,* 2009, Tougaard *et al.,* 2009, Brandt *et al.,* 2011). Conversely, a study by Niu *et al.,* (2012) reported moderate level responses to non-pulsed noise by bottlenose dolphins at received SPLs of 140 dB re 1µPa. Another high frequency cetacean, Risso's dolphin, reported no behavioural response at received SPLs of 135 dB re 1µPa (Southall *et al.,* 2010). Whilst both species showed a high degree of variability in responses and a general positive trend with higher responses at higher received levels, moderate level responses were observed above 80 dB re 1µPa in harbour porpoise and above 140 dB re 1µPa in bottlenose dolphins (Moray Offshore Renewables Limited, 2012), indicating that moderate level responses by bottlenose dolphins will be exhibited at a higher received SPL and, therefore, they are likely to show a lesser response to disturbance.

In addition to this, the density estimate used in the assessment for white-beaked dolphins is considered to be conservative. The density value of 0.19 dolphins/km^2 was obtained from the site-specific surveys of the ScotWind N1 lease area plus a 4 km buffer, with a survey area of 1,321 km^2. By contrast, the area considered within dose-response assessment (down to 120 dB SEL_{ss}) totals 69,254.9 km^2. Therefore, the area surveyed in the site-specific surveys represents only 1.9% of the total area within the 120 dB SEL_{ss} impact contour used in the dose-response assessment. It is highly conservative to assume that the density estimate for the site-specific survey area is the same throughout this much wider impact area, especially when other data sources estimate much lower density estimates across this wider area (e.g. SCANS III density estimate for block S was 0.021 dolphins/km^2).

The movement patterns of white-beaked dolphins in UK waters are poorly understood, and as such, it is not known the level of repeated disturbance an individual dolphin would be expected to receive. At one extreme, it could be assumed that there is no movement/turn-over of individuals in the area, and thus the same dolphins would be expected to be disturbed repeatedly on up to 290 piling days over the three-year piling activity period. However, this is considered to be highly conservative since the limited data available of white-beaked dolphin movement patterns suggests that white-beaked dolphins have large home range areas and show low site fidelity (Bertulli *et al.,* 2015). It is more likely that animals transit through the area within their large home-range, and thus individuals are only available to be disturbed over a limited number of days when present in the disturbance area.

Given the lack of data on white-beaked dolphin responses to pile driving, and the fact that iPCoD is not available for this species to determine whether or not this level of impact is likely to result in a population level impact, **it is conservative to conclude a Medium magnitude, since it is possible that impacts could result in a deviation from the baseline.**

Table 8.13 Predicted impact of disturbance from pile driving activities on white-beaked dolphins.

Location	# Impacted	% UK MU	% Full MU	Magnitude
Monopile (hard sediment – 5,000 kJ)				
NW	1,709	5.02	3.89	Medium
SE	1,299	3.82	2.96	Medium
SW	1,273	3.74	2.90	Medium
Monopile (soft sediment – 3,000 kJ)				
NW	1,541	4.53	3.51	Medium
SE	1,192	3.50	2.71	Medium

SW	1,141	3.35	2.60	Medium
Jacket (hard/soft sediment – 3,000 kJ)				
NW	1,456	4.28	3.31	Medium
SE	1,144	3.36	2.60	Medium
SW	1,084	3.19	2.47	Medium
SE+SW	1,607	4.72	3.66	Medium

8.3.2.2 Sensitivity

There is a single study detailing white-beaked dolphin responses to playbacks of amplitude-modulated tones and synthetic pulse-bursts; responses were observed in 90 out of 123 exposures and received levels varied between 153 and 161 dB re 1 µPa for pulse-burst signals (Rasmussen *et al.,* 2016). Due to the limited information on the effects of disturbance on white-beaked dolphins, bottlenose dolphins can be used as a proxy since both species are categorised as high-frequency cetaceans.

Bottlenose dolphins have been shown to be displaced from an area as a result of the noise produced by offshore construction activities; for example, avoidance behaviour in bottlenose dolphins has been shown in relation to dredging activities, piling and seismic surveys (Pirotta *et al.,* 2013, Graham *et al.,* 2017b, Fernandez-Betelu *et al.,* 2021). In a study on bottlenose dolphins in the Moray Firth (in relation to the construction of the Nigg Energy Park in the Cromarty Firth), small effects of pile driving on dolphin presence have been observed; however, dolphins were not excluded from the vicinity of the piling activities (Graham *et al.,* 2017b). In this study the median peak-to-peak source levels recorded during impact piling were estimated to be 240 dB re 1µPa (range 8 dB) with a single pulse source level of 198 dB re 1 $\mu Pa^2 s$. The pile driving resulted in a slight reduction of the presence, detection positive hours and the encounter duration for dolphins within the Cromarty Firth; however, this response was only significant for the encounter durations. Encounter durations decreased within the Cromarty Firth (though only by a few minutes) and increased outside of the Cromarty Firth on days of piling activity. These data highlight a small spatial and temporal scale disturbance to bottlenose dolphins as a result of impact piling activities.

According to the opinions of the experts, disturbance would be most likely to affect bottlenose dolphin calf survival, where: *"it exceeded 30-50 days, because it could result in mothers becoming separated from their calves and this could affect the amount of milk transferred from the mother to her calf"* (Harwood *et al.,* 2014a). There is the potential for behavioural disturbance and displacement to result in disruption in foraging and resting activities and an increase in travel and energetic costs. However, it has been previously shown that bottlenose dolphins have the ability to compensate for behavioural responses as a result of increased commercial vessel activity, where longer term overall activity time budget remained the same despite the immediate behavioural response to disturbance (New *et al.,* 2013). Therefore, while there remains the potential for disturbance and displacement to affect individual behaviour, it is not expected that this would result in an overall change in individual energy budget since animals have been shown to compensate for time lost due to disturbance. Therefore, no change to vital rates is expected, and thus bottlenose dolphins are considered to have a Low sensitivity to disturbance from pile driving.

In the absence of species-specific data for white-beaked dolphins, bottlenose dolphin information is used instead. Therefore, **white-beaked dolphins are considered to have a Low sensitivity to disturbance from pile driving.**

8.3.2.3 Significance

The magnitude of disturbance to white-beaked dolphins from piling has been assessed as **Medium**.

The sensitivity of white-beaked dolphins to disturbance from piling has been assessed as **Low**.

Therefore, the consequence of disturbance from piling to white-beaked dolphins is Minor, which is not significant in EIA terms.

8.3.3 Common dolphin

8.3.3.1 Magnitude

The harbour porpoise dose-response function has been used as a proxy for common dolphin response in the absence of similar empirical data. As detailed above for white-beaked dolphins, it is anticipated that this approach will be highly precautionary as evidence suggests that dolphin species are less sensitive to disturbance compared to harbour porpoise.

Despite this overly precautionary approach, given the low expected density of common dolphins in the area, the number of animals predicted to be disturbed by pile driving on any given day is very low (maximum 90 individuals), representing a very low proportion of both the UK MU (0.16%) and the Full MU (0.09%) (**Table 8.14**). Given the extremely low numbers of animals expected to be disturbed per piling day, there is expected to be no resulting impact to the common dolphin population, and thus no change to the conservation status or the integrity of the receptor.

Therefore, disturbance of common dolphins from pile driving is concluded to be of Low magnitude (no significant effect on the conservation status or the integrity of the receptor, local to medium scale spatial extent and short to medium term duration 1-5 years).

Table 8.14 Predicted impact of disturbance from pile driving activities on common dolphins.

Location	# Impacted	% UK MU	% Full MU	Magnitude
Monopile (hard sediment – 5,000 kJ)				
NW	90	0.16	0.09	Low
SE	68	0.12	0.07	Low
SW	67	0.12	0.07	Low
Monopile (soft sediment – 3,000 kJ)				
NW	81	0.14	0.08	Low
SE	63	0.11	0.06	Low
SW	60	0.10	0.06	Low
Jacket (hard/soft sediment – 3,000 kJ)				
NW	77	0.13	0.08	Low
SE	60	0.10	0.06	Low
SW	57	0.10	0.06	Low
SE+SW	85	0.15	0.08	Low

8.3.3.2 Sensitivity

The hearing range of common dolphins is currently estimated from their sound production, and has been labelled medium-high frequency, spanning between 150 Hz to 160 kHz (Finneran, 2016, Houser *et al.,* 2017). There are few studies investigating the effects of pile driving on common dolphins, which could relate to their occupation of deeper waters, contrasting with the shallower habitat in which offshore construction frequently occurs. However, an analysis of pile driving activity in Broadhaven Bay, Ireland, found construction activity to be associated with a reduction in the presence of minke whales and harbour porpoise, but not with common dolphins (Culloch *et al.,* 2016). Conversely, increased vessel presence during the construction period was associated with a decrease of common dolphins in the surrounding area. While there is little information on the impacts of pile driving on common dolphins, there are a few studies documenting the impacts of seismic activity. Although the noise produced by airguns differs in its duration and cumulative acoustic energy levels, it may be similar in its frequency range to the low-frequency noise produced by pile driving. In general, there is contrasting evidence for the response of common dolphins to seismic surveys. While some research indicates no change in the occurrence or sighting density of common dolphins when exposed to seismic activity (Stone *et al.,* 2017, Kavanagh *et al.,* 2019), Goold (1996) found a reduction in common dolphin presence within 1 km of ongoing seismic surveys near Pembrokeshire. The sparse information available for the impacts of construction (and other) activities on common dolphins makes it difficult to assess the risk for this species.

Given that they are grouped as high-frequency cetaceans alongside the other dolphin species considered in this assessment, **common dolphins are also considered to have a Low sensitivity to behavioural disturbance from piling.**

8.3.3.3 Significance

The magnitude of disturbance to common dolphins from piling has been assessed as **Low**.

The sensitivity of common dolphins to disturbance from piling has been assessed as **Low**.

Therefore, the consequence of disturbance from piling to common dolphins is Negligible, which is not significant in EIA terms.

8.3.4 Risso's dolphin

8.3.4.1 Magnitude

The harbour porpoise dose response function has been used as a proxy for Risso's dolphin response in the absence of similar empirical data. As detailed above for white-beaked dolphins, it is anticipated that this approach will be highly precautionary as evidence suggests that dolphin species are less sensitive to disturbance compared to harbour porpoise.

Despite this overly precautionary approach, given the low expected density of Risso's dolphins in the area, the number of animals predicted to be disturbed by pile driving on any given day is low (maximum 121 individuals), representing a low proportion of both the UK MU (1.4%) and the Full MU (1.0%) (**Table 8.14**). Given the low numbers of animals expected to be disturbed per piling day, there is expected to be no resulting impact to the Risso's dolphin population, and thus no change to the conservation status or the integrity of the receptor.

Therefore, disturbance of Risso's dolphins from pile driving is concluded to be of Low magnitude (no significant effect on the conservation status or the integrity of the receptor, local to medium scale spatial extent and short to medium term duration 1-5 years).

Table 8.15 Predicted impact of disturbance from pile driving activities on Risso's dolphins.

Location	# Impacted	% UK MU	% Full MU	Magnitude
Monopile (hard sediment – 5,000 kJ)				
NW	121	1.4	1.0	Low
SE	92	1.1	0.8	Low
SW	90	1.0	0.7	Low
Monopile (soft sediment – 3,000 kJ)				
NW	110	1.3	0.9	Low
SE	85	1.0	0.7	Low
SW	81	0.9	0.7	Low
Jacket (hard/soft sediment – 3,000 kJ)				
NW	103	1.2	0.8	Low
SE	81	0.9	0.7	Low
SW	77	0.9	0.6	Low
SE+SW	114	1.3	0.9	Low

8.3.4.2 Sensitivity

In the absence of any species-specific data, given that they are grouped as high-frequency cetaceans alongside the other dolphin species considered in this assessment, **Risso's dolphins are also considered to have a Low sensitivity to behavioural disturbance from piling.**

8.3.4.3 Significance

The magnitude of disturbance to Risso's dolphins from piling has been assessed as **Low**.

The sensitivity of Risso's dolphins to disturbance from piling has been assessed as **Low**.

Therefore, the consequence of disturbance from piling to Risso's dolphins is Negligible, which is not significant in EIA terms.

8.3.5 Minke whale

8.3.5.1 Magnitude

The harbour porpoise dose response function has been used as a proxy for minke whale response in the absence of similar empirical data. This is highly conservative given the extremely different hearing capabilities of these two species. Despite this precautionary approach, given the low expected density of minke whales in the area, the number of animals predicted to be disturbed by pile driving on any given day is low (maximum 90 individuals), representing a low proportion of both the UK MU (0.87%) and the Full MU (0.45%) (**Table 8.14**). Given the extremely low numbers of animals expected to be disturbed per piling day, there is expected to be no resulting impact to the minke whale population, and thus no change to the conservation status or the integrity of the receptor.

Therefore, disturbance of minke whales from pile driving is concluded to be of Low Magnitude (no significant effect on the conservation status or the integrity of the receptor, local to medium scale spatial extent and short to medium term duration 1-5 years).

Table 8.16 Predicted impact of disturbance from pile driving activities on minke whales.

Location	# Impacted	% UK MU	% Full MU	Magnitude
Monopile (hard sediment – 5,000 kJ)				
NW	90	0.87	0.45	Low
SE	68	0.66	0.34	Low
SW	67	0.65	0.33	Low
Monopile (soft sediment – 3,000 kJ)				
NW	81	0.79	0.40	Low
SE	63	0.61	0.31	Low
SW	60	0.58	0.30	Low
Jacket (hard/soft sediment – 3,000 kJ)				
NW	77	0.74	0.38	Low
SE	60	0.59	0.30	Low
SW	57	0.55	0.28	Low
SE+SW	85	0.82	0.42	Low

8.3.5.2 Sensitivity

There is little information available on the behavioural responses of minke whales to underwater noise. Minke whales have been shown to change their diving patterns and behavioural state in response to disturbance from whale watching vessels; and it was suggested that a reduction in foraging activity at feeding grounds could result in reduced reproductive success in this capital breeding species (Christiansen *et al.,* 2013). There is only one study showing minke whale reactions to sonar signals (Sivle *et al.,* 2015) with behavioural response severity scores above 4 (the stage at which avoidance to a sound source first occurs) for a received SPL of 146 dB re 1 µPa (score 7[5]) and a received SPL of 158 dB re 1 µPa (score 8[6]). There is a study detailing minke whale responses to a Lofitech Acoustic Deterrent Device (ADD) which has a source level of 204 dB re 1 µPa @ 1 m, which showed minke whales within 500 m and 1,000 m of the source exhibiting a behavioural response. The estimated received level at 1,000 m was 136.1 dB re 1 µPa (McGarry *et al.,* 2017). There are no equivalent such studies of responses to pile driving noise.

Since minke whales are known to forage in UK waters in the summer months, there is the potential for displacement to impact on reproductive rates. However, due to their large size and capacity for energy storage, it is expected that minke whales will be able to tolerate temporary displacement from foraging areas much better than harbour porpoise and individuals are expected to be able to recover from any impact on vital rates. Therefore, **minke whales have been assessed as having a Low sensitivity to disturbance from pile driving**.

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[5] Defined in Sivle *et al.,* (2015) as: Prolonged avoidance – The animal increased speed and swam directly away from the sound source throughout the rest of the exposure. Opportunistic visual observations of skim feeding at the surface before the start of the sonar exposure indicated that this response might also have involved a cessation of feeding.

[6] Defined in Sivle *et al.,* (2015) as: Obvious progressive aversion (and sensitization) – The animal continued to increase its speed as the exposure progressed, swimming at such a high speed that the distance to the source ship remained constant. About halfway through the exposure, the dive pattern changed to shallower diving, which may be a way to move more effectively away from the source.

8.3.5.3 Significance

The magnitude of disturbance to minke whales from piling has been assessed as **Low**.

The sensitivity of minke whales to disturbance from piling has been assessed as **Low**.

Therefore, the consequence of disturbance from piling to minke whales is Negligible, which is not significant in EIA terms.

8.3.6 Harbour seal

8.3.6.1 Magnitude

Up to a maximum of 176 (CI: 18 – 328) harbour seals (9% MU, CI: 0.9-16.8% MU) are predicted to be disturbed from pile driving activities at the SE modelling location for the installation of a monopile in hard sediment (**Table 8.17** and **Figure 8.15**). To determine whether this level of disturbance is expected to result in population-level impacts, iPCoD modelling was conducted. As detailed in **Section 3.10**, modelling assumed the installation of pin piled jackets over three construction years (piling in May – Oct), resulting in a total of 290 piling days across this period. The disturbance value used in the modelling was 158 harbour seals per day since this was the highest number of animals predicted to be impacted by a single pin pile jacket location[7]. This is considered to be conservative since modelling has shown lesser impact at other model locations within the OAA.

It is important to note when considering the iPCoD results for harbour seals, that the North Coast and Orkney MU is currently in decline with an average rate of decrease over the last 5 years of ~8.5% per year (SCOS, 2022) (**Figure 8.16**). It is noted in SCOS (2022) that the 2019 count was similar to the 2016 count, which could indicate that the decline has slowed, but more counts are required to confirm this. Therefore, the demographic parameters used in the iPCoD model for harbour seals are those recommended in Sinclair *et al.,* (2020), which were parameterised to maintain an annual decline of ~10% per year throughout the simulation. When interpreting the iPCoD results it is therefore necessary to understand that the un-impacted baseline MU is predicted to significantly decline in the absence of any impacts from the Project.

The results of the iPCoD modelling show that there is no effect of disturbance resulting from the Project on the size and trajectory of the harbour seal population (Table 8.18 and **Figure 8.17**). Therefore, it is expected that the level of disturbance predicted is not sufficient to result in any changes at the population level, since the impacted population is predicted to continue declining at exactly the same rate as the un-impacted population. The magnitude of impact is therefore assessed as **Negligible**, as there is expected to be no change from the baseline condition.

[7] Note: while more individuals are predicted to be disturbed per day from a single monopile compared to pin-piles (176 vs 158), the duration of piling is significantly longer for pin-piles than for monopiles (290 days vs 125 days). Since disturbance on numerous repeated days is expected to result in more impact on vital rates, the longer pin-piling scenario was considered worst case for the population modelling.

Table 8.17 Predicted impact of disturbance from pile driving activities on harbour seals. Numbers in brackets represent the confidence intervals.

Location	# Impacted	% MU	Magnitude (informed by iPCoD)
Monopile (hard sediment – 5,000 kJ)			
NW	57 (3 – 117)	2.9 (0.2 – 6.0)	Negligible
SE	176 (18 – 328)	9.0 (0.9 – 16.8)	Negligible
SW	27 (3 – 51)	1.4 (0.2 – 2.6)	Negligible
Monopile (soft sediment – 3,000 kJ)			
NW	42 (2 – 86)	2.2 (0.1 – 4.4)	Negligible
SE	164 (17 – 307)	8.4 (0.9 – 15.7)	Negligible
SW	24 (2 – 44)	1.2 (0.1 – 2.3)	Negligible
Jacket (hard/soft sediment – 3,000 kJ)			
NW	35 (2 – 72)	1.8 (0.1 – 3.7)	Negligible
SE	158 (17 – 296)	8.1 (0.9 – 15.2)	Negligible
SW	22 (2 – 41)	1.1 (0.1 – 2.1)	Negligible
SE+SW	168 (18 – 313)	8.6 (0.9 – 16.0)	Negligible

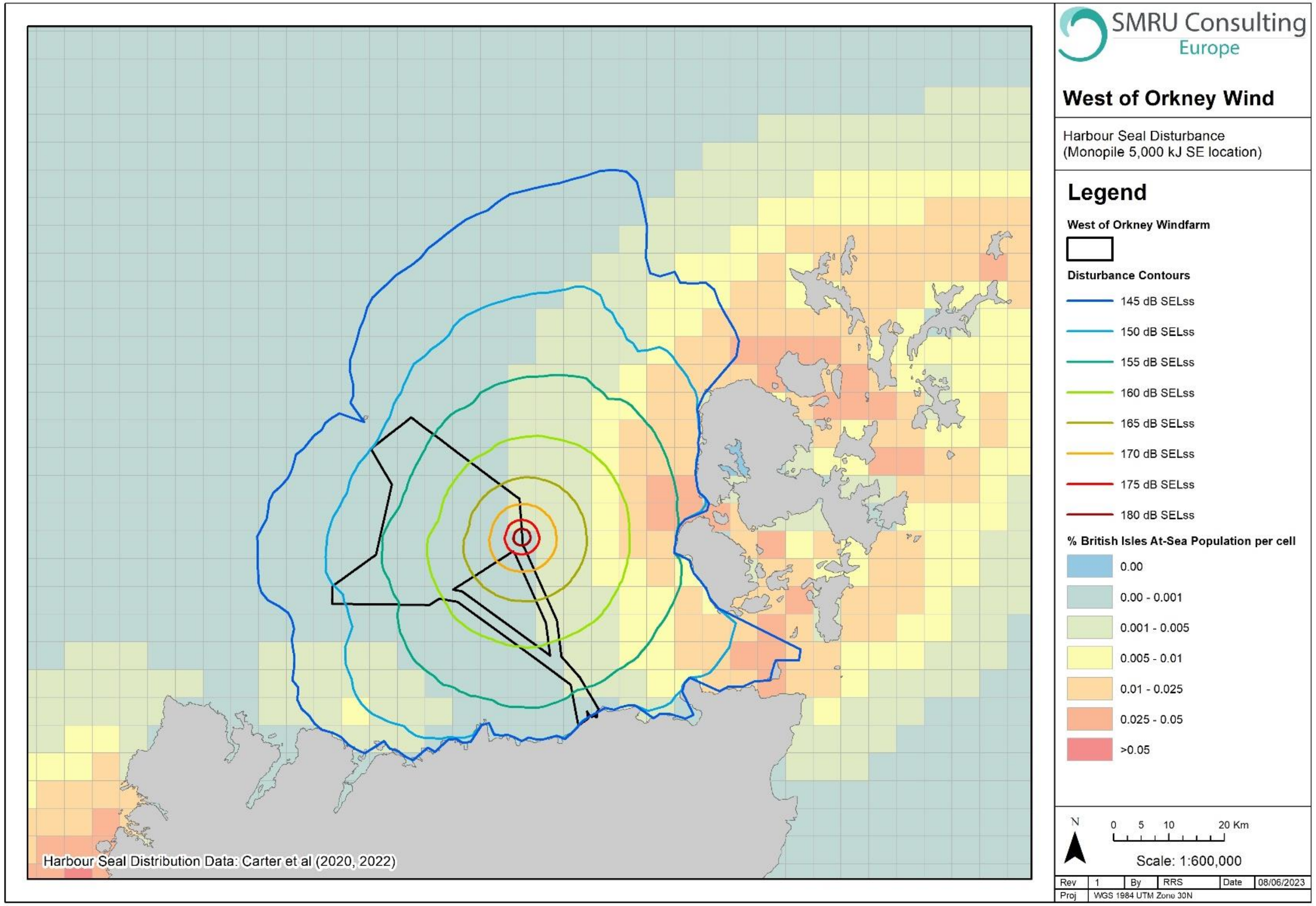


Figure 8.15 Harbour seal disturbance contours for the installation of a monopile at 5,000 kJ at the SE location

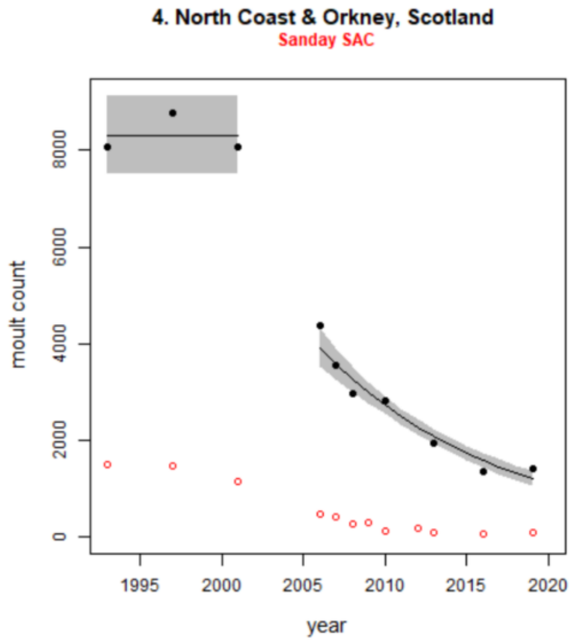


Figure 8.16 The predicted trend and associated 95% confidence intervals for harbour seal August counts in the North Coast & Orkney SMU (SCOS, 2022) (Figure 4(a) from SCOS-BP 21/03). Black dots represent counts for the MU overall, red dots denote counts specific to the Sanday SAC within the MU.

Table 8.18 Results of iPCoD modelling for harbour seals.

Simulation year	Un-impacted mean population size	Impacted mean population size	Impacted as % of un-impacted population size	Median ratio impacted:un-impacted growth rate
End 2027 (before piling commences)	791	791	100	1.00
End 2030 (after piling stops)	570	570	100	1.00
End 2036 (6 years after piling stops)	293	293	100	1.00
End 2042 (12 years after piling stops)	151	151	100	1.00

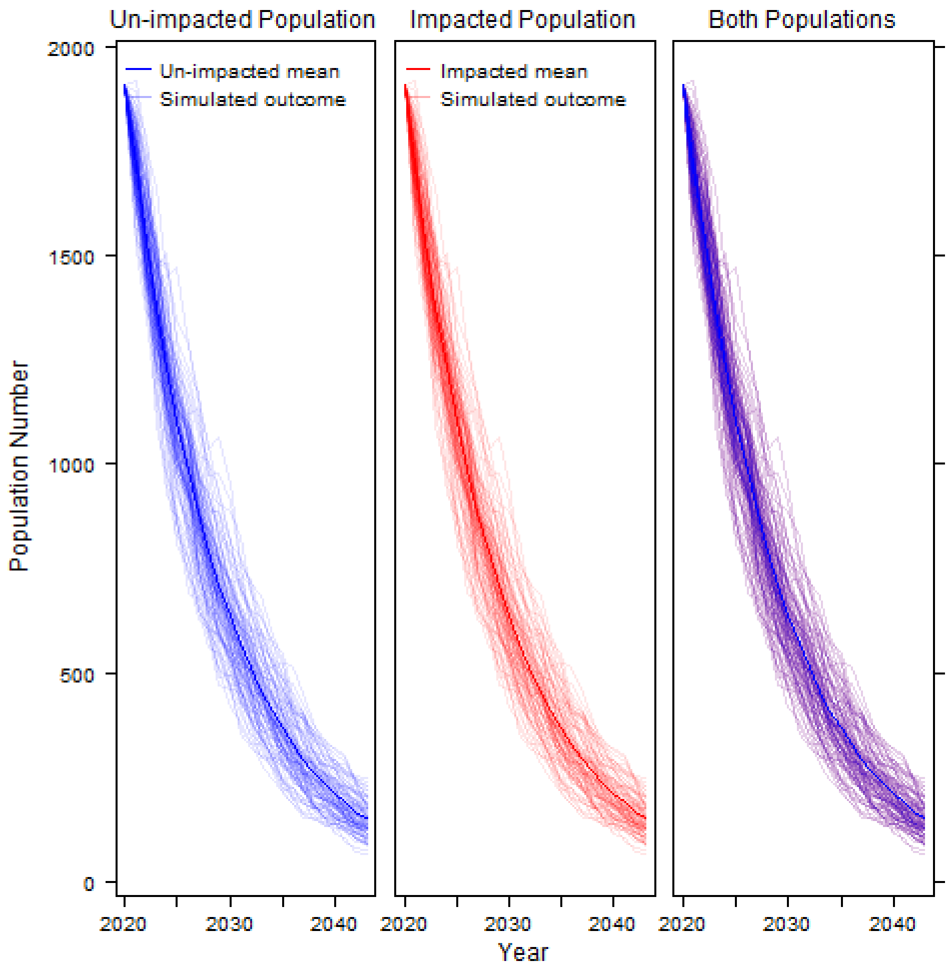


Figure 8.17 Predicted population trajectories for the un-impacted (baseline) and impacted harbour seal iPCoD simulations (simulation starting in 2020 and piling occurring in 2028, 2029 and 2030).

8.3.6.2 Sensitivity

A study of tagged harbour seals in the Wash has shown that they are displaced from the vicinity of piles during impact piling activities. Russell *et al.,* (2016a) showed that seal abundance was significantly reduced within an area with a radius of 25 km from a pile during piling activities, with a 19 to 83% decline in abundance during impact piling compared to during breaks in piling. The duration of the displacement was only in the short-term as seals returned to non-piling distributions within two hours after the end of a piling event. Unlike harbour porpoise, harbour 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.

At the expert elicitation workshop (Booth *et al.,* 2019), experts agreed the most likely potential consequences of a six hour period of zero energy intake, assuming that disturbance (from exposure to low frequency broadband pulsed noise (e.g., impact piling, airgun pulses)) resulted in missed foraging opportunities. In general, 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 adequate fat stores. The survival of 'weaned of the year' animals and fertility were determined to be the most sensitive life history parameters to disturbance (i.e., leading to reduced energy intake). Juvenile harbour seals are typically considered to be coastal foragers (Booth *et al.,* 2019) and so less likely to be exposed to disturbances and similarly pups were thought to be unlikely to be exposed to disturbance due to their proximity to land. Unlike for harbour porpoise, there was no DEB model available to simulate the effects of disturbance on seal energy intake and reserves; therefore, the opinions of the experts were less certain. Experts considered that the location of the disturbance would influence the effect of the disturbance, with a greater effect if animals were disturbed at a foraging ground as opposed to when animals were transiting through an area. It was thought that for an animal in bad condition, moderate levels of repeated disturbance might be sufficient to reduce fertility (**Figure 8.18 left**); however, there was a large amount of uncertainty in this estimate. The 'weaned of the year' were considered to be most vulnerable following the post-weaning fast, and that during this time, experts felt it might take ~60 days of repeated disturbance before there was expected to be any effect on the probability of survival (**Figure 8.18 right**); however, again, there was a lot of uncertainty surrounding this estimate. Similar to above, it is considered unlikely that individual harbour seals would repeatedly return to a site where they had been previously displaced from in order to experience this number of days of repeated disturbance.

Due to observed responsiveness to piling, **harbour seals have been assessed as having Medium sensitivity to disturbance and resulting displacement from foraging grounds during impact piling events.**

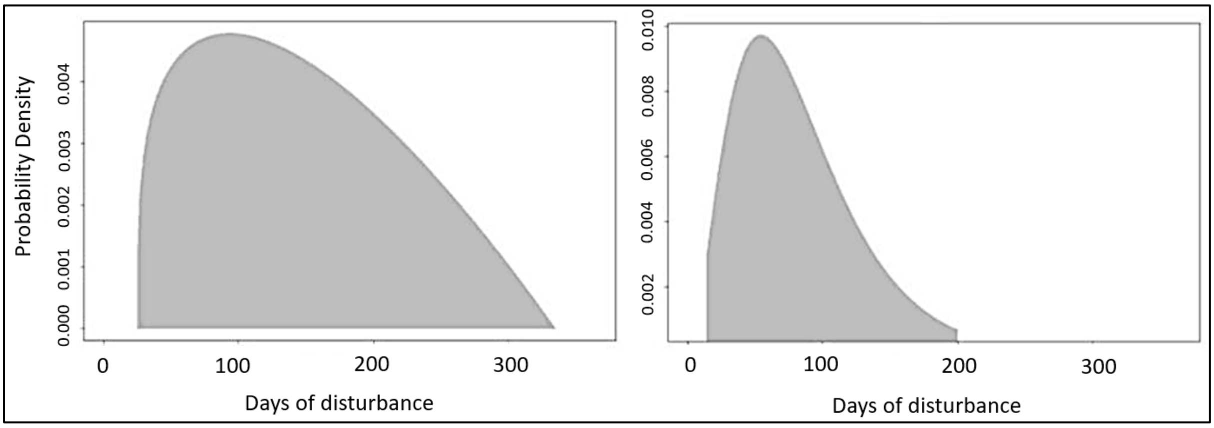


Figure 8.18 Probability distributions showing the consensus of the expert elicitation for harbour seal disturbance from piling. X-axis = days of disturbance; y-axis = probability density. Left: the number of days of disturbance (i.e. days on which an animal does not feed for six hours) a pregnant female could 'tolerate' before it has any effect on fertility. Right: the number of days of disturbance (of six hours zero energy intake) a 'weaned of the year' harbour seal could 'tolerate' before it has any effect on survival. Figures obtained from Booth *et al.,* (2019).

8.3.6.3 Significance

The magnitude of disturbance to harbour seals from piling has been assessed as **Negligible**.

The sensitivity of harbour seals to disturbance from piling has been assessed as **Medium**.

Therefore, the consequence of disturbance from piling to harbour seals is Negligible which is not significant in EIA terms.

8.3.7 Grey seal

8.3.7.1 Magnitude

Up to a maximum of 2,887 (CI: 328 – 5,318) grey seals (8.4% MU, CI: 1.0 – 15.6% MU) are predicted to be disturbed from pile driving activities at the SE modelling location for the installation of a monopile in hard sediment (**Table 8.19** and **Figure 8.19**). To determine whether this level of disturbance is expected to result in population level impacts, iPCoD modelling was conducted. As detailed in **Section 3.10**, modelling assumed the installation of pin piled jackets over three construction years, resulting in a total of 290 piling days throughout this period. The disturbance value used in the modelling was

2,596 grey seals per day since this was the highest number of animals predicted to be impacted by a single pin pile jacket location. This is considered to be conservative since modelling has shown lesser impact at other model locations within the OAA.

The results of the iPCoD modelling show that there is no effect of disturbance resulting from the Project on the size and trajectory of the grey seal population (Table 8.20 and Figure 8.20). Therefore, it is expected that the level of disturbance predicted is not sufficient to result in any changes at the population level since the impacted population is predicted to continue increasing at exactly the same rate as the un-impacted population. **Therefore, the magnitude of impact of disturbance from pile driving is considered to be Negligible.**

Table 8.19 Predicted impact of disturbance from pile driving activities on grey seals. Numbers in brackets represent the confidence intervals.

Location	# Impacted	% MU	Magnitude (informed by iPCoD)
Monopile (hard sediment – 5,000 kJ)			
NW	1,628 (122 – 3,216)	4.8 (0.4 – 9.4)	Negligible
SE	2,887 (328 – 5,318)	8.4 (1.0 – 15.6)	Negligible
SW	802 (82 – 1521)	2.3 (0.2 – 4.4)	Negligible
Monopile (soft sediment – 3,000 kJ)			
NW	1,315 (95 – 2,604)	3.8 (0.3 – 7.6)	Negligible
SE	2,691 (296 - 4985)	7.9 (0.9 – 14.6)	Negligible
SW	693 (69 - 1316)	2.0 (0.2 – 3.8)	Negligible
Jacket (hard/soft sediment – 3,000 kJ)			
NW	1,179 (84 – 2,335)	3.4 (0.2 – 6.8)	Negligible
SE	2,596 (282 – 4,819)	7.6 (0.8 – 14.1)	Negligible
SW	645 (64 - 1226)	1.9 (0.2 – 3.6)	Negligible
SE+SW	2,817 (316 – 5196)	8.2 (0.9 – 15.2)	Negligible

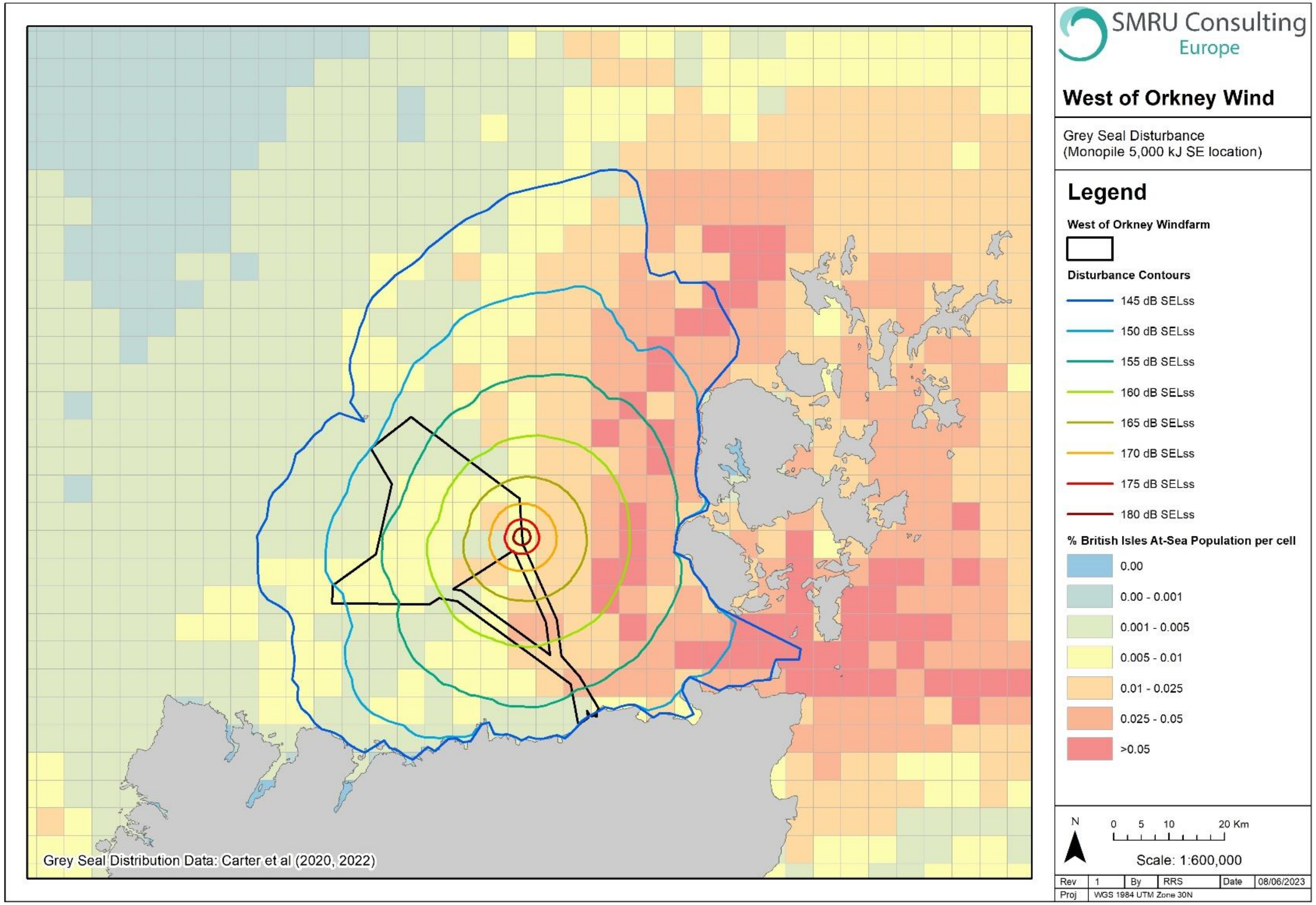


Figure 8.19 Grey seal disturbance contours for the installation of a monopile at 5,000 kJ at the SE location

Table 8.20 Results of iPCoD modelling for grey seals.

Simulation year	Un-impacted mean population size	Impacted mean population size	Impacted as % of un-impacted population size	Median ratio impacted:un-pacted growth rate
End 2027 (before piling commences)	36,060	36,060	100	1.00
End 2030 (after piling stops)	36,902	36,902	100	1.00
End 2036 (6 years after piling stops)	38,441	38,441	100	1.00
End 2042 (12 years after piling stops)	39,998	39,998	100	1.00

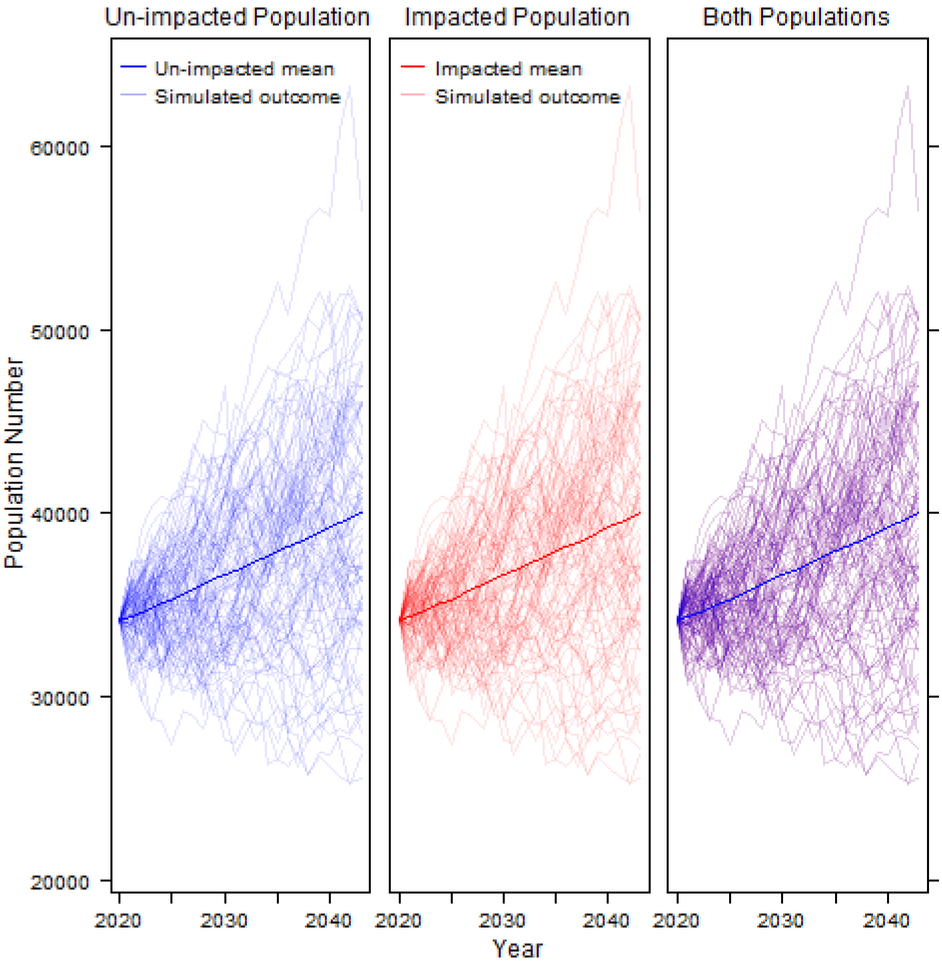


Figure 8.20 Predicted population trajectories for the un-impacted (baseline) and impacted grey seal iPCoD simulations (simulation starting in 2020 and piling occurring in 2028, 2029 and 2030).

8.3.7.2 Sensitivity

There are still limited data on grey seal behavioural responses to pile driving. The key dataset on this topic is presented in Aarts *et al.,* (2018) where 20 grey seals were tagged in the Wadden Sea to record their responses to pile driving at two offshore wind farms: Luchterduinen in 2014 and Gemini in 2015. The grey seals showed varying responses to the pile driving, including no response, altered surfacing and diving behaviour, and changes in swimming direction. The most common reaction was a decline in descent speed and a reduction in bottom time, which suggests a change in behaviour from foraging to horizontal movement.

The distances at which seals responded varied significantly; in one instance a grey seal showed responses at 45 km from the pile location, while other grey seals showed no response when within 12 km. Differences in responses could be attributed to differences in hearing sensitivity between individuals and in sound transmission with environmental conditions or the behaviour and motivation for the seal to be in the area. The telemetry data also showed that seals returned to the pile driving area after pile driving ceased. While this evidence base is from studies of grey seals tagged in the Wadden Sea, it is expected that grey seals in waters north of Scotland would respond in a similar way, and therefore the data are considered to be applicable.

The expert elicitation workshop in Amsterdam in 2018 (Booth *et al.,* 2019) concluded that grey seals were considered to have a reasonable ability to compensate for lost foraging opportunities due to their generalist diet, mobility, life history and adequate fat stores and that the survival of 'weaned of the year' animals and fertility were determined to be the most sensitive parameters to disturbance (i.e. reduced energy intake). However, in general, experts agreed that grey seals would be much more robust than harbour seals to the effects of disturbance due to their larger energy stores and more generalist and adaptable foraging strategies. It was agreed that grey seals would require moderate-high levels of repeated disturbance before there was any effect on fertility rates (**Figure 8.21 left**). The 'weaned of the year' were considered to be most vulnerable following the post-weaning fast, and that during this time it might take ~60 days of repeated disturbance before there was expected to be any effect on weaned-of-the-year survival (**Figure 8.21 right**), however there was a lot of uncertainty surrounding this estimate.

Grey seals are capital breeders and store energy in a thick layer of blubber, which means that, in combination with their large body size, they are tolerant of periods of fasting as part of their normal life history. Grey seals are also highly adaptable to a changing environment and are capable of adjusting their metabolic rate and foraging tactics, to compensate for different periods of energy demand and supply (Beck *et al.,* 2003, Sparling *et al.,* 2006). Grey seals are also very wide ranging and are capable of moving large distances between different haul out and foraging regions (Russell *et al.,* 2013). Therefore, they are unlikely to be particularly sensitive to displacement from foraging grounds during periods of active piling.

Hastie *et al.,* (2021) found that grey seal avoidance rates in response to pile driving sounds were dependent on the quality of the prey patch, with grey seals continuing to forage at high density prey patches when exposed to pile driving sounds but showing reduced foraging success at low density prey patches when exposed to pile driving sounds. Additionally, the seals showed an initial aversive response to the pile driving playbacks (lower proportion of dives spent foraging) but this diminished during each trial. Therefore, the likelihood of grey seal response is expected to be linked to the quality of the prey patch.

Due to observed responsiveness to piling, and their life-history characteristics, **grey seals have been assessed as having Negligible sensitivity to disturbance and resulting displacement from foraging grounds during pile-driving events.**

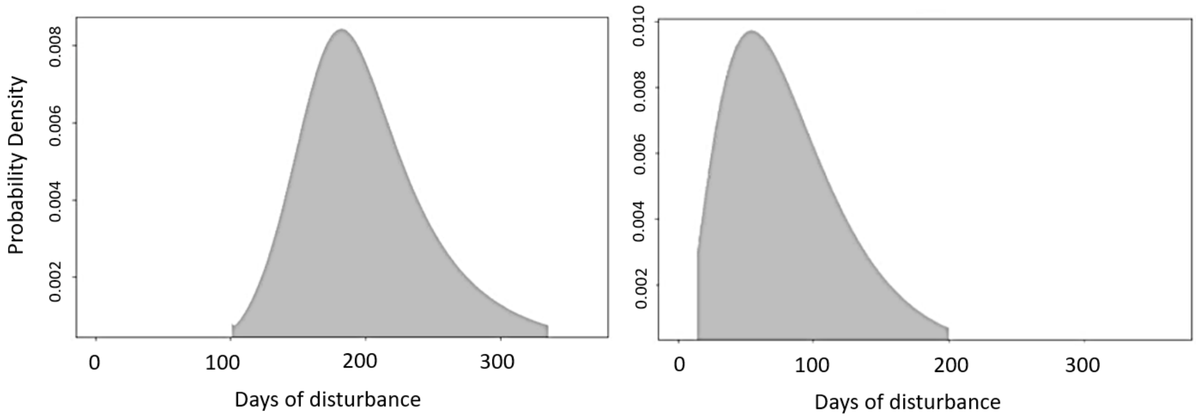


Figure 8.21: Probability distributions showing the consensus of the expert elicitation for grey seal disturbance from piling (Booth *et al.,* 2019). Left: the number of days of disturbance (i.e. days on which an animal does not feed for six hours) a pregnant female could 'tolerate' before it has any effect on fertility. Right: the number of days of disturbance (of six hours zero energy intake) a 'weaned of the year' grey seal could 'tolerate' before it has any effect on survival.

8.3.7.3 Significance

The magnitude of disturbance to grey seals from piling has been assessed as **Negligible**.

The sensitivity of grey seals to disturbance from piling has been assessed as **Negligible**.

Therefore, the consequence of disturbance from piling to grey seals is Negligible, which is not significant in EIA terms.

8.3.8 Summary

Across all marine mammal species, the effect of disturbance from pile driving is considered to be **Negligible or Minor**, both of which are **not significant** in EIA terms (Table 8.21).

Table 8.21 Summary of the effect of disturbance to marine mammals resulting from pile driving activities (ɫ denotes where the magnitude conclusion was informed by iPCoD modelling)

Species	Max # disturbed	% UK MU	% Full MU	Magnitude	Sensitivity	Consequence	Significance in EIA terms
Harbour porpoise	1,349	0.73	0.36	Negligible ɫ	Low	Negligible	Not significant
White-beaked dolphin	1,709	5.02	3.89	Medium	Low	Minor	Not significant
Common dolphin	90	0.16	0.09	Low	Low	Negligible	Not significant
Risso's dolphin	121	1.4	1.0	Low	Low	Negligible	Not significant
Minke whale	90	0.87	0.45	Low	Low	Negligible	Not significant
Harbour seal	176	NA	9.00	Negligible ɫ	Medium	Negligible	Not significant
Grey seal	2,887	NA	8.40	Negligible ɫ	Negligible	Negligible	Not significant

9 Non-piling construction activities

9.1 Project Description

Underwater noise is also expected to be generated during other non-piling construction related activities such as cable laying, dredging, drilling, rock placement and trenching. A brief description of each activity and an estimate of their associated source levels are outlined in Table 9.1. For further information see the chapter 5: Project description.

Table 9.1 Underwater noise generated by non-piling construction activities

Activity	Description	Estimated unweighted SL (dB re 1 µPa @ 1 m (RMS))
Cable laying	Noise from the cable laying vessel and any other associated noise during the offshore cable installation.	171
Dredging	Dredging will be required at the HDD exit pit at the landfall. Dredging techniques may be required on site for seabed preparation work for certain foundation options, and, there is potential that dredging may be required for the export cable, array cables and interconnector cable installation. Suction dredging has been assumed as a worst-case.	Backhoe: 165 Suction: 186
Drilling	There is the potential for WTG foundations to be installed using drilling depending on seabed type or if a pile refuses during impact piling operations.	169
Rock placement	Potentially required on site for installation of offshore cables (cable crossings and cable protection) and scour protection around foundation structures.	172
Trenching	Trenching may be required during offshore cable installation.	172

9.2 Auditory injury from non-piling construction activities

Subacoustech provided underwater noise modelling for PTS from non-piling construction activities. Full details of the modelling approach is described in SS11: Underwater noise modelling report.

9.2.1 Magnitude

For all non-piling construction activities assessed (Table 9.2), the PTS-onset impact ranges are <100 m. Non-piling construction noise sources will have a local spatial extent and are transient and intermittent. Therefore, **the magnitude of impact of PTS from non-piling construction noise is considered Negligible.**

Table 9.2 Auditory injury impact ranges for non-piling construction noise

	Fleeing animal				Stationary animal			
	LF 199 dB	HF 198 dB	VHF 173 dB	PCW 201 dB	LF 199 dB	HF 198 dB	VHF 173 dB	PCW 201 dB
Cable laying	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m
Dredging (Backhoe)	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m
Dredging (Suction)	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	570 m	< 100 m
Drilling	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m
Rock placement	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	900 m	< 100 m
Trenching	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m	< 100 m

9.2.2 Sensitivity

9.2.2.1 Dredging

Dredging is described as a continuous broadband sound source, with the main energy below 1 kHz; however, the frequency and sound pressure level can vary considerably depending on the equipment, activity, and environmental characteristics (Todd *et al.,* 2015). For the offshore Project, dredging will potentially be required for seabed preparation work for foundations as well as for export cable, array cable and interconnector cable installations. The source level of dredging has been described to vary between SPL 172-190 dB re 1 µPa @ 1 m with a frequency range of 45 Hz to 7 kHz (Evans, 1990, Thompson *et al.,* 2009, Verboom, 2014). It is expected that the underwater noise generated by dredging will be below the PTS-onset threshold (Todd *et al.,* 2015) and thus the risk of injury is unlikely, though disturbance may occur. For harbour porpoise, dolphins and seals, the hearing sensitivity below 1 kHz is relatively poor and thus it is expected that a PTS at this frequency would result in little impact to vital rates. Therefore, **the sensitivity of** harbour **porpoise, dolphins and seals to PTS from dredging is assessed as Low.**

The low frequency noise produced during dredging may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Minke whale communication signals have been demonstrated to be below 2 kHz (Edds-Walton, 2000, Mellinger *et al.,* 2000, Gedamke *et al.,* 2001, Risch *et al.,* 2013, Risch *et al.,* 2014). Tubelli *et al.,* (2012) estimated the most sensitive hearing range (the region with thresholds within 40 dB of best sensitivity) to extend from 30 to 100 Hz up to 7.5 to 25 kHz, depending on the specific model used. Therefore, **the sensitivity of minke whale to PTS from dredging is precautionarily assessed as Medium.**

9.2.2.2 Drilling

The continuous sound produced by drilling has been likened to that produced by potential dredging activity; low frequency noise caused by rotating machinery (Greene, 1987). Recordings of drilling at the North Hoyle offshore windfarm suggest that the sound produced has a fundamental frequency at 125 Hz (Nedwell *et al.,* 2003). For harbour porpoise, dolphins and seals, the hearing sensitivity below 1 kHz is relatively poor and thus it is expected that a PTS at these low frequency ranges would result in little impact to vital rates. Therefore, **the sensitivity of** harbour **porpoise, dolphins and seals to PTS from drilling noise is assessed as Low.** The low frequency noise produced during cable laying may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Therefore, **the sensitivity of minke whales to PTS from drilling is precautionarily assessed as Medium.**

9.2.2.3 Cable laying

Underwater noise generated during cable installation is generally considered to have a low potential for impacts to marine mammals due to the non-impulsive nature of the noise generated and the fact that any generated noise is likely to be dominated by the vessel from which installation is taking place (Genesis, 2011). OSPAR (2009) summarise general characteristics of commercial vessel noise. Vessel noise is continuous, and is dominated by sounds from propellers, thrusters and various rotating machinery (e.g., power generation, pumps). In general, support and supply vessels (50-100 m) are expected to have broadband source levels in the range 165-180 dB re 1µPa, with the majority of energy below 1 kHz (OSPAR, 2009). Large commercial vessels (>100 m) produce relatively loud and predominately low frequency sounds, with the strongest energy concentrated below several hundred Hz. For harbour porpoise, dolphins and seals, the hearing sensitivity below 1 kHz is relatively poor and thus it is expected that a PTS at these low frequency ranges would result in little impact to vital rates. Therefore, **the sensitivity of** harbour **porpoise, dolphins and seals to PTS from cable laying is assessed as Low.** The low frequency noise produced during cable laying may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Therefore, **the sensitivity of minke whales to PTS from cable laying is assessed as Medium.**

9.2.2.4 Trenching

Underwater noise generation during cable trenching is highly variable and dependent on the physical properties of the seabed that is being cut. At the North Hoyle OWF, trenching activities had a peak energy between 100 Hz – 1 kHz and in general the sound levels were generally only 10-15 dB above background levels (Nedwell *et al.,* 2003). For harbour porpoise, dolphins and seals, the hearing sensitivity below 1 kHz is relatively poor and thus it is expected that a PTS at these low frequency ranges would result in little impact to vital rates. Therefore, **the sensitivity of harbour porpoise, dolphins and seals to PTS from trenching is assessed as Low.** The low frequency noise produced during trenching may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Therefore, **the sensitivity of minke whale to PTS from trenching is precautionarily assessed as Medium.**

9.2.2.5 Rock Placement

Underwater noise generation during rock placement activities is largely unknown. One study of rock placement activities in the Yell Sound in Shetland found that rock placement noise produced low frequency tonal noise from the machinery, but that measured noise levels were within background levels (Nedwell and Howell, 2004). Therefore, it is highly likely that any generated noise is likely to be dominated by the vessel from which activities taking place. Therefore, **the sensitivity of harbour porpoise, dolphins and seals to PTS from rock placement is expected to be Low.** The low frequency noise produced during rock placement may be more likely to overlap with the hearing range of low frequency cetacean species such as minke whales. Therefore, **the sensitivity of minke whale to PTS from rock placement is precautionarily assessed as Medium.**

9.2.3 Significance

The sensitivity of harbour porpoise, dolphins and seals to auditory injury from other construction activities has been assessed as **Low** and minke whales have precautionarily been assessed as **Medium** sensitivity.

The magnitude of impact of PTS to all marine mammals from other construction activities has been assessed as **Negligible**.

Therefore, the consequence of auditory injury from other non-piling construction activities is Negligible for harbour porpoise, dolphins and seals and Minor for minke whales, both of which are not significant in EIA terms.

9.3 Disturbance from non-piling construction activities

9.3.1 Magnitude

9.3.1.1 Dredging

Harbour porpoise: Dredging at a source level of 184 dB re1µPa at 1 m resulted in avoidance up to 5 km from the dredging site (Verboom, 2014). Conversely, found much more localised impacts; using Passive Acoustic Monitoring there was short term avoidance (~3 hours) at distances of up to 600 m from the dredging vessel, but no significant long-term effects. Modelling potential impacts of dredging using a case study of the Maasvlatke port expansion (assuming maximum source levels of 192 dB re1µPa) predicted a disturbance range of 400 m, while a more conservative approach predicted avoidance of harbour porpoise up to 5 km (McQueen *et al.,* 2020).

White-beaked dolphin: There is currently no information available on the impacts of dredging for white beaked dolphins. Currently their hearing range has only been investigated at frequencies above 16 kHz (Nachtigall *et al.,* 2008) which is above the typical range for dredging. Localised, temporary avoidance of dredging activities is assumed.

Other dolphin species: Increased dredging activity at Aberdeen Harbour was associated with a reduction in bottlenose dolphin presence and, during the initial dredge operations, bottlenose dolphins were absent for five weeks (Pirotta *et al.,* 2013). Based on the results of Pirotta *et al.,* (2013), subsequent studies have assumed that dredging activities exclude dolphins from a 1 km radius of the dredging site (Pirotta *et al.,* 2015a). Dredging operations had no impact on sightings of Indo-Pacific bottlenose dolphins (*Tursiops aduncus*) in South Australia (Bossley *et al.,* 2022).

Minke whale: In northwest Ireland, construction-related activity (including dredging) has been linked to reduced minke whale presence (Culloch *et al.,* 2016). Minke whale distance to construction site increased and relative abundance decreased during dredging and blasting activities in Newfoundland (Borggaard *et al.,* 1999).

Grey and harbour seal: Based on the generic threshold of behavioural avoidance of pinnipeds (140 dB re1µPa SPL) (Southall *et al.,* 2007), acoustic modelling of dredging demonstrated that disturbance could be caused to individuals between 400 m to 5 km from site (McQueen *et al.,* 2020).

9.3.1.2 Drilling

Information on the disturbance effects of drilling is limited and the majority of the research available was conducted more than 20 years ago and is focussed on baleen whales (Sinclair *et al.,* 2021). For example, drilling and dredging playback experiments observed that 50% of bowhead whales exposed to noise levels of 115 dB re 1 µPa exhibited some form of response, including changes to calling, foraging and dive patterns (Richardson and Wursig, 1990). More recent studies of bowhead whales also observed changes in behaviour from increased drilling noise levels, specifically an increase in call rate. However, the call rate plateaued and then declined as noise levels continued to increase, which could be interpreting as the whales aborting their attempt to overcome the masking effects of the drilling noise (Blackwell *et al.,* 2017). Playback experiments of drilling and industrial noise have also been undertaken with grey whales at a noise level of 122 dB re 1 µPa. This resulted in a 90% response from the individuals in the form of diverting their migration track (Malme *et al.,* 1984). Overall, the literature indicates that the impacts of drilling disturbance on marine mammals may occur at distances of between 10-20 km, and will vary depending on the species (Greene Jr, 1986, LGL and Greeneridge, 1986, Richardson and Wursig, 1990).

Whilst information is not available for the species of concern for the offshore Project, it is still considered useful as it suggests that at least some species of cetacean may experience disturbance as a result of drilling. Furthermore, drilling is considered under the umbrella of industrial and construction noise, and has similar properties to dredging, for which more information is available for species relevant to the offshore Project. Therefore, it is considered that drilling could potentially cause disturbance over distances of up to 5-10 km from the noise source based on results for dredging, or potentially up to 20 km based on results from the drilling literature, although this literature is considered slightly outdated.

9.3.1.3 Other

There is a lack of information in the literature on disturbance ranges for other non-piling construction activities such as cable laying, trenching or rock placement. While construction-related activities (acoustic surveys, dredging, rock trenching, pipe laying and rock placement) for an underwater pipeline in northwest Ireland resulted in a decline in harbour porpoise detections, there was a considerable increase in detections after construction-activities ended which suggests that any impact is localised and temporary (Todd *et al.,* 2020).

9.3.1.4 Summary

It is expected that any disturbance impact will be primarily driven by the underwater noise generated by the vessel during non-piling construction-related activities, and, as such, it is expected that any impact of disturbance is highly localised (within 5 km). **The magnitude of this impact is considered to be Low across all marine mammal species** since the impact will be of short-term duration (<5 years), will occur intermittently at low intensity and is expected to be of limited spatial extent.

9.3.2 Sensitivity

Information regarding the sensitivity of marine mammals to other construction activities is currently limited. Available studies focus primarily on disturbance from dredging and confirmed behavioural responses have been observed in cetaceans. Pirotta *et al.,* (2013) noted that bottlenose dolphin presence in foraging areas of Aberdeen harbour decreased as dredging intensity increased. Due to the consistently high presence of shipping activity all year round, the dolphins were considered to be habituated to high levels of vessel disturbance and, therefore, in this particular instance, Pirotta *et al.,* (2013) concluded that the avoidance behaviour was a direct result of dredging activity. However, this distinction in the source of the disturbance reaction cannot always be determined. For example, Anderwald *et al.,* (2013) observed minke whales off the coast of Ireland in an area of high vessel traffic during the installation of a gas pipeline where dredging activity occurred. The data suggested that the avoidance response observed was likely attributed to the vessel presence rather than the dredging and construction activities themselves. As the disturbance impact from other construction activities is closely associated with the disturbance from vessel presence required for the activity, it is difficult to determine the sensitivity specifically to disturbance from other construction activities in isolation (Todd *et al.,* 2015).

Harbour porpoise occurrence decreased at the Beatrice and Moray East offshore wind farms during non-piling construction periods (Benhemma-Le Gall *et al.,* 2021). The probability of detecting harbour porpoise in the absence of piling decreased by 17% as the sound pressure levels from vessels during the construction period increased by 57 dB (note: vessel activity included not only windfarm construction related vessels, but also other third-party traffic such as fishermen, bulk carrier and cargo vessels). Despite this, harbour porpoise continued to regularly use both the Beatrice and Moray East sites throughout the three-year construction period. While a reduction in occurrence and buzzing was associated with increased vessel activity, this was of local scale and buzzing activity increased beyond a certain distance from the exposed areas, suggesting displaced animals resumed foraging once a certain distance from the noise source, or potential compensation behaviour for lost foraging or the increased energy expenditure of fleeing. While harbour porpoise may be sensitive to disturbance from other construction-related activities, it is expected that they are able to compensate for any short-term local displacement, and thus it is not expected that individual vital rates would be impacted. Therefore, **the sensitivity of harbour porpoise to disturbance from other non-piling construction activities is considered to be Low.**

For dolphin species, disturbance responses to non-piling construction activity appears to vary. Increased dredging activity at Aberdeen harbour was associated with a reduction in bottlenose dolphin presence and, during the initial dredge operations, bottlenose dolphins were absent for five weeks (Pirotta *et al.,* 2013). In an urbanised estuary in Western Australia, bottlenose dolphin responses to dredging varied between sites. At one site no bottlenose dolphins were sighted on days when backhoe dredging was present, while dolphins remained using the other site (Marley *et al.,* 2017b). A study conducted in northwest Ireland concluded that construction related activity (including dredging) did not result in any evidence of a negative impact to common dolphins (Culloch *et al.,* 2016). Therefore, **the sensitivity of dolphin species to disturbance from other non-piling construction activities is assessed as Low.**

The same study conducted by Culloch *et al.,* (2016) found evidence that the fine-scale temporal occurrence of minke whales in northwest Ireland was influenced by the presence of construction activity, with lower occurrence rates on these days (Culloch *et al.,* 2016). Due to their large size and capacity for energy storage, it is expected that minke whales will be able to tolerate temporary displacement from foraging areas much better than harbour porpoise and individuals are expected to be able to recover from any impact on vital rates. Therefore, **the sensitivity of minke whales to disturbance from other non-piling construction activities is assessed as Low.**

While seals are sensitive to disturbance from pile driving activities, there is evidence that the displacement is limited to the piling activity period only. At the Lincs windfarm, seal usage in the vicinity of construction activity was not significantly decreased during breaks in the piling activities and displacement was limited to within 2 hours of the piling activity (Russell *et al.,* 2016a). There was no evidence of displacement during the overall construction period, and the authors recommended that environmental assessments should focus on short-term displacement to seals during piling rather than displacement during construction as a whole. Even during periods of piling at the Lincs offshore wind farm, individual seals travelled in and out of the Wash which suggests that the motivation to forage offshore and come ashore to haul out could outweigh the deterrence effect of piling. The OAA is located in a relatively low-density area for both species of seal (compared to the coastal waters surrounding Orkney), and thus it is not expected that any short term-local displacement caused by construction related activities would result in any changes to individual vital rates. Therefore, **the sensitivity of both seal species to disturbance from other non-piling construction activities is considered to be Negligible.**

9.3.3 Significance

The magnitude of disturbance to all marine mammal species from non-piling construction activities has been assessed as **Low**.

The sensitivity of marine mammals to disturbance from non-piling construction activities has been assessed as **Negligible** to **Low**.

Therefore, the consequence of disturbance from non-piling construction activities is Negligible, which is not significant in EIA terms.

10 Vessel Disturbance

Disturbance to marine mammals by vessels will be driven by a combination of underwater noise and the physical presence of the vessel itself (e.g. Pirotta *et al.,* 2015b). It is not simple to disentangle these drivers and thus disturbance from vessels is assessed here in general terms, covering disturbance driven by both vessel presence and underwater noise.

Vessel noise levels from construction vessels will result in an increase in non-impulsive, continuous sound in the vicinity of the offshore Project, typically in the range of 10 - 100 Hz (although higher frequencies will also be produced) (Erbe *et al.,* 2019) with an estimated source level of 161-168 SEL_{cum} dB re 1 µPa@1m (RMS) for medium and large construction vessels, travelling at a speed of 10 knots (SS11: Underwater noise modelling report).

OSPAR (2009) summarise general characteristics of commercial vessel noise. Vessel noise is continuous, and is dominated by sounds from propellers, thrusters and various rotating machinery (e.g., power generation, pumps). In general, support and supply vessels (50-100 m) are expected to have broadband source levels in the range 165-180 dB re 1µPa, with the majority of energy below 1 kHz (OSPAR, 2009). Large commercial vessels (>100 m) produce relatively loud and predominately low frequency sounds, with the strongest energy concentrated below several hundred Hz.

10.1 Sensitivity

10.1.1 Harbour porpoise

In a large-scale study of harbour porpoise density in UK waters, increased vessel activity was generally associated with lower harbour porpoise densities. However, in northwest Scottish waters, shipping had little effect on the density of individuals given the low shipping densities in the area (Heinänen and Skov, 2015).

During the construction of the Beatrice and Moray East offshore windfarms within the Moray Firth, harbour porpoise occurrence decreased with increasing vessel presence, with the magnitude of decrease depending on the distance to the vessel (Benhemma-Le Gall *et al.,* 2021). For example, the probability of harbour porpoise occurrence at a mean vessel distance of 2 km decreased by up to 95% from a probability of occurrence of 0.37 when no vessels were present to 0.02 for the highest vessel intensity of 9.8 min per km^2 (the sum of residence times for all vessels present in that hour per kilometre squared). At a mean vessel distance of 3 km, the probability decreased by up to 57% to 0.16 for the highest vessel intensity, and no apparent response was observed at 4 km.

Additional studies conducted during offshore windfarm construction demonstrated that harbour porpoise detections in the vicinity of the pile driving location decline prior to a piling event (Brandt *et al.,* 2018, Benhemma-Le Gall *et al.,* 2021). For example, during a study conducted at seven offshore wind farms in the German Bight, Brandt *et al.,* (2018) observed a decline in harbour porpoise detections within 2 km of the construction site, and continued to be reduced for 1 to 2 days after. This was considered to be attributed in part to the increased vessel activity and traffic associated with construction related activities (Brandt *et al.,* 2018). During this study, six of the wind farms used noise abatement techniques to reduce source noise levels. However, it is possible that the use of such techniques may require additional vessel presence or extend the construction timeline, thereby increasing the likelihood of a disturbance response (Brandt *et al.,* 2018, Graham *et al.,* 2019, Thompson *et al.,* 2020). Therefore, management efforts to reduce the risk of injury and disturbance from piling activities must also take into consideration potential increases in disturbance from vessel activity (Graham *et al.,* 2019, Thompson *et al.,* 2020).

Behavioural responses of harbour porpoises to vessel noise have also been observed in more controlled conditions. Dyndo *et al.,* (2015) conducted an exposure study using four harbour porpoise contained in a semi-natural net pen and exposed to noise from passing vessels. Behavioural responses were observed as a result of low levels of medium to high frequency vessel noise. During 80 high quality recordings of boat noise, porpoising, a stereotypical disturbance behaviour, was observed in 27.5% of cases (Dyndo *et al.,* 2015).

Data examining the surfacing behaviour of harbour porpoise in relation to vessel traffic in Swansea Bay from land-based surveys found a significant correlation between harbour porpoise sightings and the number of vessels present. When vessels were up to 1 km away, 26% of the interactions observed were considered to be negative (animal moving away or prolonged diving). The proximity of the vessel being an important factor, with the greatest reaction occurring just 200 m from the vessel. The type of vessel was also relevant, as smaller motorised boats (e.g. jet-ski, speed boat, small fishing vessels), were associated with more negative behaviours than larger cargo ships, although this type of vessel was a less common occurrence (Oakley *et al.,* 2017). Vessels associated with offshore wind farm construction are typically larger than these types of small, motorised vessels, and, therefore, it would be anticipated that the behavioural response would not be as severe.

Telemetry data can also be used to identify fine-scale changes in behaviour. Between 2012-2016, seven harbour porpoises were tagged in a region of high shipping density in the inner Danish waters and Belt seas. Periods of high vessel noise coincided with erratic behaviour including 'vigorous fluking', bottom diving, interrupted foraging, and the cessation of vocalisations. Four out of six of the animals that were exposed to noise levels above 96 dB re 1 µPa (16 kHz third octave levels) produced significantly fewer buzzes with high quantities of vessel noise. In one case, the proximity of a single vessel resulted in a 15 minute cessation in foraging (Wisniewska *et al.,* 2018).

Behaviour-based modelling has indicated the potential for vessel disturbance to have population-level effects under certain circumstances. Nabe-Nielsen *et al.,* (2014) simulated harbour porpoise response to vessels did not result in further population decline when prey sources recovered fast (after two days), but if prey availability remained low then vessels were estimated to have a significant negative impact on the population. However, whilst this negative trend was estimated, when comparing the theoretical impact of vessel presence versus bycatch, the latter was found to have a greater effect on population size as it causes direct mortality and, therefore, Nabe-Nielsen *et al.,* (2014) suggest that conservation efforts should instead focus more closely on this issue.

In conclusion, there is some evidence that changes in harbour porpoise behaviour and presence can result from disturbance by vessel presence. Behavioural reactions observed include increased fluking, interrupted foraging, change to vocalisations, prolonged dives and directed movement away from the sound source (Oakley *et al.,* 2017, Wisniewska *et al.,* 2018). Several studies have also observed an increase in vessel presence to correlate with a decrease in harbour porpoise presence (Brandt *et al.,* 2018, Benhemma-Le Gall *et al.,* 2021). While disturbance from vessels can result in short term changes to porpoise behaviour, it is unlikely to result in alterations in vital rates in the longer term and no population level impacts are expected (unless there is simultaneously a significant impact to their prey species). **The sensitivity of harbour porpoise to disturbance from vessel activity is therefore classified as Low.**

10.1.2 Dolphin species

10.1.2.1 White-beaked dolphins

There is currently no information pertaining to the effects of vessel disturbance on white-beaked dolphins. As such, the information provided below for bottlenose and short-beaked common dolphins have been used as a proxy for the assessment of effects of vessel disturbance on white-beaked dolphin. **The sensitivity of white-beaked dolphin to disturbance from vessel activity has therefore been classified as Low.**

10.1.2.2 Common dolphins

There are currently limited studies available regarding the effects of vessel disturbance on short-beaked common dolphins. Of the few studies available, disturbance effects on common dolphins have mainly focused on those from cetacean watching vessels.

Meissner *et al.,* (2015) reported that the presence of interacting vessels affected the behavioural budget of common dolphins, and common dolphin groups spent significantly less time foraging. Once disrupted, dolphins took at least twice as long to return to foraging when compared to control conditions (vessels >300 m away from dolphin group). In addition, Meissner *et al.,* (2015) reported that the probability of starting to forage while engaged in travelling in the presence of a cetacean-watching vessel decreased by two thirds. Given foraging tactics used by common dolphins include cooperative herding of prey (Neumann and Orams, 2003), it is possible that the behavioural changes of some individuals, as a result of approaching vessels, could compromise the success of the overall foraging event (Meissner *et al.,* 2015).

When considering the impacts of cetacean-watching vessels reported by Meissner *et al.,* (2015) to those likely to occur from construction vessel activities, they cannot be directly transposed, as the likely interactions between common dolphins and vessels during the construction and operation of the offshore Project are unlikely to be deliberate and targeted to dolphin groups. As such, it is not anticipated that vessels will regularly persist within 300 m of a dolphin group (the distance in which behavioural responses occurred) for extended periods of time. Therefore, it is assumed that **the sensitivity of common dolphins to disturbance from vessel activity can be classified as Low.**

10.1.2.3 Risso's dolphins

There is currently no information pertaining to the effects of vessel disturbance on Risso's dolphins. As such, the information provided under bottlenose and common dolphins have been used as a proxy for the assessment of effects of vessel disturbance on Risso's dolphins. **The sensitivity of Risso's dolphin to disturbance from vessel activity has therefore been classified as Low.**

10.1.2.4 Bottlenose dolphins

Compared to other dolphin species, there is significantly more information available on bottlenose dolphin responses to vessels of varying types.

Vessel disturbance has been shown to negatively affect foraging activity. Pirotta *et al.,* (2015b) used passive acoustic monitoring to quantify how vessel disturbance affected foraging activity. The results indicated a short-term 49% reduction in foraging activity (though this did not vary with noise level), with animals resuming foraging after the vessel had travelled through the area was associated with vessel presence. The susceptibility to disturbance was variable depending on the location and year, suggesting circumstantial impacts of vessel noise on bottlenose dolphins. The study concluded that the physical presence of vessels, and not just the noise created, plays a large role in disturbance responses (Pirotta *et al.,* 2015b). The variability in disturbance from vessels is also observed in

Aberdeen harbour, a busy shipping area that is frequently occupied by bottlenose dolphins (Pirotta *et al.,* 2013).

A study of Indo-Pacific bottlenose dolphin habitat occupancy along the coast of Western Australia found dolphin density to be negatively affected by vessels at one site, but no significant impact at the other (Marley *et al.,* 2017a). It is hypothesised that, as the latter habitat is a known foraging site, the quality of the habitat impacts the behavioural response to disturbance. Differences in water depth were also hypothesised as important, as the site that was characterised by changes in dolphin density with vessel activity was shallower than the other location (average depths of 1 m and 13 m respectively). Dolphins have been demonstrated to avoid shallow waters as a predator avoidance response, and similar responses have resulted from vessel disturbance (Lusseau, 2006).

In the same area of Western Australia, increased vessel presence was also associated with significantly increased swimming speeds for individuals when resting or socialising. In addition, animals exposed to high levels of shipping traffic were found to generally spend more time travelling and less time resting or socialising. Finally, the characteristics of their whistles were found to change with increased broadband exposure, with the greatest variation occurring in the presence of low frequency noise (Marley *et al.,* 2017b). These findings are further supported by a study of common bottlenose dolphins in Galveston Ship Channel (Piwetz, 2019). The presence of boats was associated with significantly less foraging and socialising activity states. For this population, a significant increase in swimming speeds was observed during the presence of recreational and tourism vessels and shrimp trawlers.

Bottlenose dolphins have also been known to exhibit different behavioural responses to different vessel types. In New Zealand, a CATMOD analysis undertaken showed that bottlenose dolphin resting behaviour decreased as the number of tour boats increased (Constantine *et al.,* 2004). In a study conducted in Italy, dolphins exhibited an avoidance response to motorboats once disturbance became too great but changed their acoustic behaviour in response to trawler vessels, presumably to compensate for masking (La Manna *et al.,* 2013). This study also found that bottlenose dolphins would tolerate vessel presence within certain levels and were more likely to leave an area if disturbance was persistent (La Manna *et al.,* 2013). Similarly, high levels of tolerance to vessel disturbance were observed in Aberdeen harbour where vessel traffic is consistently high (Pirotta *et al.,* 2013). Therefore, the degree to which an animal will be disturbed is likely linked to their baseline level of tolerance (Bejder *et al.,* 2009).

New *et al.,* (2013) developed a mathematical model simulating the complex interactions of the coastal bottlenose dolphin population in the Moray Firth to determine if an increased rate of disturbance resulting from vessel traffic was biologically significant. The scenario modelled increased vessel traffic from 70 to 470 vessels a year to simulate the potential increase from the proposed offshore development. An increase in commercial vessel traffic only is not anticipated to result in a biologically significant increase in disturbance because the dolphins have the ability to compensate for their immediate behavioural response and, therefore, their health and vital rates are unaffected (New *et al.,* 2013).

In conclusion, vessel disturbance can elicit a variety of responses in bottlenose dolphins including changed to foraging behaviour, swim speed, behavioural state and acoustic behaviour and causing an avoidance responses and changing (Constantine *et al.,* 2004, La Manna *et al.,* 2013, Pirotta *et al.,* 2015b, Marley *et al.,* 2017a, Marley *et al.,* 2017b). However, bottlenose dolphins have been observed to display tolerance to vessel disturbance, particularly in areas where vessel traffic has always been high (Pirotta *et al.,* 2013). Furthermore, behavioural changes in bottlenose dolphins are not always considered biologically significant (New *et al.,* 2013). The sensitivity of bottlenose dolphins to disturbance from vessel activity is therefore classified as Low. While bottlenose dolphins are not included in this assessment, information on bottlenose dolphin responses provides a proxy for both white-beaked dolphins and Risso's dolphins, for which there is no data.

10.1.3 Minke whale

There are currently limited studies available regarding the effects of vessel disturbance on minke whale. Of the few studies available, minke whale foraging activity has been found to decrease with increased vessel interactions (Christiansen *et al.,* 2013), exemplified by shorter dives and changes in movement patterns. In addition, by analysing the respiration rate of minke whales, energy expenditure was estimated to be 28% higher during boat interactions, regardless of swim speed. Swim speed was also found to increase with vessel presence and these combined physiological and behavioural changes are thought to represent a stress response. As noise levels were not measured within the study, behavioural responses were therefore related to vessel presence. In addition, when considering the temporal and spatial rates of individuals' exposure over an entire season, there appeared to be no potential for a population-level effect of these acute disturbances (Christiansen *et al.,* 2015).

Further study by Christiansen and Lusseau (2015) developed a mechanistic model for minke whales to examine the bioenergetic effects of disturbance from whale watching vessels, specifically on foetal growth. The presence of whale watching vessels resulted in an immediate 63.5% reduction in net energy intake. However, the impact of disturbance was considered to be below the threshold value at which whale watching would have a significant impact on foetal growth as the number of interactions with vessels was low during the feeding season and was, therefore, of negligible impact.

When considering the impacts of whale watching vessels to those likely to occur from construction vessel activities, they cannot be directly transposed, as disturbance effects from whale watching are direct impacts, whilst those from construction activities are indirect, and the vessel types and underwater noise produced are very different. However, as there are little empirical data on the behavioural plasticity of minke whale as a result of vessel disturbance, the information presented above is used as a proxy to inform this assessment.

As Christiansen and Lusseau (2015) reported negligible impacts of whale watching activity on foetal growth and no potential for a population-level effect from acute disturbances (Christiansen *et al.,* 2015), **it is assumed that the sensitivity of minke whale to disturbance from vessel activity can be classified as Low.**

10.1.4 Seals

10.1.4.1 Harbour seals

A telemetry study that included the tagging of 28 harbour seals in the UK found high exposure levels of harbour seals to shipping noise (Jones *et al.,* 2017). Twenty individuals may have experienced a temporary threshold shift due to cumulative sound exposure levels exceeding the TTS-threshold for pinnipeds exposed to continuous underwater noise (183 dB re 1 μPa^2) proposed by Southall *et al.,* (2007). The overlap between seals and vessel activity most frequently occurred within 50 km of the coast, and in proximity to seal haul outs. Despite the distributional overlap and high cumulative sound levels, there was no evidence of reduced harbour seal presence as a result of vessel traffic (Jones *et al.,* 2017). **The sensitivity of harbour seals to disturbance from vessel activity is therefore classified as Low.**

10.1.4.2 Grey seals

A combined study of grey seal pup tracks in the Celtic Sea and adult grey seals in the English Channel found that no animals were exposed to cumulative shipping noise that exceeded thresholds for TTS (using the Southall *et al.,* 2019 thresholds) (Trigg *et al.,* 2020). On the northwest coast of Ireland, a study of vessel traffic and marine mammal presence found grey seals sightings to decrease with increased vessel activity in the surrounding area, though the effect size was small (Anderwald *et al.,* 2013); and the authors noted that relationships between sightings and vessel numbers were weaker than those with environmental variables such as sea state.

The sensitivity of grey seals to disturbance from vessel activity is therefore classified as Low.

10.2 Magnitude

It is anticipated there will be a maximum of 30 vessels on site simultaneously during the construction period. There are very few studies that indicate a critical level of activity in relation to risk of collisions, but an analysis presented in Heinänen and Skov (2015) suggested that harbour porpoise density was significantly lower in areas with vessel transit rates of greater than 80 per day (within a 5 km^2 area). Even considering the existing levels of vessel traffic in the area, the addition of construction traffic during construction activities at the offshore Project will still be well below this figure.

The commitment to the adoption of best practice vessel-handing protocols (e.g., following the Codes of Conduct provided by the WiSe (Wildlife-Safe) Scheme, Scottish Marine Wildlife Watching Code or Guide to Best Practice for Watching Marine Wildlife), which will all be incorporated into a Environmental Management Plan (EMP) during construction, will minimise the potential for any effects (see OMP1: EMP). The magnitude of disturbance from vessel activity is therefore assessed as **Low**.

10.3 Significance

The sensitivity of marine mammals to disturbance from vessels has been assessed as **Low** for all species.

The magnitude of disturbance from vessels to marine mammals has been assessed as **Low** for all species.

Therefore, the effect significance of disturbance from vessels is Negligible, which is significant in EIA terms.

11 Cumulative Effects Assessment

11.1 Approach to identifying relevant projects

The marine mammal CEA screened in all offshore projects that are constructing or decommissioning in the species specific MUs between 2026-2037 (**Table 11.1**). It has been assumed that pre-construction UXO clearance will occur at the Project in 2027, followed by 3 years of piling activity in 2028-2030 inclusive. While available data is provided for the offshore projects up to 2037, as per the screening, the marine mammal CEA focusses on the period between 2027 and 2030 inclusive as this is the key construction period in terms of the impact of underwater noise to marine mammals.

Operational tidal projects (such as MeyGen, EMEC sites, Morlais etc.) have not been included since underwater noise disturbance during operation is expected to be negligible. It is noted however that while not a consideration for disturbance from underwater noise, there does remain a potential collision risk impact to marine mammals from these projects. This is not included quantitatively here.

Table 11.1 Offshore development projects screened into the marine mammal CEA (2026-2037). IA = Impact Assessment[8], C = Construction, D = Decomissioning, OWF = Offshore Wind Farm, CCS = Carbon Capture & Storage, O&G = Oil and Gas, HP = Harbour porpoise, WD = White-beaked dolphin. RD = Risso's dolphin, CD = Common dolphin, GS = Grey seal, HS = Harbour seal, Y = within species specific MU, N = not in species specific MU.[9]

Project	Type	Stage	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037	HP	WD/CD/ RD/MW	GS/ HS
Mona Offshore Wind Farm	OWF	Pre-consent (scoping)	PEIR	C	C	C	C	C								N	Y	N
Morgan Offshore Wind Farm	OWF	Pre-consent (scoping)	PEIR	C	C	C	C	C								N	Y	N
Pentland Offshore Wind Farm	OWF	Pre-consent (application)	ES	C												Y	Y	Y
Morecambe Offshore Windfarm	OWF	Pre-consent (scoping)	PEIR	C	C	C										N	Y	N
Berwick Bank Offshore Wind Farm	OWF	Pre-consent (application)	ES	C	C	C	C	C	C	C	C					Y	Y	N
Levenmouth demonstration turbine[10]	OWF	Operational	EIA					D	D	D	D	D	D	D	D	Y	Y	N
Green Volt Floating Offshore Wind Farm	OWF	Pre-consent (scoping)	EIA	C	C											Y	Y	N
Sofia	OWF	Consented	ES	C												Y	Y	N
Dogger Bank South	OWF	Pre-consent (scoping)	PEIR	C	C	C	C	C	C	C								
Hornsea Four	OWF	Pre-consent (application stage)	ES	C	C	C										Y	Y	N
Norfolk Vanguard	OWF	Pre-consent (application stage)	ES	C	C											Y	Y	N
East Anglia One North	OWF	Consented	ES	C	C											Y	Y	N
East Anglia Two	OWF	Consented	ES	C	C	C										Y	Y	N
East Anglia Three	OWF	Consented	ES	C												Y	Y	N
Five Estuaries	OWF	Pre-consent (scoping)	PEIR			C	C	C								Y	Y	N
Rampion 2	OWF	Pre-consent	PEIR	C	C	C	C									Y	Y	Y
Outer Dowsing	OWF	Pre-consent (scoping)	PEIR		C	C	C	C								Y	Y	N
SHE-T Caithness to Orkney HVAC Link	CCS	Consented	ES	C	C											Y	Y	N
Awel y Môr	OWF	Pre-consent (application stage)	ES	C	C	C	C	C								N	Y	N
Erebus	OWF	Pre-consent (application stage)	ES	C	C	C										N	Y	N
Atlantic Marine Energy Test Site	Wave	Pre-consent (scoping)	EIS	C												N	Y	N
Scotland England Green Link 1	Connector	Pre-consent (scoping)	EA	C	C											Y	Y	N
Scotland England Green Link 2	Connector	Pre-consent	EA	C	C	C	C									Y	Y	N

[8] Denotes Whether or not a quantitative impact assessment was available to use in this CEA

[9] Note: Projects were screened out if no timeline information was available at all on the construction years. This includes projects such as: Hatston Pier and Terminal Expansion

[10] Note: impacts from the Levenmouth demonstration turbine decommissioning were excluded from the quantitative assessment since the project consists of a single turbine and thus will not have a significant impact

NorthConnect	Connector	Consented (UK)	ES	C												Y	Y	Y
Celtic Interconnector	Connector	Pre-consent	EIA	C												N	Y	N
NeuConnect	Connector	Pre-consent	PEIR	C	C	C										Y	Y	N
French-Alderney-Britain (FAB) Link	CCS	Consented	ES	C	C	C										Y	Y	N
Faray slipway extension and landing jetty	Jetty	Consented	ES	C												Y	Y	Y
North Falls	OWF	Pre-consent (scoping)	PEIR			C	C	C								Y	Y	N
Rosebank development	O&G	Pre-consent (application stage)	ES	C												Y	Y	N
Teal West Development	O&G	Pre-consent (application stage)	ES	C	C											Y	Y	N
Avalon Field Development	O&G	Pre-consent (application stage)	ES	C												Y	Y	N
Dudgeon and Sheringham Shoal Extension	OWF	Pre-consent (application stage)	ES		C	C				C	C					Y	Y	N
Valorous	OWF	Pre-consent (scoping)	No			C	C									N	Y	N
Caledonia Offshore Wind Farm	OWF	Pre-consent (scoping)	No			C	C	C								Y	Y	N
Whitecross Offshore Wind	OWF	Pre-consent (application stage)	No	C												N	Y	N
Codling Wind Park	OWF	Pre-consent (scoping)	No	C	C											N	Y	N
Dublin Array	OWF	Pre-consent (scoping)	No	C	C											N	Y	N
North Irish Sea Array Offshore Wind Farm	OWF	Pre-consent (Scoping)	No	C	C	C										N	Y	N
Thor	OWF	Pre-consent	No	C	C											Y	Y	N
Galatea-Galene	OWF	Pre-consent	No			C	C	C								N	Y	N
Stora Middelgrund	OWF	Pre-consent	No	C												N	Y	N
Northern Endurance Partnership	CCS	Pre-consent (scoping)	No	C												Y	Y	N
Acorn	CCS	Pre-consent	No	C												Y	Y	Y
V-Net Zero (Viking)	CCS	Pre-consent	No	C	C											Y	Y	Y
HyNet North West	Pipeline	Pre-Consent (Scoping)	No	C												N	Y	N
Arklow Bank Phase 2	OWF	Pre-consent (scoping)	No	C	C	C	C									N	Y	N
Cenos Offshore Wind Farm	OWF	Pre-consent (scoping)	No		C	C	C	C								Y	Y	N
Sound of Islay Community Tidal turbine	Tidal	Consented	No	C	C											Y	Y	N
Sea Link	Cable	Pre-consent	No			C	C	C								Y	Y	N
Scapa Deep Water Quay	Port / Harbour	Pre-consent (application stage)	No	C	C											Y	Y	Y
Various oil and gas decommissioning	O&G	Planned	EA/N	D	D	D	D	D	D	D	D	D	D	D	D	Y	Y	Y
Seismic airgun surveys	O&G	Indicative	No	S	S	S	S	S	S	S	S	S	S	S	S	Y	Y	Y

11.2 Screening Noise Impacts

Certain noise impacts assessed for the Offshore Development alone are not considered in the marine mammal CEA due to:

- the highly localised nature of the impacts,
- management and mitigation measures in place for the Offshore Development and on other projects will reduce the risk occurring, and
- where the potential significance of the effect from the Offshore Development alone has been assessed as negligible significance.

The noise impacts excluded from the marine mammal CEA for these reasons are:

- Auditory injury (PTS) (all marine mammals): where PTS may result from activities such as pile driving and UXO clearance, suitable mitigation will be put in place to reduce injury risk to marine mammals to negligible levels (as a requirement of European Protected Species legislation);
- Disturbance from vessels (all marine mammals): highly localised and negligible significance. In addition, it is expected that all offshore projects will employ a vessel management plan or follow best practice guidance to reduce the potential for disturbance effects;

Therefore, the only impacts associated with the offshore Project that is considered in the marine mammal CEA (for the noise impact assessment) is the potential for disturbance from underwater noise during construction activities to all marine mammal species.

11.3 Disturbance from underwater noise

11.3.1 Method

11.3.1.1 Offshore wind farms

Different OWF EIAs have assessed disturbance using a variety of thresholds and methods, including effective deterrence ranges, fixed noise thresholds and dose-response functions. This means that the predicted number of animals disturbed is not comparable between projects. However, since the consents for these Projects are based on the number of animals impacted in the EIAs, they have been presented here as the most relevant indication of the number of animals that may be impacted by each OWF Project. For all OWF projects screened into this CEA, the worst-case disturbance ranges for impact piling (single location) presented in the respective EIAs are included in the assessment.

For those Projects where data may be unavailable (for example, Project EIAs undertaken in other countries or Projects that haven't yet released Preliminary Environmental Information Report (PEIR) or EIA Reports) the assessment of disturbance follows the advice provided in JNCC (2020) where unabated impact pile-driving of a monopile and clearance of a UXO is predicted to have an effective deterrence range (EDR) of 26 km for harbour porpoise. For EU projects, it is assumed that noise abatement methods will be implemented, and thus a 15 km EDR is assumed. In the absence of recommended EDRs for other species, this has been applied to all marine mammals. For floating OWF projects, an EDR of 15 km has been assumed for the worst-case scenario that pin piles may be required to anchor mooring lines. EDRs are combined with the estimated density of animals from the SCANS-III survey block relevant to each development (highest density selected if project covered multiple blocks).

11.3.1.2 Seismic airgun surveys

The potential number of seismic airgun surveys that could be undertaken is unknown. Therefore, for all cetacean species, two seismic airgun surveys were assumed to occur within the UK EEZ at any one time. For seal species, the relevant MU is significantly smaller than for cetaceans, therefore it was assumed that one seismic airgun survey may occur within the North Coast and Orkney MU at any one time. It has been assumed that the EDR for seismic airgun surveys is 12 km as per the advice provided in JNCC (2020). It is considered that this approach is sufficiently precautionary (i.e., it is unlikely that seismic surveys will be occur concurrently with the offshore Project construction) to also account for any behavioural disturbance resulting from high-resolution geophysical site surveys (HRGS) within relevant regions (e.g., to support wind farm development). While the potential for behavioural disturbance from HRGS is poorly understood, it is acknowledged to be of a considerably lower magnitude than that of seismic surveys (e.g., precautionary 5 km EDR suggested in JNCC *et al.,* (2020) and see Ruppel *et al.,* (2022)).

It is acknowledged that seismic airgun surveys are a moving sound source and not a point source. Therefore, data on shooting statics provided by Sarah Canning (JNCC, pers. comm April 2023[11]) was used to provide an indicative distance travelled while shooting. The mean distance travelled while shooting for 3D seismic surveys between 2011 and 2020 was 116 km. Therefore, it has been assumed that a seismic survey vessel travelling 116 km of survey line while shooting in a single 24 hr period and therefore impact an area of 3,236 km² per day.

11.3.1.3 Oil and gas decommissioning

A total of 40 oil and gas projects were screened into the CIA long list for marine mammals, all of which are scheduled to conduct decommissioning activities at some point between 2026 and 2037. Of these, 31 projects had Environmental Appraisal documents that were obtained and checked for the assessment of underwater noise to marine mammals. In the majority of these projects (25), underwater noise was either scoped out of assessment or was considered a non-issue with the implementation of mitigation. Only 5 projects provided any form of quantitative assessment for the impact of underwater noise on marine mammals; however, impact ranges were considered to be highly localised and in most cases no estimate of the number of animals impacted was provided. For this reason, oil and gas decommissioning activities were not considered further in this CEA.

11.3.1.4 Other offshore developments

For all other offshore development projects (wave and tidal, connectors, carbon capture and storage and harbour expansion), if a quantitative assessment was not provided in an EIA, then it was assumed that the maximum disturbance impact range would be 5 km for construction-related activities (based on potential impact ranges from non-piling activities such as dredging, cable laying, vessel presence etc).

11.3.2 Precaution in the assessment

It should be noted that there are significant levels of precaution / conservatism within this CEA, resulting in the estimated effects being highly precautionary. The main areas of precaution / conservatism in the assessment include:

- The approach of summing across concurrent activities assumes that there is no spatial overlap in the impact footprints between individual activities, which is highly conservative considering the close proximity of many of the OWF projects;

[11] Data from: Stone, C.J. in prep. Compliance with JNCC guidelines during geophysical surveys in UK waters between 2011 and 2020 and long-term trends in compliance. JNCC Report

- The inclusion of projects with a high degree of uncertainty; for example, those lacking consent, an EIAR, PEIR, and/or Scoping Report. In such instances, worst-case scenarios are assumed in the absence of other information;
- The exact timing of pile driving for each development is unknown, therefore it has been assumed that these activities could occur at any point throughout the construction window. This has resulted in piling activities occurring over multiple consecutive years with associated estimated disturbance levels far greater than would occur in reality;
- The timelines presented in PEIR and EIAR chapters are worst-case scenarios and the true period of piling activity will likely be shorter;
- The assumption that all OWF developments will install pile-driven monopile foundations. The project envelope for most of these developments includes options for pin-piles or monopiles, alongside options for non-piled foundations. As a worst-case assumption monopiles have been assumed; however, a portion of these projects may instead use jacket foundations with pin-piles, which will have a much lower recommended effective deterrence range (15 km instead of 26 km, equating to a 66% smaller area) (JNCC, 2020), and will therefore disturb far fewer animals;
- In the absence of project-specific assessments of the number of disturbed animals, EDRs based on those recommended for harbour porpoise have been applied; these can be considered precautionary for other species of marine mammal, which have not been reported to respond as strongly to relevant underwater noise as harbour porpoise; and,
- The assumption that the extent of the disturbance effects remains constant throughout the construction of each wind farm. Passive acoustic monitoring during pin piling at the Beatrice wind farm in the Moray Firth showed a 50% probability of harbour porpoise response (a significant reduction in detection relative to baseline) within 7.4 km at the first location piled, with decreasing response levels over the construction period, to a 50% probability of response within 1.3 km by the final piling location (Graham *et al.,* 2019).

11.3.3 Harbour porpoise

11.3.3.1 Assessment using only those projects with a quantitative impact assessment available

In the CEA period considered (2026-2037), the highest level of impact to the harbour porpoise MU is in 2026, the year prior to UXO clearance commencing at the offshore Project (**Table 11.2**). In 2026 an estimated 34,150 harbour porpoise are potentially disturbed across the 21 CEA projects constructing at the time, equating to 9.1% of the MU (18.6% UK MU) (assuming underwater noise disturbance across all projects on the same day within that year).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 30,907 harbour porpoise are potentially disturbed per day across 17 CEA projects constructing at the time, equating to 8.2% MU (16.8% UK MU) (assuming underwater noise disturbance across all 17 projects on the same day within that year). The disturbance impact from the offshore Project contributes only 0.5% of the total disturbance estimate.
- In 2028, when piling is planned at the offshore Project, an estimated 28,625 harbour porpoise are potentially disturbed per day across 12 CEA projects constructing at the time, equating to 7.6% MU (15.6% UK MU) (assuming underwater noise disturbance across all 12 projects on the same day within that year). The disturbance impact from the offshore Project contributes 4.7% of the total disturbance estimate.

- In 2029, when piling is planned at the offshore Project, an estimated 25,322 harbour porpoise are potentially disturbed per day across 8 CEA projects constructing at the time, equating to 6.7% MU (13.8% UK MU) (assuming underwater noise disturbance across all 8 projects on the same day within that year). The disturbance impact from the offshore Project contributes 5.3% of the total disturbance estimate.
- In 2030, when piling is planned at the offshore Project, an estimated 24,701 harbour porpoise are potentially disturbed per day across 6 CEA projects constructing at the time, equating to 6.6% MU (13.4% UK MU) (assuming underwater noise disturbance across all 6 projects on the same day within that year). The disturbance impact from the offshore Project contributes 5.5% of the total disturbance estimate.

11.3.3.2 Assessment using all CEA projects (including those without a quantitative impact assessment)

In the CEA period considered (2026-2037), the highest level of impact to the harbour porpoise MU is in 2026, the year prior to UXO clearance commencing at the offshore Project (**Table 11.2**). In 2026 an estimated 36,788 harbour porpoise are potentially disturbed across 26 CEA projects constructing at the time alongside 2 indicative seismic survey projects, equating to 9.8% of the MU (20.0% UK MU) (assuming underwater noise disturbance across all projects on the same day within that year).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 35,972 harbour porpoise are potentially disturbed per day, equating to 9.6% MU (19.6% UK MU) (assuming underwater noise disturbance across all 22 CEA projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes only 0.4% of the total disturbance estimate.
- In 2028, when piling is planned at the offshore Project, an estimated 33,472 harbour porpoise are potentially disturbed per day, equating to 8.9% MU (18.2% UK MU) (assuming underwater noise disturbance across all 16 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 4.0% of the total disturbance estimate.
- In 2029, when piling is planned at the offshore Project, an estimated 28,897 harbour porpoise are potentially disturbed per day, equating to 7.7% MU (15.7% UK MU) (assuming underwater noise disturbance across all 11 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 4.7% of the total disturbance estimate.
- In 2030, when piling is planned at the offshore Project, an estimated 28,276 harbour porpoise are potentially disturbed per day, equating to 7.5% MU (15.4% UK MU) (assuming underwater noise disturbance across all 9 projects alongside 2 indicative seismic surveys projects on the same day within that year). The disturbance impact from the offshore Project contributes 4.8% of the total disturbance estimate.

It is important to consider these numbers as highly precautionary, given all the levels of precaution inherent in this additive CEA approach (see **Section 11.3.1.4** for details).

While population modelling has not been conducted for this specific CEA scenario due to the lack of information on piling schedules for each of the projects considered, other cumulative population modelling has previously been conducted for harbour porpoise which can be used to inform the conclusions here. Nabe-Nielsen *et al.,* (2018) used the DEPONS model to predict the impact of 65 windfarms installed (3,900 WTGs) between 2011 and 2020 on the North Sea harbour porpoise population. They showed that if realistic response distances were assumed (based on those observed at the Gemini wind farm), the population dynamics for the impacted population were indistinguishable from the baseline population. They showed that under their modelled scenario, wind farm construction noise only influenced population dynamics in the North Sea when harbour porpoise were assumed to respond at distances exceeding 50 km from the wind farms. This is highly conservative since monitoring at the Beatrice and Moray East OWFs have shown that a 50% probability of response occurs at only 7.4 km at the first location piled, decreasing to 1.3 km by the final location (Graham *et al.,* 2019).

Table 11.2 Harbour porpoise cumulative effect of disturbance from underwater noise. Numbers denote the number of harbour porpoise predicted to be disurbed per day at each project in each year.

Development	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
West of Orkney			**153**	**1349**	**1349**	**1349**							
North Falls	PEIR			1072	1072	1072							
Pentland	ES	641											
Berwick Bank	ES	1754	1754	1754	1754	1754	1754	1754	1754				
Green Volt Floating	EIA	537	537										
Sofia	ES	2035											
Dogger Bank South[12]	PEIR	12207	12207	12207	12207	12207	12207	12207					
Hornsea Four	ES	6417	6417	6417									
Norfolk Vanguard	ES	2676	2676										
East Anglia One North	ES	1289	1289										
East Anglia Two	ES	1551	1551	1551									
East Anglia Three	ES	3828											
Five Estuaries	PEIR				7031	7031							
Rampion 2	PEIR	551	551	551	551								
Outer Dowsing	PEIR		1288	1288	1288	1288							
SHE-T Caithness to Orkney HVAC	ES	0	0										
Scotland England Green Link 1	ES	47	47										
Scotland England Green Link 2	ES	70	70	70	70								
NorthConnect	ES	47											
NeuConnect	PEIR	70	70	70									
French-Alderney-Britain (FAB) Link	ES	0	0	0									
Rosebank development	ES	0											
Teal West Development	ES	1	1										
Avalon Field Development	ES	423											
Dudgeon and Sheringham Shoal Ext	ES		2296	2296				2296	2296				
Faray slipway extension and jetty	ES	6											
RESULTS FOR PROJECTS WITH A QUANTITATIVE IMPACT ASSESSMENT AVAILABLE													
TOTAL		34150	**30907**	**28625**	**25322**	**24701**	13961	16257	4050	0	0	0	0
% MU		9.1%	**8.2%**	**7.6%**	**6.7%**	**6.6%**	3.7%	4.3%	1.1%	0.0%	0.0%	0.0%	0.0%
% UK MU		18.6%	**16.8%**	**15.6%**	**13.8%**	**13.4%**	7.6%	8.8%	2.2%	0.0%	0.0%	0.0%	0.0%
WOW contribution to total %		0.0%	**0.5%**	**4.7%**	**5.3%**	**5.5%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
CNSE Project	*N*		*1272*	*1272*									
Cenos	*N*		*1272*	*1272*	*1272*	*1272*							

[12] Numbers of animals provided assumes simultaneous piling at the East and West parts of the development.

Caledonia	*N*			*323*	*323*	*323*							
Thor	*N*	*196*	*196*										
Sea Link	*N*			*48*	*48*	*48*							
Northern Endurance	*N*	*70*											
Acorn	*N*	*47*											
V-Net Zero (Viking)	*N*	*70*	*70*										
Scapa Deep Water Quay	*N*	*323*	*323*										
Seismic (UK North Sea MU)	*N*	*1600*	*1600*	*1600*	*1600*	*1600*	*1600*	*1600*	*1600*	*1600*	*1600*	*1600*	*1600*
Seismic (UK West Scotland MU)	*N*	*332*	*332*	*332*	*332*	*332*	*332*	*332*	*332*	*332*	*332*	*332*	*332*
RESULTS FOR ALL PROJECTS IN THE CEA (including those without an impact assessment available)													
TOTAL		*36788*	***35972***	***33472***	***28897***	***28276***	*15893*	*18189*	*5982*	*1932*	*1932*	*1932*	*1932*
% MU		*9.8%*	***9.6%***	***8.9%***	***7.7%***	***7.5%***	*4.2%*	*4.8%*	*1.6%*	*0.5%*	*0.5%*	*0.5%*	*0.5%*
% UK MU		*20.0%*	***19.6%***	***18.2%***	***15.7%***	***15.4%***	*8.6%*	*9.9%*	*3.3%*	*1.1%*	*1.1%*	*1.1%*	*1.1%*
WOW contribution to total %		*0.0%*	***0.4%***	***4.0%***	***4.7%***	***4.8%***	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*

11.3.3.3 Result

The magnitude of disturbance to harbour porpoise from underwater noise across the CEA projects is considered to be **Medium** (though the high levels of precaution in this assessment should be noted). The impact of disturbance to the MU is expected to be of a medium-term duration (12 years considered here), though the contribution of the offshore Project to this is only across four years. No alteration to the conservation status of harbour porpoise is expected from this level of disturbance, and the level of impact across the various projects is unlikely to result in population level impact based on the results shown in other examples of population modelling.

Harbour porpoise have been assessed as having a **Low** sensitivity to disturbance from pile driving (see Section 8.3.1.2) (the same has been assumed here for all other disturbance pathways).

Therefore, the consequence of cumulative disturbance from underwater noise to harbour porpoise is Minor, which is not significant in EIA terms.

11.3.4 Dolphin Species

11.3.4.1 White-beaked dolphin

11.3.4.1.1 Assessment using only those projects with a quantitative impact assessment available

There were 31 projects with impact assessments available screened into the white-beaked dolphin CEA. However, most of these projects were located in the Irish Sea and the central/southern North Sea where white-beaked dolphins are rare and as such the offshore projects did not assess this species (resulting in 0 disturbance listed in Table 11.3).

In the CEA period considered (2026-2037), the highest level of impact to the white-beaked dolphin MU is in 2026, prior to offshore construction work at the offshore Project (Table 11.3). In 2026 an estimated 1,422 white-beaked dolphins are potentially disturbed per day across 27 CEA projects with an impact assessment available, equating to 3.2% MU (4.2% UK MU) (assuming underwater noise disturbance across all 27 projects on the same day within that year). The disturbance impact from the offshore Project contributes 0% of the total disturbance estimate.

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 653 white-beaked dolphins are potentially disturbed per day across 22 CEA projects with an impact assessment available, equating to 1.5% MU (1.9% UK MU) (assuming underwater noise disturbance across all 22 projects on the same day within that year). The disturbance impact from the offshore Project contributes 0% of the total disturbance estimate since no white-beaked dolphins were predicted to be impacted by UXO clearance activities at the offshore Project.
- In 2028, when piling is planned at the offshore Project, an estimated 2,343 white-beaked dolphins are potentially disturbed per day across 17 CEA projects with an impact assessment available, equating to 5.3% MU (6.9% UK MU) (assuming underwater noise disturbance across all 17 projects on the same day within that year). The disturbance impact from the offshore Project contributes 72.9% of the total disturbance estimate.
- In 2029, when piling is planned at the offshore Project, an estimated 2,245 white-beaked dolphins are potentially disturbed per day across 12 CEA projects with an impact assessment available, equating to 5.1% MU (6.6% UK MU) (assuming underwater noise disturbance across all 12 projects on the same day within that year). The disturbance impact from the offshore Project contributes 76.1% of the total disturbance estimate.

- In 2030, when piling is planned at the offshore Project, an estimated 2,226 white-beaked dolphins are potentially disturbed per day across 10 CEA projects with an impact assessment available, equating to 5.1% MU (6.5% UK MU) (assuming underwater noise disturbance across all 10 projects on the same day within that year). The disturbance impact from the offshore Project contributes 76.8% of the total disturbance estimate.

11.3.4.1.2 Assessment using all CEA projects (including those without a quantitative impact assessment)

A total of 49 offshore development projects were screened into the white-beaked dolphin cumulative assessment, alongside 2 indicative seismic surveys. Many of the projects have yet to submit an EIA, and of these, most are expected to have zero impact to white-beaked dolphins as they are not expected to be present in the area according to the SCANS III data (Table 11.3).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 2,046 white-beaked dolphins are potentially disturbed per day, equating to 4.7% (6.0% UK MU) (assuming underwater noise disturbance across all 31 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 0% of the total disturbance estimate as no white-beaked dolphins are predicted to experience disturbance from UXO clearance at the offshore Project.
- In 2028, when piling is planned at the offshore Project, an estimated 3,736 white-beaked dolphins are potentially disturbed per day, equating to 8.5% (11.0% UK MU) (assuming underwater noise disturbance across all 25 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 33.0% of the total disturbance.
- In 2029, when piling is planned at the offshore Project, an estimated 3,122 white-beaked dolphins are potentially disturbed per day, equating to 7.1% (9.2% UK MU) (assuming underwater noise disturbance across all 18 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 54.7% of the total disturbance.
- In 2030, when piling is planned at the offshore Project, an estimated 3,103 white-beaked dolphins are potentially disturbed per day, equating to 7.1% MU (9.1% UK MU) (assuming underwater noise disturbance across all 14 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 55.1% of the total disturbance estimate.

Table 11.3 White-beaked dolphin cumulative effect of disturbance from underwater noise. Numbers denote the number of white-beaked dolphins predicted to be disurbed per day at each project in each year.

Development	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
West of Orkney	**Y**		**0**	**1709**	**1709**	**1709**							
North Falls	PEIR			0	0	0							
Mona	PEIR	0	0	0	0	0							
Morgan	PEIR	0	0	0	0	0							
Pentland Floating	ES	337											
Morecambe	PEIR	0	0	0	0	0							
Berwick Bank	ES	516	516	516	516	516	516	516	516				
Green Volt Floating	PEIR	0	0										
Sofia	ES	3											
Dogger Bank South	PEIR	0	0	0	0	0	0	0					
Hornsea Project Four	ES	85	85	85									
Norfolk Vanguard	ES	0	0										
East Anglia One North	ES	0	0										
East Anglia Two	ES	0	0	0									
East Anglia Three	ES	0											
Five Estuaries	PEIR				0	0							
Rampion 2	PEIR	0	0	0	0								
Erebus	ES	0	0	0									
Awel y Môr	ES	0	0	0	0	0							
Outer Dowsing	PEIR		1	1	1	1							
SHE-T Caithness to Orkney HVAC	ES	0	0										
Scotland England Green Link 1	ES	19	19										
Scotland England Green Link 2	ES	19	19	19	19								
NorthConnect	ES	19											
Celtic Interconnector	ES	0											
NeuConnect	PEIR	0	0	0									
French-Alderney-Britain Link	ES	0	0	0									
Rosebank development	ES	0											
Teal West Development	ES	0	0										
Avalon Field Development	ES	423											
Dudgeon and Sheringham Shoal Ext	ES		13	13				13	13				
Faray slipway extension and jetty	ES		0	1709	1709	1709							
RESULTS FOR PROJECTS WITH A QUANTITATIVE IMPACT ASSESSMENT AVAILABLE													
TOTAL		1422	**653**	**2343**	**2245**	**2226**	516	529	529	0	0	0	0
% MU		3.2%	**1.5%**	**5.3%**	**5.1%**	**5.1%**	1.2%	1.2%	1.2%	0.0%	0.0%	0.0%	0.0%
% UK MU		4.2%	**1.9%**	**6.9%**	**6.6%**	**6.5%**	1.5%	1.6%	1.6%	0.0%	0.0%	0.0%	0.0%
WOW contribution to total %		0.0%	**0.0%**	**72.9%**	**76.1%**	**76.8%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

CNSE	*N*		*516*	*516*									
Cenos	*N*		*516*	*516*	*516*	*516*							
Valorous	*N*			*0*	*0*								
Caledonia	*N*			*45*	*45*	*45*							
White Cross	*N*	*0*											
Arklow Bank Phase 2	*N*	*0*	*0*	*0*	*0*								
Codling Wind Park	*N*	*0*	*0*										
Dublin Array	*N*	*0*	*0*										
North Irish Sea Array	*N*	*0*	*0*	*0*									
Thor	*N*	*0*	*0*										
Galatea-Galene	*N*			*0*	*0*	*0*							
Stora Middelground	*N*	*0*											
Sea Link	*N*			*0*	*0*	*0*							
Northern Endurance Partnership	*N*	*0*											
Acorn	*N*	*19*											
V-Net Zero	*N*	*0*	*0*										
HyNet North West Pipeline	*N*	*0*											
Scapa Deep Water Quay	*N*	*45*	*45*										
Seismic survey 1	*N*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*
Seismic survey 2	*N*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*	*158*
RESULTS FOR ALL PROJECTS IN THE CEA (including those without an impact assessment available)													
TOTAL		*1802*	***2046***	***3736***	***3122***	***3103***	*832*	*845*	*845*	*316*	*316*	*316*	*316*
% MU		*4.1%*	***4.7%***	***8.5%***	***7.1%***	***7.1%***	*1.9%*	*1.9%*	*1.9%*	*0.7%*	*0.7%*	*0.7%*	*0.7%*
% UK MU		*5.3%*	***6.0%***	***11.0%***	***9.2%***	***9.1%***	*2.4%*	*2.5%*	*2.5%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*
WOW contribution to total %		*0.0%*	***0.0%***	***45.7%***	***54.7%***	***55.1%***	*0.0%*	*0.0%*	*0.0%*	*0%*	*0%*	*0%*	*0%*

11.3.4.2 Common dolphin

11.3.4.2.1 Assessment using only those projects with a quantitative impact assessment available

There were 31 projects with impact assessments available screened into the common dolphin CEA. However, most of these projects were located in the central/southern North Sea where common dolphins are rare and as such the offshore projects did not assess this species (resulting in 0 disturbance listed in Table 11.4).

In the CEA period considered (2026-2037), the highest level of impact to the common dolphin MU is in 2028, during the first year of piling at the offshore Project offshore Project (Table 11.4).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 2,735 common dolphins are potentially disturbed per day across 22 CEA projects with an impact assessment available, equating to 2.7% MU (4.8% UK MU) (assuming underwater noise disturbance across all 22 projects on the same day within that year). The disturbance impact from the offshore Project contributes 0% of the total disturbance estimate as no common dolphins are predicted to experience disturbance from UXO clearance at the offshore Project.
- In 2028, when piling is planned at the offshore Project, an estimated 2,825 common dolphins are potentially disturbed per day across 17 CEA projects with an impact assessment available, equating to 2.8% MU (4.9% UK MU) (assuming underwater noise disturbance across all 17 projects on the same day within that year). The disturbance impact from the offshore Project contributes 3.2% of the total disturbance estimate.
- In 2029, when piling is planned at the offshore Project, an estimated 758 common dolphins are potentially disturbed per day across 12 CEA projects with an impact assessment available, equating to 0.7% MU (1.3% UK MU) (assuming underwater noise disturbance across all 12 projects on the same day within that year). The disturbance impact from the offshore Project contributes 11.9% of the total disturbance estimate.
- In 2030, when piling is planned at the offshore Project, an estimated 316 common dolphins are potentially disturbed per day across 10 CEA projects with an impact assessment available, equating to 0.3% MU (0.6% UK MU) (assuming underwater noise disturbance across all 10 projects on the same day within that year). The disturbance impact from the offshore Project contributes 28.5% of the total disturbance estimate.

11.3.4.2.2 Assessment using all CEA projects (including those without a quantitative impact assessment)

A total of 49 offshore development projects were screened into the common dolphin cumulative assessment, alongside 2 indicative seismic surveys. Many of the projects have yet to submit an EIA, and of these, most are expected to have zero impact to common dolphins as they are not expected to be present in the area according to the SCANS III data (resulting in 0 disturbance listed in Table 11.4).

In the CEA period considered (2026-2037), the highest level of impact to the common dolphin MU is in 2028.

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 3,269 common dolphins are potentially disturbed per day, equating to 3.2% MU (5.7% UK MU) (assuming underwater noise disturbance across all 31 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 0% of the total disturbance estimate as no common dolphins are predicted to experience disturbance from UXO clearance at the offshore Project.

- In 2028, when piling is planned at the offshore Project, an estimated 3,624 common dolphins are potentially disturbed per day, equating to 3.5% MU (6.3% UK MU) (assuming underwater noise disturbance across all 25 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 2.5% of the total disturbance estimate.
- In 2029, when piling is planned at the offshore Project, an estimated 1,557 common dolphins are potentially disturbed per day, equating to 1.5% MU (2.7% UK MU) (assuming underwater noise disturbance across all 18 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 5.8% of the total disturbance estimate.
- In 2030, when piling is planned at the offshore Project, an estimated 850 common dolphins are potentially disturbed per day, equating to 0.8% MU (1.5% UK MU) (assuming underwater noise disturbance across all 14 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 10.6% of the total disturbance estimate.

Table 11.4 Common dolphin cumulative effect of disturbance from underwater noise. Numbers denote the number of common dolphins predicted to be disurbed per day at each project in each year.

Development	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
West of Orkney	**Y**		0	90	90	90							
North Falls	PEIR			0	0	0							
Mona	PEIR	109	109	109	109	109							
Morgan	PEIR	100	100	100	100	100							
Pentland Floating	ES	8											
Morecambe	PEIR	0	0	0	0	0							
Berwick Bank	ES	0	0	0	0	0	0	0	0				
Green Volt Floating	PEIR	0	0										
Sofia	ES	0											
Dogger Bank South	PEIR	0	0	0	0	0	0	0					
Hornsea Project Four	ES	0	0	0									
Norfolk Vanguard	ES	0	0										
East Anglia One North	ES	0	0										
East Anglia Two	ES	0	0	0									
East Anglia Three	ES	0											
Five Estuaries	PEIR				0	0							
Rampion 2	PEIR	442	442	442	442								
Erebus	ES	2067	2067	2067									
Awel y Môr	ES	17	17	17	17	17							
Outer Dowsing	PEIR		0	0	0	0							
SHE-T Caithness to Orkney HVAC	ES	0	0										
Scotland England Green Link 1	ES	0	0										
Scotland England Green Link 2	ES	0	0	0	0								
NorthConnect	ES	0											
Celtic Interconnector	ES	62											
NeuConnect	PEIR	0	0	0									
French-Alderney-Britain Link	ES	0	0	0									
Rosebank development	ES	0											
Teal West Development	ES	0	0										
Avalon Field Development	ES	0											
Dudgeon and Sheringham Shoal Ext	ES		0	0				0	0				
Faray slipway extension and jetty	ES		0	90	90	90							
RESULTS FOR PROJECTS WITH A QUANTITATIVE IMPACT ASSESSMENT AVAILABLE													
TOTAL		2808	**2735**	**2825**	**758**	**316**	0	0	0	0	0	0	0
% MU		2.7%	**2.7%**	**2.8%**	**0.7%**	**0.3%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% UK MU		4.9%	**4.8%**	**4.9%**	**1.3%**	**0.6%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WOW contribution to total %		0.0%	**0.0%**	**3.2%**	**11.9%**	**28.5%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

CNSE Project	*N*		*0*	*0*									
Cenos	*N*		*0*	*0*	*0*	*0*							
Valorous	*N*			*265*	*265*								
Caledonia	*N*			*0*	*0*	*0*							
White Cross	*N*	*265*											
Arklow Bank Phase 2	*N*	*0*	*0*	*0*	*0*								
Codling Wind Park	*N*	*0*	*0*										
Dublin Array	*N*	*0*	*0*										
North Irish Sea Array	*N*	*0*	*0*	*0*									
Thor	*N*	*0*	*0*										
Galatea-Galene	*N*			*0*	*0*	*0*							
Stora Middelground	*N*	*0*											
Sea Link	*N*			*0*	*0*	*0*							
Northern Endurance Partnership	*N*	*0*											
Acorn	*N*	*0*											
V-Net Zero	*N*	*0*	*0*										
HyNet North West Pipeline	*N*	*0*											
Scapa Deep Water Quay	*N*	*0*	*0*										
Seismic survey 1	*N*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*
Seismic survey 2	*N*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*	*267*
RESULTS FOR ALL PROJECTS IN THE CEA (including those without an impact assessment available)													
TOTAL		*3607*	***3269***	***3624***	***1557***	***850***	*534*	*534*	*534*	*534*	*534*	*534*	*534*
% MU		*3.5%*	***3.2%***	***3.5%***	***1.5%***	***0.8%***	*0.5%*	*0.5%*	*0.5%*	*0.5%*	*0.5%*	*0.5%*	*0.5%*
% UK MU		*6.3%*	***5.7%***	***6.3%***	***2.7%***	***1.5%***	*0.9%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*
WOW contribution to total %		*0.0%*	***0.0%***	***2.5%***	***5.8%***	***10.6%***	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*

11.3.4.3 Risso's dolphin

11.3.4.3.1 Assessment using only those projects with a quantitative impact assessment available

There were 31 projects with impact assessments available screened into the Risso's dolphin CEA. However, most of these projects were located in the central/southern North Sea where Risso's dolphins are rare and as such the offshore projects did not assess this species (resulting in 0 disturbance listed in **Table 11.5**).

In the CEA period considered (2026-2037), the highest level of impact to the common dolphin MU is between 2028-2030, during the three years of piling at the offshore Project offshore Project (**Table 11.5**).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 429 Risso's dolphins are potentially disturbed per day across 22 CEA projects with an impact assessment available, equating to 3.5% MU (4.9% UK MU) (assuming underwater noise disturbance across all projects on the same day within that year). The disturbance impact from the offshore Project contributes 0% of the total disturbance estimate as no Risso's dolphins are predicted to experience disturbance from UXO clearance at the offshore Project.
- In 2028, 2029 and 2030, when piling is planned at the offshore Project, an estimated 550 Risso's dolphins are potentially disturbed per day across a maximum of 17 CEA projects with an impact assessment available, equating to 4.5% MU (6.3% UK MU) (assuming underwater noise disturbance across all projects on the same day within that year). The disturbance impact from the offshore Project contributes 22% of the total disturbance estimate.

11.3.4.3.2 Assessment using all CEA projects (including those without a quantitative impact assessment)

A total of 49 offshore development projects were screened into the Rosso's dolphin cumulative assessment, alongside 2 indicative seismic surveys. Many of the projects have yet to submit an EIA, and of these, most are expected to have zero impact to Risso's dolphins as they are not expected to be present in the area according to the SCANS III data (resulting in 0 disturbance listed in **Table 11.5**).

In the CEA period considered (2026-2037), the highest level of impact to the Risso's dolphin MU is in 2026, the year prior to UXO clearance commencing at the offshore Project. In 2026 an estimated 831 Risso's dolphins are potentially disturbed, equating to 6.8% MU (9.6% UK MU) (assuming underwater noise disturbance across all 39 projects on the same day within that year).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 773 Risso's dolphins are potentially disturbed per day, equating to 6.3% MU (8.9% UK MU) (assuming underwater noise disturbance across all 31 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 0% of the total disturbance estimate as no Risso's dolphins are predicted to experience disturbance from UXO clearance at the offshore Project.
- In 2028, when piling is planned at the offshore Project, an estimated 762 Risso's dolphins are potentially disturbed per day, equating to 6.2% MU (8.8% UK MU) (assuming underwater noise disturbance across all 25 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 15.9% of the total disturbance estimate.
- In 2029, when piling is planned at the offshore Project, an estimated 696 Risso's dolphins are potentially disturbed per day, equating to 5.7% MU (8.0% UK MU) (assuming underwater noise disturbance across all 18 projects alongside 2 indicative seismic surveys on the same day

within that year). The disturbance impact from the offshore Project contributes 17.4% of the total disturbance estimate.

- In 2030, when piling is planned at the offshore Project, an estimated 630 Risso's dolphins are potentially disturbed per day, equating to 5.1% MU (7.3% UK MU) (assuming underwater noise disturbance across all 14 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 19.2% of the total disturbance estimate.

Table 11.5 Risso's dolphin cumulative effect of disturbance from underwater noise. Numbers denote the number of Risso's dolphins predicted to be disurbed per day at each project in each year.

Development	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
West of Orkney			**0**	**121**	**121**	**121**							
North Falls	PEIR			0	0	0							
Mona	PEIR	190	190	190	190	190							
Morgan	PEIR	174	174	174	174	174							
Pentland Floating	ES	57											
Morecambe	PEIR	0	0	0	0	0							
Berwick Bank	ES	0	0	0	0	0	0	0	0				
Green Volt Floating	PEIR	0	0										
Sofia	ES	0											
Dogger Bank South	PEIR	0	0	0	0	0	0	0					
Hornsea Project Four	ES	0	0	0									
Norfolk Vanguard	ES	0	0										
East Anglia One North	ES	0	0										
East Anglia Two	ES	0	0	0									
East Anglia Three	ES	0											
Five Estuaries	PEIR				0	0							
Rampion 2	PEIR	0	0	0	0								
Erebus	ES	0	0	0									
Awel y Môr	ES	65	65	65	65	65							
Outer Dowsing	PEIR		0	0	0	0							
SHE-T Caithness to Orkney HVAC	ES	0	0										
Scotland England Green Link 1	ES	0	0										
Scotland England Green Link 2	ES	0	0	0	0								
NorthConnect	ES	0											
Celtic Interconnector	ES	0											
NeuConnect	PEIR	0	0	0									
FAB Link	ES	0	0	0									
Rosebank Development	ES	0											
Teal West Development	ES	0	0										
Avalon Field Development	ES	0											
Dudgeon and Sheringham Shoal Ext	ES		0	0				0	0				
Faray slipway & landing jetty	ES	1											
RESULTS FOR PROJECTS WITH A QUANTITATIVE IMPACT ASSESSMENT AVAILABLE													
TOTAL		487	**429**	**550**	**550**	**550**	0	0	0	0	0	0	0
% MU		4.0%	**3.5%**	**4.5%**	**4.5%**	**4.5%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
% UK MU		5.6%	**4.9%**	**6.3%**	**6.3%**	**6.3%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
WOW contribution to total %		0.0%	**0.0%**	**22.0%**	**22.0%**	**22.0%**	0%	0%	0%	0%	0%	0%	0%

CNSE Project	*N*		*0*	*0*									
CENOS	*N*		*0*	*0*	*0*	*0*							
Valorous	*N*				*0*	*0*							
Caledonia	*N*				*0*	*0*							
White Cross	*N*		*0*										
Arklow Bank Phase 2	*N*		*66*	*66*	*66*	*66*							
Codling Wind Park	*N*		*66*	*66*									
Dublin Array	*N*		*66*	*66*									
North Irish Sea Array	*N*		*66*	*66*	*66*								
Thor	*N*		*0*	*0*									
Galatea-Galene	*N*				*0*	*0*							
Stora Middelground	*N*		*0*										
Sea Link	*N*				*0*	*0*							
Northern Endurance Partnership	*N*		*0*										
Acorn	*N*		*0*										
V-Net Zero	*N*		*0*	*0*									
HyNet North West Pipeline	*N*		*0*										
Scapa Deep Water Quay	*N*	*0*	*0*										
Seismic survey 1	*N*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
Seismic survey 2	*N*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*	*40*
RESULTS FOR ALL PROJECTS IN THE CEA (including those without an impact assessment available)													
TOTAL		*831*	***773***	***762***	***696***	***630***	*80*	*80*	*80*	*80*	*80*	*80*	*80*
% MU		*6.8%*	***6.3%***	***6.2%***	***5.7%***	***5.1%***	*0.7%*	*0.7%*	*0.7%*	*0.7%*	*0.7%*	*0.7%*	*0.7%*
% UK MU		*9.6%*	***8.9%***	***8.8%***	***8.0%***	***7.3%***	*0.9%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*
WOW contribution to total %		*0.0%*	***0.0%***	***15.9%***	***17.4%***	***19.2%***	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*	*0%*

11.3.4.4 Conclusion

It is important to consider the disturbance numbers for all dolphin species as highly precautionary, given all the levels of precaution inherent in this additive CEA approach (see **Section 11.3.1.4** for details). Additionally, the disturbance estimates for all dolphin species at the offshore Project alone are highly precautionary since the assessment used the harbour porpoise dose-response function which is expected to largely over-estimate impacts to dolphin species that are comparatively less sensitive to underwater noise than harbour porpoise (see **Section 8.3.2.1** for further details).

The expected impact of disturbance cumulatively from the offshore Project and other projects in the MU is unknown since there is no information on dolphin disturbance from piling potentially affecting dolphin vital rates and population dynamics. It is conservative to assume a **Medium** magnitude, since it is possible that cumulative impacts could result in a deviation from the baseline, though it is considered unlikely that the predicted impacts would result in an alteration to the conservation status of any of the dolphin species considered here. The cumulative impact of disturbance to the dolphin MUs is of medium-term duration, since impacts to the MUs are expected across multiple years from multiple different offshore projects between 2026 and 2037.

All dolphin species have been assessed as having a **Low** sensitivity to disturbance from pile driving (the same has been assumed here for all other disturbance pathways).

Therefore, the consequence of cumulative disturbance from underwater noise to dolphin species is Minor, which is not significant in EIA terms.

11.3.5 Minke whale

11.3.5.1.1 Assessment using only those projects with a quantitative impact assessment available

There were 31 projects with impact assessments available screened into the minke whale CEA. However, most of these projects were located in the southern North Sea where minke whale are rare and as such the offshore projects did not assess this species (resulting in 0 disturbance listed in **Table 11.6**).

The highest level of predicted impact to the minke whale MU is in 2027, when pre-construction UXO clearance at the offshore Project overlaps with construction activities at several offshore projects (**Table 11.6**).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 795 minke whales are potentially disturbed per day, equating to 4.0% MU (7.7% UK MU) (assuming underwater noise disturbance across all 22 projects constructing on the same day within that year). The disturbance impact from the offshore Project contributes 23.4% of the total disturbance estimate.
- In 2028, when piling is planned at the offshore Project, an estimated 764 minke whales are potentially disturbed per day, equating to 3.8% MU (7.4% UK MU) (assuming underwater noise disturbance across all 16 projects construction on the same day within that year). The disturbance impact from the offshore Project contributes 11.8% of the total disturbance estimate.
- In 2029, when piling is planned at the offshore Project, an estimated 642 minke whales are potentially disturbed per day, equating to 3.2% MU (6.2% UK MU) (assuming underwater noise disturbance across all 12 projects constructing on the same day within that year). The disturbance impact from the offshore Project contributes 14% of the total disturbance estimate.

- In 2030, when piling is planned at the offshore Project, an estimated 634 minke whales are potentially disturbed per day, equating to 3.2% MU (6.2% UK MU) (assuming underwater noise disturbance across all 10 projects constructing on the same day within that year). The disturbance impact from the offshore Project contributes 14.2% of the total disturbance estimate.

11.3.5.1.2 Assessment using all CEA projects (including those without a quantitative impact assessment)

A total of 49 offshore development projects were screened into the minke whale cumulative assessment, alongside 2 indicative seismic surveys. Many of the projects have yet to submit an EIA, and of these, most are expected to have zero impact to minke whales as they are not expected to be present in the area according to the SCANS III data (resulting in 0 disturbance listed in Table 11.6).

- In 2027, when UXO clearance is planned at the offshore Project, an estimated 1,224 minke whales are potentially disturbed per day, equating to 6.1% MU (11.9% UK MU) (assuming underwater noise disturbance across all 31 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 15.2% of the total disturbance estimate.
- In 2028, when piling is planned at the offshore Project, an estimated 1,126 minke whales are potentially disturbed per day, equating to 5.6% MU (10.9% UK MU) (assuming underwater noise disturbance across all 25 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 8.0% of the total disturbance estimate.
- In 2029, when piling is planned at the offshore Project, an estimated 885 minke whales are potentially disturbed per day, equating to 4.4% MU (8.6% UK MU) (assuming underwater noise disturbance across all 18 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 10.2% of the total disturbance estimate.
- In 2030, when piling is planned at the offshore Project, an estimated 832 minke whales are potentially disturbed per day, equating to 4.1% MU (8.1% UK MU) (assuming underwater noise disturbance across all 14 projects alongside 2 indicative seismic surveys on the same day within that year). The disturbance impact from the offshore Project contributes 10.8% of the total disturbance estimate.

It is important to consider these numbers as highly precautionary, given all the levels of precaution inherent in this additive CEA approach (see Section 11.3.1.4 for details). In addition to this, the approach for minke whales is based on responses of harbour porpoise to various underwater sound sources. Given their large size and capacity for energy storage, it is expected that minke whales will be able to tolerate temporary displacement from foraging areas much better than harbour porpoise. Finally, since minke whales are primarily present in UK waters in the summer months, the amount of time they are expected to be present to be disturbed is limited.

11.3.5.2 Result

The magnitude of disturbance to minke whales from underwater noise across the CEA projects is considered to be **Medium** (though the high levels of precaution in this assessment should be noted). The impact of disturbance to the MU is expected to be of a medium-term duration (12 years considered here), though the contribution of the offshore Project to this is only across four years. No alteration to the conservation status of minke whales is expected, and the level of impact across the various projects is unlikely to result in population level impact.

Minke whales have been assessed as having a **Low** sensitivity to disturbance from pile driving (the same has been assumed here for all other disturbance pathways).

Therefore, the consequence of cumulative disturbance from underwater noise to minke whales is Minor, which is not significant in EIA terms.

Table 11.6 Minke whale cumulative effect of disturbance from underwater noise. Numbers denote the number of minke whales predicted to be disurbed per day at each project in each year.

Development	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
West of Orkney			**186**	**90**	**90**	**90**							
North Falls	PEIR			70	70	70							
Mona	PEIR	105	105	105	105	105							
Morgan	PEIR	96	96	96	96	96							
Pentland Floating	ES	40											
Morecambe	PEIR	2	2	2	2	2							
Berwick Bank	ES	82	82	82	82	82	82	82	82				
Green Volt Floating	PEIR	2	2										
Sofia	ES	36											
Dogger Bank South	PEIR	148	148	148	148	148	148	148					
Hornsea Project Four	ES	46	46	46									
Norfolk Vanguard	ES	0	0										
East Anglia One North	ES	0	0										
East Anglia Two	ES	0	0	0									
East Anglia Three	ES	0											
Five Estuaries	PEIR				0	0							
Rampion 2	PEIR	5	5	5	5								
Erebus	ES	55	55	55									
Awel y Môr	ES	36	36	36	36	36							
Outer Dowsing	PEIR		5	5	5	5							
SHE-T Caithness to Orkney HVAC	ES	0	0										
Scotland England Green Link 1	ES	3	3										
Scotland England Green Link 2	ES	3	3	3	3								
NorthConnect	ES	1											
Celtic Interconnector	ES	1											
NeuConnect	PEIR	0	0	0									
FAB Link	ES	0	0	0									
Rosebank development	ES	0											
Teal West Development	ES	0	0										
Avalon Field Development	ES	0											
Dudgeon and Sheringham Shoal Ext	ES		21	21									
Faray slipway and landing jetty	ES	2											
RESULTS FOR PROJECTS WITH A QUANTITATIVE IMPACT ASSESSMENT AVAILABLE													
TOTAL		663	**795**	**764**	**642**	**634**	230	251	103	0	0	0	0
% MU		3.3%	**4.0%**	**3.8%**	**3.2%**	**3.2%**	1.1%	1.2%	0.5%	0.0%	0.0%	0.0%	0.0%
% UK MU		6.4%	**7.7%**	**7.4%**	**6.2%**	**6.2%**	2.2%	2.4%	1.0%	0.0%	0.0%	0.0%	0.0%
WOW contribution to total %		0.0%	**23.4%**	**11.8%**	**14.0%**	**14.2%**	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%

CNSE Project	*N*		*82*	*82*									
Cenos	*N*		*82*	*82*	*82*	*82*							
Valorous	*N*			*8*	*8*								
Caledonia	*N*			*20*	*20*	*20*							
White Cross	*N*	*8*											
Arklow Bank Phase 2	*N*	*37*	*37*	*37*	*37*								
Codling Wind Park	*N*	*37*	*37*										
Dublin Array	*N*	*37*	*37*										
North Irish Sea Array	*N*	*37*	*37*	*37*									
Thor	*N*	*0*	*0*										
Galatea-Galene	*N*			*0*	*0*	*0*							
Stora Middelground	*N*	*0*											
Sea Link	*N*			*0*	*0*	*0*							
Northern Endurance Partnership	*N*	*1*											
Acorn	*N*	*3*											
V-Net Zero	*N*	*1*	*1*										
HyNet North West Pipeline	*N*	*0*											
Scapa Deep Water Quay	*N*	*20*	*20*										
Seismic survey 1	*N*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*
Seismic survey 2	*N*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*	*48*
RESULTS FOR ALL PROJECTS IN THE CEA (including those without an impact assessment available)													
TOTAL		*940*	***1224***	***1126***	***885***	***832***	*326*	*347*	*199*	*96*	*96*	*96*	*96*
% MU		*4.7%*	***6.1%***	***5.6%***	***4.4%***	***4.1%***	*1.6%*	*1.7%*	*1.0%*	*0.5%*	*0.5%*	*0.5%*	*0.5%*
% UK MU		*9.1%*	***11.9%***	***10.9%***	***8.6%***	***8.1%***	*3.2%*	*3.4%*	*1.9%*	*0.9%*	*0.9%*	*0.9%*	*0.9%*
WOW contribution to total %		*0.0%*	***15.2%***	***8.0%***	***10.2%***	***10.8%***	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*	*0.0%*

11.3.6 Harbour seal

The North Coast and Orkney MU is currently in decline (SCOS, 2022), and is expected to continue declining in the absence of the Project. During the piling offshore construction window for the offshore Project, it is predicted that up to a maximum of 16.4% of the harbour seal MU could be disturbed, assuming disturbance occurs from piling activity at the offshore Project at the same time as piling activity at Caledonia and from an indicative seismic survey (**Table 11.7**). The approach used to assess the indicative seismic survey here is highly precautionary since it assumes the same disturbance range to harbour seals as is expected for harbour porpoise, despite their different hearing groups and sensitivities. Disturbance to harbour seals from pile driving at the offshore Project alone was considered to be a Negligible magnitude given the results of the population modelling. Since only one other project is expected to construct at the same time as the piling period for the offshore Project, additional impacts to the population are considered Negligible. The main source of potential additional disturbance is from an indicative oil and gas seismic survey, for which the assessment is considered to be highly conservative. Even if cumulative underwater noise disturbance does occur, given the already declining population, it is not expected that there would be any significant change to the baseline trajectory or the integrity of the receptor. The cumulative disturbance impact would therefore be of **Low** magnitude.

The sensitivity of harbour seals to disturbance from piling has been assessed as **Medium** (see **Section 8.3.6.2**).

Therefore, the consequence of cumulative disturbance from underwater noise to harbour seals is Minor which is not significant in EIA terms.

Table 11.7 Harbour seal cumulative effect of disturbance from underwater noise. Numbers denote the number of harbour seals predicted to be disurbed per day at each project in each year.

Development	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
West of Orkney	**Y**		**6**	**176**	**176**	**176**							
Pentland Floating	Y	116											
Green Volt Floating	Y	0	0										
Faray slipway & jetty	Y	5											
Caledonia	*N*			*3*	*3*	*3*							
Acorn	*N*	*0*											
Scapa Deep Water Quay	*N*	*59*	*59*										
Seismic (NC&O MU)[13]	*N*	*141*	*141*	*141*	*141*	*141*	*141*	*141*	*141*	*141*	*141*	*141*	*141*
TOTAL		321	**206**	**320**	**320**	**320**	**141**	**141**	**141**	**141**	**141**	**141**	**141**
% MU		16.5%	**10.6%**	**16.4%**	**16.4%**	**16.4%**	**7.2%**	**7.2%**	**7.2%**	**7.2%**	**7.2%**	**7.2%**	**7.2%**
West of Orkney %		0%	**3%**	**55%**	**55%**	**55%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**	**0%**

11.3.7 Grey seal

Disturbance impacts to grey seals in the North Coast and Orkney MU are expected across five offshore development projects, in addition to the offshore Project and an indicative seismic survey. During the UXO and piling offshore construction window for the offshore Project, it is predicted that up to a maximum of 18% of the grey seal MU could be disturbed, assuming disturbance occurs from piling activity at the offshore Project at the same time as piling activity at Caledonia and from an indicative seismic survey (**Table 11.8**). The approach used to assess the indicative seismic survey here is highly precautionary since it assumes the same disturbance range to grey seals as is expected for harbour porpoise, despite their different hearing groups and sensitivities. Likewise, no impact assessment is

[13] Average harbour seal at-sea density across the NC&O MU = 0.027 seals/km^2

available for the Caledonia offshore windfarm project yet, and so a highly precautionary 26 km EDR was assumed for grey seals from piling activities at this project. Disturbance to grey seals from pile driving at the offshore Project alone was considered to be a Negligible magnitude given the results of the population modelling (where 7.6% of the MU was disturbed over 290 piling days).

The cumulative assessment predicts disturbance to ~18% of the MU over 4 years (1 year prior to offshore construction work at the offshore Project and over the 3 years of piling at the offshore Project). The magnitude of disturbance to grey seals from underwater noise across the CEA projects is considered to be **Medium** (though the high levels of precaution in this assessment should be noted). The impact of disturbance to the MU is expected to be of a medium-term duration (12 years considered here), though the main disturbance impacts are expected over only 4 years (2027-2030). No alteration to the conservation status of grey seals is expected, though the effect of disturbance across these four years could potentially reduce the rate at which the MU population size is increasing.

The sensitivity of grey seals to disturbance from piling has been assessed as **Negligible** (see Section 8.3.7.2) and the same has been assumed here for disturbance from seismic surveys.

Therefore, the consequence of cumulative disturbance from underwater noise to grey seals is Negligible which is not significant in EIA terms.

Table 11.8 Grey seal cumulative effect of disturbance from underwater noise. Numbers denote the number of grey seals predicted to be disurbed per day at each project in each year.

Development	IA?	2026	2027	2028	2029	2030	2031	2032	2033	2034	2035	2036	2037
West of Orkney	**Y**		343	2887	2887	2887							
Pentland Floating	Y	1890											
Green Volt Floating	Y	3	3										
Faray slipway & jetty	Y	922											
Caledonia	*N*			*675*	*675*	*675*							
Acorn	*N*	*650*											
Scapa Deep Water Quay	*N*	*589*	*589*										
Seismic (NC&O MU)[14]	*N*	*2583*	*2583*	*2583*	*2583*	*2583*	*2583*	*2583*	*2583*	*2583*	*2583*	*2583*	*2583*
TOTAL		6637	**3518**	**6145**	**6145**	**6145**	2583	2583	2583	2583	2583	2583	2583
% MU		19.4%	**10.3%**	**18.0%**	**18.0%**	**18.0%**	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%	7.6%
West of Orkney %		0%	**10%**	**47%**	**47%**	**47%**	0%	0%	0%	0%	0%	0%	0%

12 Conclusion

The underwater noise impact assessment for the offshore Project has concluded **no significant impact** to any marine mammal species.

A non-zero number of individual harbour porpoise and minke whales (both of which are EPS) are predicted to experience auditory injury (PTS) from pile driving. Further mitigation measures will be considered, as required, in relation to future EPS Licence applications, once all the appropriate information is collated to inform the Piling Strategy.

[14] Average grey seal at-sea density across the NC&O MU = 0.494 seals/km^2

13 References

6 Alpha Associates Ltd. (2022a). Magnetic and acoustic data collected across the OWF and ECCs, 2022.

6 Alpha Associates Ltd. (2022b). N1 ScotWind West of Orkney OWF - Underwater Noise Modelling Assessment Review: Considering UXO Disposal Best Practice.

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

Anderwald, P., A. Brandecker, M. Coleman, C. Collins, H. Denniston, M. D. Haberlin, M. O'Donovan, R. Pinfield, F. Visser, and L. Walshe. (2013). Displacement responses of a mysticete, an odontocete, and a phocid seal to construction-related vessel traffic. Endangered Species Research **21**.

Arons, A. (1954). Underwater explosion shock wave parameters at large distances from the charge. The Journal of the Acoustical Society of America **26**:343-346.

Barett, R. (1996). Guidelines for the safe use of explosives underwater. MTD Publication **96**:101.

Beck, C. A., W. D. Bowen, and S. J. Iverson. (2003). Sex differences in the seasonal patterns of energy storage and expenditure in a phocid seal. Journal of Animal Ecology **72**:280-291.

Bejder, L., A. Samuels, H. Whitehead, H. Finn, and S. Allen. (2009). Impact assessment research: use and misuse of habituation, sensitisation and tolerance in describing wildlife responses to anthropogenic stimuli. Marine Ecology Progess Series **395**:177-185.

Benhemma-Le Gall, A., I. M. Graham, N. D. Merchant, and P. M. Thompson. (2021). Broad-scale responses of harbor porpoises to pile-driving and vessel activities during offshore windfarm construction. Frontiers in Marine Science **8**:664724.

Bertulli, C. G., M. J. Tetley, E. E. Magnúsdóttir, and M. H. Rasmussen. (2015). Observations of movement and site fidelity of white-beaked dolphins (Lagenorhynchus albirostris) in Icelandic coastal waters using photo-identification. Journal of Cetacean and Research Management **15**:27-34.

Blackwell, S. B., C. S. Nations, A. Thode, M. Kauffman, A. S. Conrad, R. G. Norman, and K. Kim. (2017). Effects of tones associated with drilling activities on bowhead whale calling rate. PLoS ONE **12(11)**.

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. (2020). Food for thought: Harbor porpoise foraging behavior and diet inform vulnerability to disturbance. Marine Mammal Science.

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).

Borggaard, D., J. Lien, and P. Stevick. (1999). Assessing the effects of industrial activity on large cetaceans in Trinity Bay, Newfoundland (1992-1995). Aquatic Mammals **25**:149-161.

Bossley, M. I., A. Steiner, G. J. Parra, F. Saltré, and K. J. Peters. (2022). Dredging activity in a highly urbanised estuary did not affect the long-term occurrence of Indo-Pacific bottlenose dolphins and long-nosed fur seals. Marine Pollution Bulletin **184**:114183.

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.

Brandt, M. J., C. Hoeschle, A. Diederichs, K. Betke, R. Matuschek, S. Witte, and G. Nehls. (2013). Far-reaching effects of a seal scarer on harbour porpoises, *Phocoena phocoena*. Aquatic Conservation-Marine and Freshwater Ecosystems **23**:222-232.

Christiansen, F., C. G. Bertulli, M. H. Rasmussen, and D. Lusseau. (2015). Estimating cumulative exposure of wildlife to non-lethal disturbance using spatially explicit capture–recapture models. The Journal of Wildlife Management **79**:311-324.

Christiansen, F., and D. Lusseau. (2015). Linking Behavior to Vital Rates to Measure the Effects of Non-Lethal Disturbance on Wildlife. Conservation Letters **8**:424-431.

Christiansen, F., M. Rasmussen, and D. Lusseau. (2013). Whale watching disrupts feeding activities of minke whales on a feeding ground. Marine Ecology Progress Series **478**:239-+.

Constantine, R., D. H. Brunton, and T. Dennis. (2004). Dolphin-watching tour boats change bottlenose dolphin (Tursiops truncatus) behaviour. Biological Conservation **117**:299-307.

Culloch, R. M., P. Anderwald, A. Brandecker, D. Haberlin, B. McGovern, R. Pinfield, F. Visser, M. Jessopp, and M. Cronin. (2016). Effect of construction-related activities and vessel traffic on marine mammals. Marine Ecology Progress Series **549**:231-242.

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.

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.

Dähne, M., J. Tougaard, J. Carstensen, A. Rose, and J. Nabe-Nielsen. (2017). Bubble curtains attenuate noise from offshore wind farm construction and reduce temporary habitat loss for harbour porpoises. Marine Ecology Progress Series **580**:221-237.

De Jong, C. A. f., and M. A. Ainslie. (2008). Underwater radiated noise due to the piling for the Q7 Offshore Wind Park. Journal of the Acoustical Society of America **123**:2987.

DECC. (2011). Review and Assessment of Underwater Sound Produced from Oil and Gas Sound Activities and Potential Reporting Requirements under the Marine Strategy Framework Directive. Genesis Oil and Gas Consultants report for the Department of Energy and Climate Change.

DEFRA, Joint Nature Conservation Committee, Natural England, Marine Management Organisation, Department of Agriculture Environment and Rural Affairs (Northern Ireland), Department for Business Energy & Industrial Strategy, and Offshore Petroleum Regulator for Environment and Decommissioning. (2021). Policy paper overview: Marine environment: unexploded ordnance clearance joint interim position statement.

Diederichs, A., G. Nehls, and M. J. Brandt. (2010). Does sand extraction near Sylt affect harbour porpoises? Wadden Sea Ecosystem No. 26 edition. Common Wadden Sea Secretariat, Wilhelmshaven, Germany.

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.

Donovan, C. R., C. M. Harris, L. Milazzo, J. Harwood, L. Marshall, and R. Williams. (2017). A simulation approach to assessing environmental risk of sound exposure to marine mammals. Ecology and Evolution.

Dunlop, R. A., M. J. Noad, R. D. McCauley, L. Scott-Hayward, E. Kniest, R. Slade, D. Paton, and D. H. Cato. (2017). Determining the behavioural dose–response relationship of marine mammals to air gun noise and source proximity. Journal of Experimental Biology **220**:2878-2886.

Dyndo, M., D. M. Wiśniewska, L. Rojano-Doñate, and P. T. Madsen. (2015). Harbour porpoises react to low levels of high frequency vessel noise. Scientific Reports **5**:11083.

Edds-Walton, P. L. (2000). Vocalizations Of Minke Whales *Balaenoptera Acutorostrata* In The St. Lawrence Estuary. Bioacoustics **11**:31-50.

Erbe, C., S. A. Marley, R. P. Schoeman, J. N. Smith, L. E. Trigg, and C. B. Embling. (2019). The Effects of Ship Noise on Marine Mammals—A Review. Frontiers in Marine Science **6**.

Evans, P. G. H. (1990). Marine Mammals in the English Channel in relation to proposed dredging scheme. Sea Watch Foundation, Oxford.

Fernandez-Betelu, O., I. M. Graham, K. L. Brookes, B. J. Cheney, T. R. Barton, and P. M. Thompson. (2021). Far-Field Effects of Impulsive Noise on Coastal Bottlenose Dolphins. Frontiers in Marine Science **8**.

Finneran, J. J. (2015). Noise-induced hearing loss in marine mammals: A review of temporary threshold shift studies from 1996 to 2015. The Journal of the Acoustical Society of America **138**:1702-1726.

Finneran, J. J. (2016). Auditory weighting functions and TTS/PTS exposure functions for marine mammals exposed to underwater noise. SSC Pacific, San Diego, CA 92152-5001.

Finneran, J. J., D. A. Carder, C. E. Schlundt, and R. L. Dear. (2010). Growth and recovery of temporary threshold shift at 3 kHz in bottlenose dolphins: Experimental data and mathematical models. The Journal of the Acoustical Society of America **127**:3256-3266.

Finneran, J. J., D. A. Carder, C. E. Schlundt, and S. H. Ridgway. (2005). Temporary threshold shift in bottlenose dolphins (Tursiops truncatus) exposed to mid-frequency tones. The Journal of the Acoustical Society of America **118**:2696-2705.

Gedamke, J., D. P. Costa, and A. Dunstan. (2001). Localization and visual verification of a complex minke whale vocalization. The Journal of the Acoustical Society of America **109**:3038-3047.

Genesis. (2011). Review and Assessment of Underwater Sound Produced from Oil and Gas Sound Activities and Potential Reporting Requirements under the Marine Strategy Framework Directive. Report for the Department of Energy and Climate Change.

Goley, G. S., W. J. Song, and J. H. Kim. (2011). Kurtosis corrected sound pressure level as a noise metric for risk assessment of occupational noises. The Journal of the Acoustical Society of America **129**:1475-1481.

Goold, J. C. (1996). Acoustic assessment of populations of common dolphin Delphinus delphis in conjunction with seismic surveying. JOURNAL-MARINE BIOLOGICAL ASSOCIATION OF THE UNITED KINGDOM **76**:811-820.

Graham, I. M., A. Farcas, N. D. Merchant, and P. Thompson. (2017a). Beatrice Offshore Wind Farm: An interim estimate of the probability of porpoise displacement at different unweighted single-pulse sound exposure levels. Prepared by the University of Aberdeen for Beatrice Offshore Windfarm Ltd.

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.

Graham, I. M., E. Pirotta, N. D. Merchant, A. Farcas, T. R. Barton, B. Cheney, G. D. Hastie, and P. M. Thompson. (2017b). Responses of bottlenose dolphins and harbor porpoises to impact and vibration piling noise during harbor construction. Ecosphere **8**.

Greene, C. (1987). Characteristics of oil industry dredge and drilling sounds in the Beaufort Sea. The Journal of the Acoustical Society of America.

Greene Jr, C. R. (1986). Acoustic studies of underwater noise and localization of whale calls. Sect. 2 In: Responses of bowhead whales to an offshore drilling operation in the Alaskan Beaufort Sea.

Hamernik, R. P., W. Qiu, and B. Davis. (2007). Hearing loss from interrupted, intermittent, and time varying non-Gaussian noise exposure: The applicability of the equal energy hypothesis. The Journal of the Acoustical Society of America **122**:2245-2254.

Harwood, J., S. King, R. Schick, C. Donovan, and C. Booth. (2014a). 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).

Harwood, J., S. L. King, R. S. Schick, C. Donovan, and C. G. Booth. (2014b). 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. Page 33 Scottish Marine and Freshwater Science.

Hastie, G., N. D. Merchant, T. Götz, D. J. Russell, P. Thompson, and V. M. Janik. (2019). Effects of impulsive noise on marine mammals: investigating range-dependent risk. Ecological Applications **29**:e01906.

Hastie, G. D., P. Lepper, J. C. McKnight, R. Milne, D. J. F. Russell, and D. Thompson. (2021). Acoustic risk balancing by marine mammals: anthropogenic noise can influence the foraging decisions by seals. Journal of Applied Ecology **n/a**.

Heinänen, S., and H. Skov. (2015). The identification of discrete and persistent areas of relatively high harbour porpoise density in the wider UK marine area. JNCC Report No. 544, JNCC, Peterborough.

Henderson, D., M. Subramaniam, M. A. Gratton, and S. S. Saunders. (1991). Impact noise: the importance of level, duration, and repetition rate. The Journal of the Acoustical Society of America **89**:1350-1357.

Hin, V., J. Harwood, and A. M. de Roos. (2019). Bio-energetic modeling of medium-sized cetaceans shows high sensitivity to disturbance in seasons of low resource supply. Ecological Applications:e01903.

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.

Houser, D. S., W. Yost, R. Burkard, J. J. Finneran, C. Reichmuth, and J. Mulsow. (2017). A review of the history, development and application of auditory weighting functions in humans and marine mammals. The Journal of the Acoustical Society of America **141**:1371-1413.

IAMMWG. (2022). Updated abundance estimates for cetacean Management Units in UK waters (Revised 2022). JNCC Report No. 680, JNCC Peterborough, ISSN 0963-8091.

JNCC. (2017). JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys.

JNCC. (2020). Guidance for assessing the significance of noise disturbance against Conservation Objectives of harbour porpoise SACs (England, Wales & Northern Ireland). Report No. 654, JNCC, Peterborough.

JNCC, NE, and CCW. (2010). The protection of marine European Protected Species from injury and disturbance. Guidance for the marine area in England and Wales and the UK offshore marine area.

Jones, E., G. Hastie, S. Smout, J. Onoufriou, N. D. Merchant, K. Brookes, and D. thompson. (2017). Seals and shipping: quantifying population risk and individual exposure to vessel noise. Journal of Applied Ecology **54**:1930-1940.

Kastak, D., M. Holt, C. Kastak, B. Southall, J. Mulsow, and R. Schusterman. 2005. A voluntary mechanism of protection from airborne noise in a harbor seal. Page 148 *in* 16th Biennial Conference on the Biology of Marine Mammals. San Diego CA.

Kastelein, R., N. Jennings, W. Verboom, D. De Haan, and N. Schooneman. (2006). Differences in the response of a striped dolphin (Stenella coeruleoalba) and a harbour porpoise (Phocoena phocoena) to an acoustic alarm. Marine Environmental Research **61**:363-378.

Kastelein, R. A., R. Gransier, and L. Hoek. (2013a). Comparative temporary threshold shifts in a harbor porpoise and harbor seal, and severe shift in a seal (L). Journal of the Acoustical Society of America **134**:13-16.

Kastelein, R. A., R. Gransier, L. Hoek, and C. A. de Jong. (2012a). The hearing threshold of a harbor porpoise (*Phocoena phocoena*) for impulsive sounds (L). Journal of the Acoustical Society of America **132**:607-610.

Kastelein, R. A., R. Gransier, L. Hoek, A. Macleod, and J. M. Terhune. (2012b). Hearing threshold shifts and recovery in harbor seals (*Phoca vitulina*) after octave-band noise exposure at 4 kHz. Journal of the Acoustical Society of America **132**:2745-2761.

Kastelein, R. A., R. Gransier, L. Hoek, and M. Rambags. (2013b). Hearing frequency thresholds of a harbor porpoise (*Phocoena phocoena*) temporarily affected by a continuous 1.5 kHz tone. Journal of the Acoustical Society of America **134**:2286-2292.

Kastelein, R. A., R. Gransier, M. A. T. Marijt, and L. Hoek. (2015). Hearing frequency thresholds of harbor porpoises (*Phocoena phocoena*) temporarily affected by played back offshore pile driving sounds. The Journal of the Acoustical Society of America **137**:556-564.

Kastelein, R. A., L. Helder-Hoek, J. Covi, and R. Gransier. (2016). Pile driving playback sounds and temporary threshold shift in harbor porpoises (*Phocoena phocoena*): Effect of exposure duration. The Journal of the Acoustical Society of America **139**:2842-2851.

Kastelein, R. A., L. Helder-Hoek, S. Van de Voorde, A. M. von Benda-Beckmann, F.-P. A. Lam, E. Jansen, C. A. de Jong, and M. A. Ainslie. (2017). Temporary hearing threshold shift in a harbor porpoise (*Phocoena phocoena*) after exposure to multiple airgun sounds. The Journal of the Acoustical Society of America **142**:2430-2442.

Kastelein, R. A., L. Hoek, R. Gransier, M. Rambags, and N. Claeys. (2014). Effect of level, duration, and inter-pulse interval of 1-2 kHz sonar signal exposures on harbor porpoise hearing. The Journal of the Acoustical Society of America **136**:412-422.

Kavanagh, A. S., M. Nykänen, W. Hunt, N. Richardson, and M. J. Jessopp. (2019). Seismic surveys reduce cetacean sightings across a large marine ecosystem. Scientific Reports **9**:19164.

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.

La Manna, G., M. Manghi, G. Pavan, F. Lo Mascolo, and G. Sara. (2013). Behavioural strategy of common bottlenose dolphins (*Tursiops truncatus*) in response to different kinds of boats in the waters of Lampedusa Island (Italy). Aquatic Conservation-Marine and Freshwater Ecosystems **23**:745-757.

LGL, R., and Greeneridge. (1986). Responses of bowhead whales to an offshore drilling operation in the Alaskan Beaufort Sea.

Lucke, K., U. Siebert, P. A. Lepper, and M. Blanchet. (2009). Temporary shift in masked hearing thresholds in a harbor porpoise (*Phocoena phocoena*) after exposure to siesmic airgun stimuli. Journal of the Acoustical Society of America **125**:4060-4070.

Lusseau, D. (2006). The short-term behavioral reactions of bottlenose dolphins to interactions with boats in Doubtful Sound, New Zealand. Marine Mammal Science **22**:802-818.

Malme, C., P. Miles, C. Clark, P. Tyack, and J. Bird. (1984). Investigations of the Potential Effects of Underwater Noise from Petroleum Industry Activities on Migrating Gray Whale Behavior—Phase II. U-S. Department of the Interior Minerals Management Service.

Marley, S., C. S. Kent, and C. Erbe. (2017a). Occupancy of bottlenose dolphins (*Tursiops aduncus*) in relation to vessel traffic, dredging, and environmental variables within a highly urbanised estuary. Hydrobiologia **792**:243-263.

Marley, S., C. Salgado-Kent, C. Erbe, and I. M. Parnum. (2017b). Effects of vessel traffic and underwater noise on the movement, behaviour and vocalisations of bottlenose dolphins in an urbanised estuary. Nature **7**.

Martin, B., K. Lucke, and D. Barclay. (2020). Techniques for distinguishing between impulsive and non-impulsive sound in the context of regulating sound exposure for marine mammals. The Journal of the Acoustical Society of America **147**:2159-2176.

McGarry, T., O. Boisseau, S. Stephenson, and R. Compton. (2017). Understanding the Effectiveness of Acoustic Deterrent Devices (ADDs) on Minke Whale (*Balaenoptera acutorostrata*), a Low

Frequency Cetacean. Report for the Offshore Renewables Joint Industry Programme (ORJIP) Project 4, Phase 2. Prepared on behalf of the Carbon Trust.

McQueen, A. D., B. C. Suedel, C. de Jong, and F. Thomsen. (2020). Ecological risk assessment of underwater sounds from dredging operations. Integrated environmental assessment and management **16**:481-493.

Meissner, A. M., F. Christiansen, E. Martinez, M. D. Pawley, M. B. Orams, and K. A. Stockin. (2015). Behavioural effects of tourism on oceanic common dolphins, Delphinus sp., in New Zealand: the effects of Markov analysis variations and current tour operator compliance with regulations. PLoS ONE **10**:e0116962.

Mellinger, D. K., C. D. Carson, and C. W. Clark. (2000). Characteristics of minke whale (Balaenoptera acutorostrata) pulse trains recorded near Puerto Rico. Marine Mammal Science **16**:739-756.

Mooney, T. A., P. E. Nachtigall, M. Breese, S. Vlachos, and W. W. Au. (2009). Predicting temporary threshold shifts in a bottlenose dolphin (*Tursiops truncatus*): The effects of noise level and duration. The Journal of the Acoustical Society of America **125**:1816-1826.

Moray Offshore Renewables Limited. (2012). Telford, Stevenson, MacColl Wind Farms and associated Transmission Infrastructure Environmental Statement: Technical Appendix 7.3 D - A comparison of behavioural responses by harbour porpoises and bottlenose dolphins to noise: Implications for wind farm risk assessments.

Nabe-Nielsen, J., R. M. Sibly, J. Tougaard, J. Teilmann, and S. Sveegaard. (2014). Effects of noise and by-catch on a Danish harbour porpoise population. Ecological Modelling **272**:242-251.

Nabe-Nielsen, J., F. van Beest, V. Grimm, R. Sibly, J. Teilmann, and P. M. Thompson. (2018). Predicting the impacts of anthropogenic disturbances on marine populations. Conservation Letters **e12563**.

Nachtigall, P., T. Mooney, K. Taylor, L. Miller, M. Rasmussen, T. Akamatsu, J. Teilmann, M. Linnenschmidt, and G. Vikingsson. (2008). Shipboard measurements of the hearing of the white-beaked dolphin Lagenorhynchus albirostris. Journal of Experimental Biology **211**:642-647.

Nedwell, J., and D. Howell. (2004). A review of offshore windfarm related underwater noise sources. Cowrie Rep **544**:1-57.

Nedwell, J., J. Langworthy, and D. Howell. (2003). Assessment of sub-sea acoustic noise and vibration from offshore wind turbines and its impact on marine wildlife; initial measurements of underwater noise during construction of offshore windfarms, and comparison with background noise. Subacoustech Report ref: 544R0423, published by COWRIE.

Neumann, D. R., and M. B. Orams. (2003). Feeding behaviours of short-beaked common dolphins, *Delphinus delphis*, in New Zealand. Aquatic Mammals **29**:137-149.

New, L. F., J. Harwood, L. Thomas, C. Donovan, J. S. Clark, G. Hastie, P. M. Thompson, B. Cheney, L. Scott-Hayward, and D. Lusseau. (2013). Modelling the biological significance of behavioural change in coastal bottlenose dolphins in response to disturbance. Functional Ecology **27**:314-322.

Niu, F.-q., Z.-w. Liu, H.-t. Wen, D.-w. Xu, and Y.-m. Yang. (2012). Behavioral responses of two captive bottlenose dolphins (Tursiops truncatus) to a continuous 50 kHz tone. The Journal of the Acoustical Society of America **131**:1643-1649.

NMFS. (2018). Revisions to: Technical Guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater Thresholds for Onset of Permanent and Temporary Threshold Shifts. Page 167. U.S. Department of Commerce, NOAA, Silver Spring.

Oakley, J. A., A. T. Williams, and T. Thomas. (2017). Reactions of harbour porpoise (Phocoena phocoena) to vessel traffic in the coastal waters of South West Wales, UK. Ocean & Coastal Management **138**:158-169.

OSPAR. (2009). Overview of the impacts of anthropogenic underwater sound in the marine environment. Report **441**:2009.

Pirotta, E., J. Harwood, P. M. Thompson, L. New, B. Cheney, M. Arso, P. S. Hammond, C. Donovan, and D. Lusseau. (2015a). Predicting the effects of human developments on individual dolphins to understand potential long-term population consequences. Proc. R. Soc. B **282**:20152109.

Pirotta, E., B. E. Laesser, A. Hardaker, N. Riddoch, M. Marcoux, and D. Lusseau. (2013). Dredging displaces bottlenose dolphins from an urbanised foraging patch. Marine Pollution Bulletin **74**:396-402.

Pirotta, E., N. D. Merchant, P. M. Thompson, T. R. Barton, and D. Lusseau. (2015b). Quantifying the effect of boat disturbance on bottlenose dolphin foraging activity. Biological Conservation **181**:82-89.

Piwetz, S. (2019). Common bottlenose dolphin (*Tursiops truncatus*) behavior in an active narrow seaport. PLoS ONE.

Richardson, J., and B. Wursig. (1990). Reactions of Bowhead Whales, *Balaena mysticetu*, to Drilling and Dredging Noise in the Canadian Beaufort Sea. Marine Environmental Research **29**:26.

Risch, D., C. W. Clark, P. J. Dugan, M. Popescu, U. Siebert, and S. M. Van Parijs. (2013). Minke whale acoustic behavior and multi-year seasonal and diel vocalization patterns in Massachusetts Bay, USA. Marine Ecology Progress Series **489**:279-295.

Risch, D., U. Siebert, and S. M. Van Parijs. (2014). Individual calling behaviour and movements of North Atlantic minke whales (*Balaenoptera acutorostrata*). Behaviour **151**:1335-1360.

Robinson, S. P., L. Wang, S.-H. Cheong, P. A. Lepper, J. P. Hartley, P. M. Thompson, E. Edwards, and M. Bellmann. (2022). Acoustic characterisation of unexploded ordnance disposal in the North Sea using high order detonations. Marine Pollution Bulletin **184**:114178.

Rojano-Doñate, L., B. I. McDonald, D. M. Wisniewska, M. Johnson, J. Teilmann, M. Wahlberg, J. Højer-Kristensen, and P. T. Madsen. (2018). High field metabolic rates of wild harbour porpoises. Journal of Experimental Biology **221**:jeb185827.

Ruppel, C. D., T. C. Weber, E. R. Staaterman, S. J. Labak, and P. E. Hart. (2022). Categorizing Active Marine Acoustic Sources Based on Their Potential to Affect Marine Animals. Journal of Marine Science and Engineering **10**:1278.

Russell, D., and G. Hastie. (2017). Associating predictions of change in distribution with predicted received levels during piling. Report produced for SMRU Consulting.

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. (2016a). Avoidance of wind farms by harbour seals is limited to pile driving activities. Journal of Applied Ecology **53**:1642-1652.

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

Russell, D. J. F., B. McConnell, D. Thompson, C. Duck, C. Morris, J. Harwood, and J. Matthiopoulos. (2013). Uncovering the links between foraging and breeding regions in a highly mobile mammal. Journal of Applied Ecology **50**:499-509.

Rutenko, A. N., and V. G. Ushchipovskii. (2015). Estimates of acoustic noise generated by supply vessels working with oil-drilling platforms. Acoustical Physics **61**:556-563.

Salomons, E. M., B. Binnerts, K. Betke, and A. M. v. Benda-Beckmann. (2021). Noise of underwater explosions in the North Sea. A comparison of experimental data and model predictions. The Journal of the Acoustical Society of America **149**:1878-1888.

Sarnocinska, J., J. Teilmann, J. B. Dalgaard, F. v. Beest, M. Delefosse, and J. Tougaard. (2019). Harbour porpoise (*Phocoena phocoena*) reaction to a 3D seismic airgun survey in the North Sea. Frontiers in Marine Science **6**:824.

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. (2022). Scientific Advice on Matters Related to the Management of Seal Populations: 2021.

Scottish Natural Heritage. (2016). Assessing collision risk between underwater turbines and marine wildlife. Scottish Natural Heritage Guidance Note.

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. **Vol 11 No 14, 74pp. DOI: 10.7489/12331-1**.

Sinclair, R., S. Kazer, M. Ryder, P. New, and U. Verfuss. (2021). Review and recommendations on assessment of noise disturbance for marine mammals. NRW Evidence Report No. 529.

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.

Soloway, A. G., and P. H. Dahl. (2014). Peak sound pressure and sound exposure level from underwater explosions in shallow water. The Journal of the Acoustical Society of America **136**:EL218-EL223.

Southall, B. (2021). Evolutions in Marine Mammal Noise Exposure Criteria. Acoustics Today **17**.

Southall, B., J. Calambokidis, P. Tyack, D. Moretti, J. Hildebrand, C. Kyburg, Carlson, R. Carlson, A. Friedlaender, E. Falcone, G. Schorr, A. Douglas, S. DeRuiter, J. Goldbogen, and J. Barlow. (2010). Biological and Behavioral Response Studies of Marine Mammals in Southern California, 2010 (SOCAL-10) Final Project Report.

Southall, B., J. J. Finneran, C. Reichmuth, P. E. Nachtigall, D. R. Ketten, A. E. Bowles, W. T. Ellison, D. Nowacek, and P. Tyack. (2019). Marine Mammal Noise Exposure Criteria: Updated Scientific Recommendations for Residual Hearing Effects. Aquatic Mammals **45**:125-232.

Southall, B. L., A. E. Bowles, W. T. Ellison, J. J. Finneran, R. L. Gentry, C. R. J. Greene, D. Kastak, D. R. Ketten, J. H. Miller, P. E. Nachtigall, W. J. Richardson, J. A. Thomas, and P. L. Tyack. (2007). Marine mammal noise exposure criteria: initial scientific recommendations. Aquatic Mammals **33**:411-414.

Sparling, C. E., J. R. Speakman, and M. A. Fedak. (2006). Seasonal variation in the metabolic rate and body composition of female grey seals: fat conservation prior to high-cost reproduction in a capital breeder? Journal of Comparative Physiology B **176**:505-512.

Stone, C. J., K. Hall, S. Mendes, and M. L. Tasker. (2017). The effects of seismic operations in UK waters: analysis of Marine Mammal Observer data. Journal of Cetacean Research and Management **16**:71-85.

Thompson, F., S. R. McCully, D. Wood, F. Pace, and P. White. (2009). A generic investigation into noise profiles of marine dredging in relation to the acoustic sensitivity of the marine fauna in UK waters with particular emphasis on aggregate dredging: PHASE 1 Scoping and review of key issues., MALSF.

Thompson, P. M., K. L. Brookes, I. M. Graham, T. R. Barton, K. Needham, G. Bradbury, and N. D. Merchant. (2013). Short-term disturbance by a commercial two-dimensional seismic survey does not lead to long-term displacement of harbour porpoises. Proceedings of the Royal Society B-Biological Sciences **280**:1-8.

Thompson, P. M., I. M. Graham, B. Cheney, T. R. Barton, A. Farcas, and N. D. Merchant. (2020). Balancing risks of injury and disturbance to marine mammals when pile driving at offshore windfarms. Ecological Solutions and Evidence **1**:e12034.

Todd, N. R. E., M. Cronin, C. Luck, A. Bennison, M. Jessopp, and A. S. Kavanagh. (2020). Using passive acoustic monitoring to investigate the occurrence of cetaceans in a protected marine area in northwest Ireland. Estuarine, Coastal and Shelf Science **232**:106509.

Todd, V. L., I. B. Todd, J. C. Gardiner, E. C. Morrin, N. A. MacPherson, N. A. DiMarzio, and F. Thomsen. (2015). A review of impacts of marine dredging activities on marine mammals. ICES Journal of Marine Science: Journal du Conseil **72**:328-340.

Tougaard, J., S. Buckland, S. Robinson, and B. Southall. (2013). An analysis of potential broad-scale impacts on harbour porpoise from proposed pile driving activities in the North Sea. Report of an expert group convened under the Habitats and Wild Birds Directive - Marine Evidence Group MB0138. 38pp.

Tougaard, J., J. Carstensen, J. Teilmann, S. Henrik, and P. Rasmussen. (2009). Pile driving zone of responsiveness extends beyond 20 km for harbor porpoises (*Phocoena phocoena* (L.)) (L). Journal of the Acoustical Society of America **126**:11-14.

Trigg, L., F. Chen, G. Shapiro, S. Ingram, C. Vincent, D. Thompson, D. Russell, M. I. D. Carter, and C. Embling. (2020). Predicting the exposure of diving grey seals to shipping noise. The Journal of the Acoustical Society of America **148**.

Tubelli, A. A., A. Zosuls, D. R. Ketten, M. Yamato, and D. C. Mountain. (2012). A prediction of the minke whale (*Balaenoptera acutorostrata*) middle-ear transfer function. Journal of the Acoustical Society of America **132**:3263-3272.

Tyack, P., and L. Thomas. (2019). Using dose–response functions to improve calculations of the impact of anthropogenic noise. Aquatic Conservation Marine and Freshwater Ecosystems. **29(S1)**:242-253.

Tyack, P. L. (2009). Acoustic playback experiments to study behavioral responses of free-ranging marine animals to anthropogenic sound.

van Beest, F. M., J. Nabe-Nielsen, J. Carstensen, J. Teilmann, and J. Tougaard. (2015). Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS): Status report on model development.

van Beest, F. M., J. Teilmann, L. Hermannsen, A. Galatius, L. Mikkelsen, S. Sveegaard, J. D. Balle, R. Dietz, and J. Nabe-Nielsen. (2018). Fine-scale movement responses of free-ranging harbour porpoises to capture, tagging and short-term noise pulses from a single airgun. Royal Society Open Science **5**:170110.

Verboom, W. (2014). Preliminary information on dredging and harbour porpoises. JunoBioacoustics.

von Benda-Beckmann, A. M., G. Aarts, H. Ö. Sertlek, K. Lucke, W. C. Verboom, R. A. Kastelein, D. R. Ketten, R. van Bemmelen, F.-P. A. Lam, and R. J. Kirkwood. (2015). Assessing the impact of underwater clearance of unexploded ordnance on harbour porpoises (*Phocoena phocoena*) in the southern North Sea. Aquatic Mammals **41**:503.

Ward, W. D. (1997). Effects of high-intensity sound. Pages 1497-1507 *in* M. J. Crocker, editor. Encyclopedia of acoustics. John Wiley & Sons, New York.

Whyte, K. F., D. J. F. Russell, C. E. Sparling, B. Binnerts, and G. D. Hastie. (2020). Estimating the effects of pile driving sounds on seals: Pitfalls and possibilities. J Acoust Soc Am **147**:3948.

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.

Wisniewska, D. M., M. Johnson, J. Teilmann, U. Siebert, A. Galatius, R. Dietz, and P. T. Madsen. (2018). High rates of vessel noise disrupt foraging in wild harbour porpoises (*Phocoena phocoena*). Proceedings of the Royal Society B: Biological Sciences **285**:20172314.

Xodus (2022). West of Orkney Windfarm: Post award support. Option Agreement Area and Export Cable Corridor EPS Risk Assessment and Protected Sites and Species Assessment for Geophysical surveys. Document number: L-100632-S00-REPT-004. (March 2022)

14 Appendix 1: Uncertainties and limitations

There are uncertainties relating to the underwater noise modelling and impact assessment. Broadly, these relate to predicting exposure of animals to underwater noise, predicting the response of animals to underwater noise and predicting potential population consequences of disturbance from underwater noise, which altogether result in an extremely precautionary impact assessment. Further detail of such uncertainty is set out below.

14.1 Exposure to noise

There are uncertainties relating to the ability to predict the exposure of animals to underwater noise, as well as in predicting the response to that exposure. These uncertainties relate to a number of factors: the ability to predict the level of noise that animals are exposed to, particularly over long periods of time; the ability to predict the numbers of animals affected, and the ability to predict the individual and ultimately population consequences of exposure to noise. These are explored in further detail in the paragraphs below.

The propagation of underwater noise is relatively well understood and modelled using standard methods. However, there are uncertainties regarding the amount of noise actually produced by each pulse at source and how the pulse characteristics change with range from the source. There are also uncertainties regarding the position of receptors in relation to received levels of noise, particularly over time, and understanding how the position of receptors in the water column may affect received level. Noise monitoring is not always carried out at distances relevant to the ranges predicted for effects on marine mammals, so effects at greater distances remain un-validated in terms of actual received levels. The extent to which ambient noise and other anthropogenic sources of noise may mask signals from the offshore wind farm construction are not specifically addressed. The dose-response curves for porpoise include behavioural responses at noise levels down to 120 dB SEL_{ss} which may be indistinguishable from ambient noise at the ranges these levels are predicted.

14.2 Cumulative PTS

The cumulative sound exposure level (SEL_{cum}) is energy-based and is a measure of the accumulated sound energy an animal is exposed to over an exposure period. An animal is considered to be at risk of experiencing "cumulative PTS" if the SEL_{cum} exceeds the energy-based threshold. The calculation of SEL_{cum} is undertaken with frequency-weighted sound levels, using species group-specific weighing functions to reflect the hearing sensitivity of each functional hearing group. To assess the risk of cumulative PTS, it is necessary to make assumptions on how animals may respond to noise exposure, since any displacement of the animal relative to the noise source will affect the sound levels received. For this assessment, it was assumed that animals would flee from the pile foundation at the onset of piling. A fleeing animal model was therefore used to determine the cumulative PTS impact ranges, to determine the minimum distance to the pile site at which an animal can start to flee, without the risk of experiencing cumulative PTS.

There is much more uncertainty associated with the prediction of the cumulative PTS impact ranges than with those for the instantaneous PTS. One reason is that the sound levels an animal receives, and which are cumulated over a whole piling sequence are difficult to predict over such long periods of time, as a result of uncertainties about the animal's (responsive) movement in terms of its changing distance to the sound source and the related speed, and its position in the water column.

Another reason is that the prediction of the onset of PTS (which is assumed to be at the SEL_{cum} threshold values provided by Southall *et al.,* 2019) is determined with the assumptions that:

a) the amount of sound energy an animal is exposed to within 24 hours will have the same effect on its auditory system, regardless of whether it is received all at once (i.e., with a single bout of sound) or in several smaller doses spread over a longer period (called the equal-energy hypothesis); and,

b) the sound keeps its impulsive character, regardless of the distance to the sound source.

In practice:

a) there is a recovery of a threshold shift caused by the sound energy if the dose is applied in several smaller doses (e.g., between pulses during pile driving or in piling breaks) leading to an onset of PTS at a higher energy level than assumed with the given SEL_{cum} threshold; and,

b) pulsed sound loses its impulsive characteristics while propagating away from the sound source, resulting in a slower shift of an animal's hearing threshold than would be predicted for an impulsive sound.

Both assumptions therefore lead to a conservative determination of the impact ranges and are discussed in further detail in the sections below.

Modelling the SEL_{cum} impact ranges of PTS with a 'fleeing animal' model, as is typical in noise impact assessments, are subject to both above-mentioned uncertainties and the result is a highly precautionary prediction of impact ranges. As a result of these and the uncertainties on animal movement, model parameters, such as swim speed, are generally highly conservative and, when considered across multiple parameters, this precaution is compounded therefore the resulting predictions are very precautionary and very unlikely to be realised.

14.2.1 Equal energy hypothesis

The equal-energy hypothesis assumes that exposures of equal energy are assumed to produce equal amounts of noise-induced threshold shift, regardless of how the energy is distributed over time. However, a continuous and an intermittent noise exposure of the same SEL will produce different levels of TTS (Ward, 1997). Ward (1997) highlights that the same is true for impulsive noise, giving the example of simulated gunfires of the same SEL_{cum} exposed to human, where 30 impulses with an SPL_{peak} of 150 dB re 1 m Pa result in a TTS of 20 dB, while 300 impulses of a respectively lower SPL_{peak} did not result in any TTS.

Finneran (2015) showed that several marine mammal studies have demonstrated that the temporal pattern of the exposure does in fact affect the resulting threshold shift (e.g., Kastak *et al.,* 2005, Mooney *et al.,* 2009, Finneran *et al.,* 2010, Kastelein *et al.,* 2013a). Intermittent noise allows for some recovery of the threshold shift in between exposures, and therefore recovery can occur in the gaps between individual pile strikes and in the breaks in piling activity, resulting in a lower overall threshold shift, compared to continuous exposure at the same SEL. Kastelein *et al.,* (2013a) showed that, for seals, the threshold shifts observed did not follow the assumptions made in the guidance regarding the equal-energy hypothesis; instead, the threshold shifts observed were more similar to the hypothesis presented in Henderson *et al.,* (1991) that hearing loss induced due to noise does not solely depend upon the total amount of energy, but on the interaction of several factors such as the level and duration of the exposure, the rate of repetition, and the susceptibility of the animal. Therefore, the equal-energy hypothesis assumption behind the SEL_{cum} threshold is not valid, and as such, models will overestimate the level of threshold shift experienced from intermittent noise exposures.

One more detailed example to give is the study of Kastelein *et al.,* (2014), where a harbour porpoise was exposed to a series of 1-2 kHz sonar down-sweep pulses of 1 second duration of various combinations, with regard to received sound pressure level, exposure duration and duty cycle (% of time with sound during a broadcast) to quantify the related threshold shift. The porpoise experienced a 6 to 8 dB lower TTS when exposed to sound with a duty cycle of 25% compared to a continuous sound (**Figure 14.1**). A 1 sec silent period in-between pulses resulted in a 3 to 5 dB lower TTS compared to a continuous sound (**Figure 14.1**).

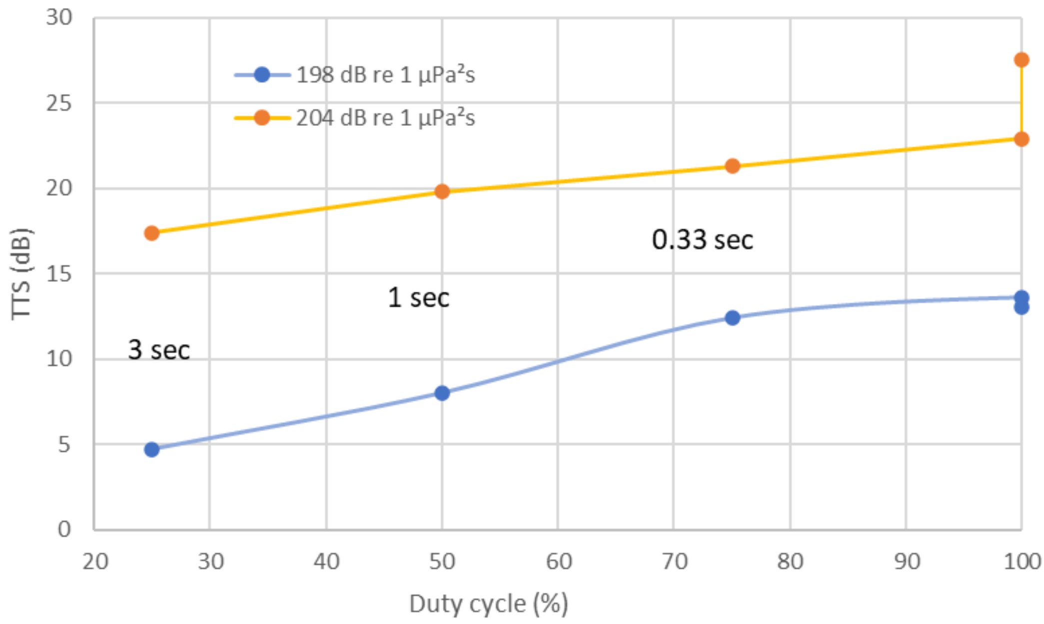


Figure 14.1: Temporary threshold shift (TTS) elicited in a harbour porpoise by a series of 1-2 kHz sonar down-sweeps of 1 second duration with varying duty cycle and a constant SEL_{cum} of 198 and 204 dB re1 µPa²s, respectively. Also labelled is the corresponding 'silent period' in-between pulses. Data from Kastelein *et al.,* (2014).

Kastelein *et al.,* (2015) showed that the 40 dB hearing threshold shift (the PTS-onset threshold) for harbour porpoise, is expected to be reached at different SEL_{cum} levels depending on the duty cycle: for a 100% duty cycle, the 40 dB hearing threshold shift is predicted to be reached at a SEL_{cum} of 196 dB re 1 µPa^{2}s, but for a 10% duty cycle, the 40 dB hearing threshold shift is predicted to be reached at a SEL_{cum} of 206 dB re 1 µPa^{2}s (thus resulting in a 10 dB re 1 µPa^{2}s difference in the threshold).

Pile strikes are relatively short signals; the signal duration of monopile pile strikes may range between 0.1 sec (De Jong and Ainslie, 2008) and approximately 0.3 sec (Dähne *et al.,* 2017) measured at a distance of 3.3 to 3.6 km. Duration will however increase with increasing distance from the pile site.

For the pile driving at WOW, the soft-start is 6 blows per minute, increasing to 40 blows per minute for the ramp-up period before reaching full hammer energy. Assuming a signal duration of around 0.5 sec for a pile strike, the soft-start will be a 5% duty cycle (0.5 sec pulse followed by 9.5 sec silence) and the ramp-up will be a 33.3% duty cycle. In the study of Kastelein *et al.,* (2014), a silent period of 3 sec corresponds to a duty cycle of 25%. The reduction in TTS at a duty cycle of 25% is 5.5-8.3 dB. Assuming similar effects to the hearing system of marine mammals in the offshore Project area, the PTS-onset threshold would be expected to be around 2.4 dB higher than that proposed by Southall *et al.,* (2019) and used in the current assessment, as reasoned in the following section.

Southall *et al.,* (2009) calculates the PTS-onset thresholds based on the assumption that a TTS of 40 dB will lead to PTS, and that an animal's hearing threshold will shift by 2.3 dB per dB SEL received from an impulsive sound. This means, if the same SEL elicits a ≥5.5 dB lower TTS at 25% duty cycle compared to 100% duty cycle, to elicit the same TTS as a sound of 100% duty cycle, a ≥2.4 dB (≥5.5 dB / 2.3) higher SEL is needed with a 25% duty cycle than with a 100% duty cycle. The threshold at which PTS-onset is likely is therefore at least 2.4 dB higher than the PTS-onset threshold proposed by Southall *et al.,* (2019). If a 2 or 3 dB increase in the PTS-threshold is assumed, then this can make a significant difference to the maximum predicted impact range for cumulative PTS (**Table 14.1**).

While more research needs to be conducted to understand the exact magnitude of this effect in relation to pile driving sound, this example proves a significant reduction in the risk of PTS even through short silent periods for TTS recovery as found in pile driving. It is noted that since methods to account for pauses between piling strikes and partial recovery of hearing threshold are not yet fully established, the quantitative impact assessment presented here does not account for this.

Table 14.1 Difference in predicted cumulative PTS impact ranges if recovery between pulses is accounted for and the PTS-onset threshold is increased by 2 or 3 dB.

Threshold		Max impact range (km)	Reduction in impact range (km)
Minke whale			
PTS	183 SEL_{cum}	44.475	-
PTS + 2 dB	185 SEL_{cum}	36.850	7.625
PTS + 3 dB	186 SEL_{cum}	33.200	11.275
Harbour porpoise			
PTS	155 SEL_{cum}	16.2	-
PTS + 2 dB	157 SEL_{cum}	11.725	4.475
PTS + 3 dB	158 SEL_{cum}	9.75	6.45

14.2.2 Impulsive characteristics

Southall *et al.,* (2019) acknowledges that as a result of propagation effects, the sound signal of certain sound sources (e.g., impact piling) loses its impulsive characteristics and could potentially be characterised as non-impulsive beyond a certain distance. The changes in noise characteristics with distance generally results in exposures becoming less physiologically damaging with increasing distance as sharp transient peaks become less prominent (Southall *et al.,* 2007). The Southall *et al.,* (2019) updated criteria proposed that, while keeping the same source categories, the exposure criteria for impulsive and non-impulsive sound should be applied based on the signal features likely to be perceived by the animal rather than those emitted by the source. Methods to estimate the distance at which the transition from impulsive to non-impulsive noise are currently being developed (Southall *et al.,* 2019).

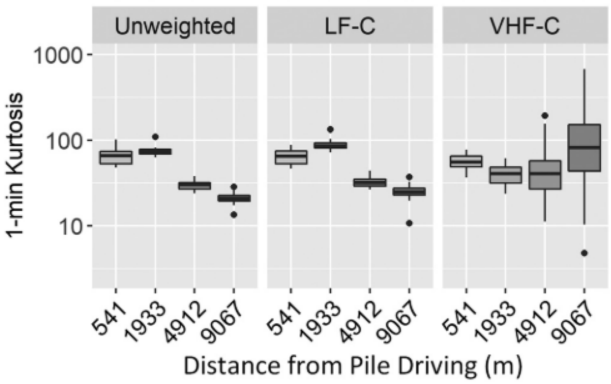
Using the criteria of signal duration, rise time, crest factor and peak pressure divided by signal duration, Hastie *et al.,* (2019) estimated the transition from impulsive to non-impulsive characteristics of impact piling noise during the installation of offshore wind turbine foundations at the Wash and in the Moray Firth. Hastie *et al.,* (2019) showed that the noise signal experienced a high degree of change in its impulsive characteristics with increasing distance. Southall *et al.,* (2019) state that mammalian hearing is most readily damaged by transient sounds with rapid rise-time, high peak pressures, and sustained duration relative to rise-time. Therefore, of the four criteria used by Hastie *et al.,* (2019), the rise-time and peak pressure may be the most appropriate indicators to determine the impulsive/non-impulsive transition. Based on this data it is expected that the probability of a signal being defined as "impulsive" (using the criteria of rise time being less than 25 milliseconds) reduces to only 20% between ~2 and 5 km from the source. Predicted PTS impact ranges based on the impulsive noise thresholds may therefore be overestimates in cases where the impact ranges lie beyond this. Any animal present beyond that distance when piling starts will only be exposed to non-impulsive noise, and therefore impact ranges should be based on the non-impulsive thresholds.

It is acknowledged that the Hastie *et al.,* (2019) study is an initial investigation into this topic, and that further data are required in order to set limits to the range at which impulsive criteria for PTS are applied.

Since the Hastie *et al.,* (2019) study, Martin *et al.,* (2020) investigated the sound emission of different sound sources to test techniques for distinguishing between the sound being impulsive or non-impulsive. For impulsive sound sources, they included impact pile driving of four 4-legged jacket foundation installed at around 20 m water depth (at the Block Island Wind Farm in the USA). For the impact piling sound they recorded sound at four distances between ~500 m and 9 km, recording the sound of 24 piling events. To investigate the impulsiveness of the sound, they used three different parameters and suggested the use of kurtosis[15] to further investigate the impulsiveness of sound, with studies on chinchilla hearing showing a positive correlation between the magnitude of PTS and the kurtosis value, with an increase in PTS for a kurtosis value from 3 up to 40 (Hamernik *et al.,* 2007). Therefore, Martin *et al.,* (2020) argued that:

- Kurtosis of 0-3 = continuous sinusoidal signal (non-impulsive);
- Kurtosis of 3-40 = transition from non-impulsive to impulsive sound; and
- Kurtosis of 40 = fully impulsive.

For the evaluation of their data, Martin *et al.,* (2020) used unweighted as well as LF-Cetacean (C) and VHF-C weighted sound, based on the species-specific weighting curves in Southall *et al.,* (2019) to investigate the impulsiveness of sound. Their results for pile driving are shown in **Figure 14.2**. For the unweighted and LF-C weighted sound, the kurtosis value was >40 within 2 km from the piling site. Beyond 2 km, the kurtosis value decreased with increasing distance. For the VHF-C weighted sound, kurtosis factor is more inconclusive with the median value >40 for the 500 m and 9 km measuring stations, and at 40 for the stations in-between. However, the variability of the kurtosis value for the VHF-C weighted sound increased with distance.



	Median value (1-min kurtosis)		
Distance (km)	Unweighted	LF-C	VHF-C
0.541	65	65	60
1.933	70	85	40
4.912	30	30	40
9.067	20	25	80

Figure 14.2: The range of kurtosis weighted by LF-C and VHF-C Southall *et al.,* (2019) auditory frequency weighting functions for 30 min of impact pile driving data measured in 25 m of water at the Block Island Wind Farm. Boxplots show the median value (horizontal lines), interquartile range (boxes) and outlier values (dots). Boxplots reproduced from Martin *et al.,* (2017); adjacent table shows approximate median values extracted from the boxplot.

From these data, Martin *et al.,* (2020) conclude that the change to non-impulsiveness *"is not relevant for assessing hearing injury because sounds retain impulsive character when SPLs are above EQT [effective quiet threshold[16]]"* (i.e., the sounds they recorded retain their impulsive character while being at sound levels that can contribute to auditory injury). However, we contest this conclusion and note that **Figure 14.2** clearly shows (for unweighted and LF-C weighted sound) that piling sound loses

[15] Kurtosis is a measure of the asymmetry of a probability distribution of a real-valued variable.

[16] From Martin *et al.,* (2020): The proposed effective quiet threshold (EQT) is the 1-min auditory frequency weighted SPL that accumulates to this 1-min SEL, which numerically is 18 dB below the 1-min SEL [because $10 \cdot \log_{10}(1 \text{ min}/1 \text{ s})$ dB¾17.7 dB]. Thus, the proposed level for effective quiet is equivalently a 1-min SPL that is 50 dB below the numeric value of the auditory frequency-weighted Southall *et al.,* (2019) daily SEL TTS threshold for non-impulsive sources.

its impulsiveness with increasing distance from the piling site - the kurtosis value decreases with increasing distance and therefore the sound loses its harmful impulsive characteristics.

There are some points that need to be considered before adopting kurtosis as an impulsiveness measure, with the recommended threshold value of 40. Firstly, this value was experimentally obtained for chinchillas that were exposed to noise for a 5-day period under controlled conditions. Caution may need to be taken to directly adopt this threshold-value (and the related dose-response of increasing PTS with increasing kurtosis between 3 and 40) to marine mammals in the wild, especially given that the PTS guidance considers time periods of up to 24 hours. Secondly, kurtosis is recommended to be computed over at least 30 seconds, which means that it is not a specific measure that can be used for single blows of a piling sequence. Instead, kurtosis has been recommended to evaluate steady-state noise in order to include the risk from embedded impulsive noise (Goley *et al.,* 2011). Metrics used by Hastie *et al.,* (2019) computed for each pile strike (e.g., rise-time) may be more suitable to be included in piling impact assessments, as, for each single pile strike, the sound exposure levels received by an animal are considered. It is currently unknown which metric is the most useful and how they correlate with the magnitude of auditory injury in (marine) mammals.

Southall (2021) points out that *"at present there are no properly designed, comparative studies evaluating TTS for any marine mammal species with various noise types, using a range of impulsive metrics to determine either the best metric or to define an explicit threshold with which to delineate impulsiveness".* He proposes that the presence of high-frequency noise energy could be used as a proxy for impulsiveness, as all currently used metrics have in common that a high frequency spectral content result in high values for those metrics. His suggestion is an interim approach: *"the range at which noise from an impulsive source lacks discernable energy (relative to ambient noise at the same location) at frequencies ≥ 10 kHz could be used to distinguish when the relevant hearing effect criteria transitions from impulsive to nonimpulsive".* Southall (2021), however, notes that *"it should be recognized that the use of impulsive exposure criteria for receivers at greater ranges (tens of kilometers) is almost certainly an overly precautionary interpretation of existing criteria".*

Considering that an increasing proportion of the sound emitted during a piling sequence will become less impulsive (and thereby less harmful) while propagating away from the sound source, and this effect starts at ranges below 5 km in all above mentioned examples, the cumulative PTS-onset threshold for animals starting to flee at 5 km should be higher than the Southall (2021) threshold adopted for this assessment (i.e., the risk of experiencing PTS becomes lower), and any impact range estimated beyond this distance should be considered as an unrealistic over-estimate, especially when they result in very large distances.

For the purpose of presenting a precautionary assessment, the quantitative impact assessment here was based on fully impulsive thresholds, but the potential for overestimation should be noted.

14.2.3 Animal depth

Empirical data on SEL_{ss} levels recorded during piling construction at the Lincs offshore wind farm have been compared to estimates obtained using the Aquarius pile driving model[17] (Whyte *et al.,* 2020). This has demonstrated that measured recordings of SEL_{ss} levels made at 1 m depth were all lower than the model predicted single-strike sound exposure levels for the shallowest depth bin (2.5 m). In contrast, measurements made at 9 m depth were much closer to the model predicted single-strike sound exposure levels. This highlights the limitations of modelling exposure using depth averaged

[17] From more information on the Aquarius model see: de Jong, C., Binnerts, B., Prior, M., Colin, M., Ainslie, M., Mulder, I., and Hartstra, I. (2019). "Wozep – WP2: update of the Aquarius models for marine pile driving sound predictions," TNO Rep. (2018), number R11671, The Hague, Netherlands, p. 94. Retrieved from https://www.noordzeeloket.nl/publish/pages/160801/update_aquarius_models_pile_driving_sound_predeictions_tno_2019.pdf

sound levels, as the acoustic model can overpredict exposure at the surface. This is important to note since animals may conduct shorter and shallower dives when fleeing (e.g. van Beest *et al.,* 2018).

14.2.4 Conclusion

Given the above, SMRU Consulting considers that the calculated SEL_{cum} PTS-onset impact ranges are highly precautionary and that the true extent of effects (impact ranges and numbers of animals experiencing PTS) will likely be considerably less than that assessed here.

14.3 Proportion experiencing PTS

It is also important to note that only 18-19% of animals are predicted to experience PTS at the PTS-onset threshold level. This was the approach adopted by Donovan *et al.,* (2017) to develop their dose response curve implemented into the SAFESIMM (Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna) model, based on the data presented in Finneran *et al.,* (2005). Therefore, where PTS-onset ranges are provided, it is not expected that all individuals within that range will experience PTS. The number of animals predicted to be within PTS-onset ranges are precautionary, as this assessment assumes that all animals within the PTS-onset range are impacted.

14.4 Density

There are uncertainties relating to the ability to predict the responses of animals to underwater noise and the number of animals potentially exposed to levels of noise that may cause an impact is uncertain. Given the high spatial and temporal variation in marine mammal abundance and distribution in any particular area of the sea, it is difficult to predict how many animals may be present within the range of noise impacts. All methods for determining at sea abundance and distribution suffer from a range of biases and uncertainties. This is described in further detail in SS9: Marine mammal and megafauna baseline report.

14.5 Predicting response

In addition, there are limited empirical data available to inform predictions of the extent to which animals may experience auditory damage or display responses to noise. The current methods for prediction of behavioural responses are based on received sound levels, but it is likely that factors other than noise levels alone will also influence the probability of response and the strength of response (e.g., previous experience, behavioural and physiological context, proximity to activities, characteristics of the sound other than level, such as duty cycle and pulse characteristics). However, at present, it is impossible to adequately take these factors into account in a predictive sense. This assessment makes use of the monitoring work that has been carried out during the construction of the Beatrice Offshore Wind Farm and therefore uses the most recent and site-specific information on disturbance to harbour porpoise as a result of pile driving noise.

There is also a lack of information on how observed effects (e.g., short-term displacement around impact piling activities) manifest themselves in terms of effects on individual fitness, and ultimately population dynamics (see the section above on marine mammal sensitivity to disturbance and the recent expert elicitation conducted for harbour porpoise and both seal species) in order to attempt to quantify the amount of disturbance required before vital rates are impacted.

14.6 Duration of effect

The duration of disturbance is another uncertainty. Studies at Horns Rev 2 demonstrated that porpoises returned to the area between 1 and 3 days (Brandt *et al.,* 2011) and monitoring at the Dan Tysk Wind Farm as part of the Disturbance Effects on the Harbour Porpoise Population in the North Sea (DEPONS) project found return times of around 12 hours (van Beest *et al.,* 2015). Two studies at

Alpha Ventus demonstrated, using aerial surveys, that the return of porpoises was about 18 hours after piling (Dähne *et al.,* 2013). A more recent study of porpoise response at the Gemini wind farm in the Netherlands, also part of the DEPONS project, found that local population densities recovered between two and six hours after piling (Nabe-Nielsen *et al.,* 2018). An analysis of data collected at the first seven offshore wind farms in Germany has shown that harbour porpoise detections were reduced between one and two days after piling (Brandt *et al.,* 2018). Analysis of data from monitoring of marine mammal activity during piling of jacket pile foundations at Beatrice Offshore Wind Farm (Graham *et al.,* 2017a, Graham *et al.,* 2019) provides evidence that harbour porpoise were displaced during pile driving but return after cessation of piling, with a reduced extent of disturbance over the duration of the construction period. This suggests that the assumptions adopted in the current assessment are precautionary as animals are predicted to remain disturbed at the same level for the entire duration of the pile driving stage of construction.

14.7 PTS-onset

There are no empirical data on the threshold for auditory injury in the form of PTS-onset for marine mammals, as to test this would be inhumane. Therefore, PTS-onset thresholds are estimated based on extrapolating from TTS-onset thresholds. For pulsed noise, such as piling, NOAA have set the onset of TTS at the lowest level that exceeds natural recorded variation in hearing sensitivity (6 dB), and assumes that PTS occurs from exposures resulting in 40 dB or more of TTS measured approximately four minutes after exposure (NMFS, 2018).

14.8 Population Modelling

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 a minke whale will not forage for 24 hours after being disturbed[18],
- 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.

14.8.1 Duration of disturbance

The iPCoD model for minke whale disturbance was last updated following the expert elicitation in 2013 (Harwood *et al.,* 2014a). 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

[18] In the updated expert elicitation in 2018, the duration of disturbance for harbour porpoise, harbour seals and grey seals was assumed to be 6 hours (Booth *et al.,* 2019). Unfortunately, minke whales were not included in the updated expert elicitation so the duration of disturbance remains 12 hours, as used in the original expert elicitation in 2013.

most recent expert elicitation in 2018 highlighted that this was an unrealistic assumption for harbour porpoises (generally considered to be more responsive than minke whales), and was amended to assume that disturbance resulted in 6 hours of non-foraging time (Booth *et al.,* 2019). Unfortunately, minke whales were not included in the updated expert elicitation for disturbance, and thus the iPCoD model still assumes 24 hours of non-foraging time for minke whales. 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 minke whales in the iPCoD model is significantly beyond that which is considered to be an extreme response, and is therefore considered to be unrealistic and will over-estimate the true disturbance levels expected from the Offshore Development. For this reason, SMRU Consulting does not recommend using the current version of iPCoD for minke whales, and as such, no population modelling is presented in this report for minke whales.

14.8.2 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.,* 2014a). The iPCoD scenario run assumes no density dependence, since there is insufficient data to parameterise this relationship. Essentially, what this means is that there is no ability for the modelled impacted population to increase in size back up 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.

14.8.3 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 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.,* 2014a). Demographic stochasticity is defined as *"variation among individuals in their realised vital rates as a result of random processes"* (Harwood *et al.,* 2014a).

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.,* 2014a).

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 14.3**, 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.

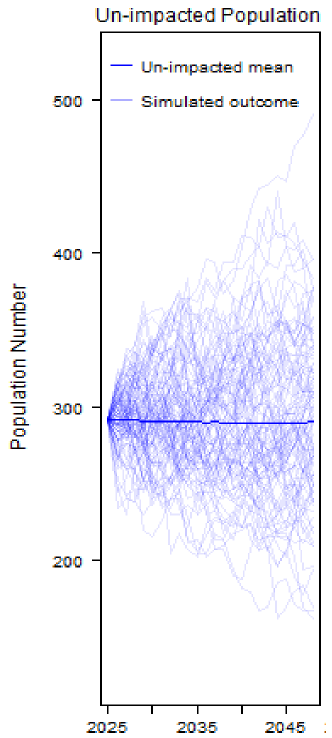


Figure 14.3 Simulated un-impacted (baseline) population size over the 25 years modelled

14.8.4 Summary

All of the precautions built into the iPCoD model mean that the results are considered to be highly precautionary. 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.

In addition to this, it is noted that iPCoD is not available for white-beaked, common or Risso's dolphins.