Dogger Bank C	Dogger Bank Offshore Wind Farm
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Dogger Bank Offshore Wind Farm

Appendix 1 Marine Mammal Technical Report

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1 Introduction

Dogger Bank Teesside A offshore wind farm was consented in 2015 under the Dogger Bank Teesside Offshore Wind Farm Order 2015 (the Development Consent Order (DCO)). In respect of the Dogger Bank Teesside A project, the DCO prescribes a number of parameters including the maximum hammer energy.

Since the DCO was granted there have been a number of advancements in technology that would make the development of the wind farm more efficient and cost effective. As a result, the Project Team is seeking to make a non-material change (NMC) to the DCO, to increase the maximum hammer energy from 1,900 kJ to 3,000 kJ for pin-piles required to install the Offshore Substation Platform (OSP).

This technical report describes how the proposed amendment could affect the marine mammal assessment presented in the Environmental Statement (ES) (Forewind, 2014a) and the Habitats Regulations Assessment (HRA) undertaken by Department of Energy and Climate Change (DECC, 2015 (now Department for Energy Security and Net Zero (DESNZ)) for the consented Teesside A project, now called Dogger Bank C (herein DBC).

2 Proposed Amendment

The proposed amendment requires an increase to the consented parameter for the OSP pin-pile maximum hammer energy, whilst leaving all other DCO parameters unchanged (**Table 2.1**). There are no proposed changes to the maximum hammer energy in relation to monopiles.

An increase in the maximum hammer energy for OSP pin-piles has the potential to affect the marine mammal assessment in the ES and HRA. A review and reassessment has been undertaken using the updated parameters shown in **Table 2.1.**

Table 2.1 Proposed consent amendments relevant to marine mammals (consented parameters shown in the grey column)

Parameter	Consented Envelope	Proposed Amendment
Maximum OSP hammer energy – pin pile	1,900 kJ	3,000 kJ
Maximum hammer energy – monopile	4,000 kJ	No change
Monopile diameter	Up to 10 m	No change
Pin-pile diameter	2.75 m	No change

3 Purpose of Assessment

The purpose of this assessment is to determine the potential impacts on marine mammals associated with the proposed increase in maximum hammer energy for the OSP pin-piles. This report provides a comparison of the original assessment for the ES and the HRA with the updated assessment for the increased maximum hammer energy for the OSP pin-piles. The original assessment referred to throughout this report is the assessment conducted for the ES, HRA and everything that led to consent, including examination.

Underwater noise propagation modelling for the original assessment was carried out by the National Physical Laboratory (NPL) (Forewind, 2014b) to assess the effects of noise from the construction of the DBC Offshore Wind Farm (OWF). Since the NPL modelling was completed for the ES, NPL no longer conduct noise modelling for individual projects. In addition, new noise thresholds and criteria have been developed by the United States (US) National Marine Fisheries Service (NMFS) and published by Southall *et al*. (2019) for both permanent threshold shift (PTS) where a permanent change in hearing sensitivity or unrecoverable hearing damage may occur, as well as temporary threshold shift (TTS) where a temporary reduction in hearing sensitivity may occur in marine mammals.

Therefore, for the proposed increase in OSP pin-pile maximum hammer energy, underwater noise modelling has been undertaken by Subacoustech for the proposed increase in maximum hammer energy of 3,000 kJ, using the latest Southall *et al*. (2019) thresholds and criteria for PTS and TTS. The results of this modelling have been compared directly to the previous NPL modelling in the ES for maximum OSP pin-pile hammer energy of 1,900 kJ. The purpose of this is to determine whether there is any significant difference in the resultant impact assessments for the consented 1,900 kJ and the proposed 3,000 kJ hammer energy for OSP pin-piles.

4 Methodology for Assessment

The ES identified the following species as requiring assessment:

- Harbour porpoise *Phocoena phocoena*
- White-beaked dolphin *Lagenorhynchus albirostris*
- Minke whale *Balaenoptera acutorostrata*
- Grey seal *Halichoerus grypus*
- Harbour seal *Phoca vitulina*

4.1 Underwater Noise modelling

The updated noise modelling for marine mammals was undertaken by Subacoustech Environmental Ltd (referred to as Subascoustech throughout), using the INSPIRE model (v5.2), as summarised in the following sections (Subacoustech, 2023).

The underwater noise modelling undertaken by NPL for the ES (Forewind, 2014b) is also summarised in the following sections.

4.1.1 *Modelling locations and environmental conditions*

The updated Subacoustech (2023) modelling is based on the location in the center of the DBC site (lat: 55.0328; long: 2.7176; water depth of 23.1m).

The underwater noise modelling undertaken by NPL for the ES (Forewind, 2014b) was undertaken for 21 locations at the then Teesside A site.

The locations and environmental conditions used in the modelling undertaken by both Subacoustech (2023) and NPL (Forewind, 2014b) are comparable and representative of the site.

4.1.2 *Pile diameter*

In the ES, the worst case scenario for the pile diameter was 2.75 m, while the pile diameter in the updated Subacoustech (2023) modelling was 2.438 m. This is due to refinements in the final project design. However, this difference in pile diameter will not affect the results of the non-material change due to the current and previous underwater noise modelling basing the findings on maximum hammer energy. Pile diameter has not been included as a parameter within the modelling.

4.1.3 *Maximum hammer energy*

The maximum hammer energies for OSP pin-piles in the original modelling for the ES (Forewind, 2014b), and updated modelling (Subacoustech, 2023), are presented in **Table 4.1**.

Table 4.1 Maximum hammer energies assessed in the original modelling and updated modelling for OSP pin-piles

Assessment	Maximum hammer energy
Original modelling for ES	1,900 kJ
Updated modelling	3,000 kJ

It is important to note that the NPL underwater noise modeling for the ES (Forewind, 2014b) was based on the worst-case of the maximum hammer energy, irrespective of pile diameter.

4.1.4 *Soft-start, strike rate and piling durations*

The original underwater noise modelling undertaken in the ES for the OSP pin-piles was based on soft-start hammer energy of 190 kJ, soft-start duration of 0.5 hours and piling duration for each pin-pile of 3 hours (excluding soft-start) (Forewind, 2014a). No information on the ramp-up and strike rate for the OSP pin-piles was provided in the NPL modelling or the ES (Forewind, 2014a, b).

The soft-start, strike rate and piling duration used in the updated noise modelling (Subacoustech, 2023) for the increased OSP pin-pile maximum hammer energy are presented in **Table 4.2**.

Table 4.2 Summary of the soft-start, strike rate and piling duration used in the updated noise modelling for increased OSP pin-pile maximum hammer energy (Subacoustech, 2023)

Piling parameter	Soft-start	Ramp-up		Maximum hammer energy
Energy (kJ)	320	850	1,500	3,000
Number of strikes	60	115	118	7809
Duration (minutes)	10	5	5	340
Strike rate (blows per minute)	6	23	23.6	22.97

The total duration to install single OSP pin-pile based on worst-case scenario in the updated noise modeling is 6 hours, with 4 pin-piles in 24 hours (Subacoustech, 2023).

4.1.5 *Cumulative SEL and swim speeds*

Cumulative sound exposure levels (SEL_{cum}) account for the total exposure of a receptor to the noise of the complete piling period, the soft start, strike rate and total duration to install either a single or multiple piles. The worst-case of four OSP pin-piles installed sequentially in 24 hours were used in the Subacoustech (2023) modelling. SEL_{cum} was not included in the ES assessments (Forewind, 2014a).

The cumulative SEL modelling uses a fleeing animal model. This assumes that the animal exposed to the noise levels will swim away from the source as it occurs. For this assessment, a constant speed of 3.25 m/s has been assumed for minke whale (Blix and Folkow, 1995). All other receptors are assumed to swim at a constant speed of 1.5 m/s (Otani *et al*. 2000).

These are considered worst-case (i.e. relatively slow, leading to greater calculated exposures) as marine mammals are expected to swim much faster under stress conditions (for example, Kastelein *et al*. (2018) recorded harbour porpoise swimming speeds of 1.97m/s during playbacks of pile driving sounds).

4.1.6 *Thresholds and criteria*

4.1.6.1 Original assessment in ES

The following criteria were used in the NPL modelling (Forewind, 2014b) for the original assessment:

- Lucke *et al*. (2009) for harbour porpoise (e.g. high-frequency cetaceans); and
- Southall *et al*. (2007) for mid-frequency cetaceans (e.g. dolphin species); low-frequency cetaceans (e.g. minke whale) and pinnipeds in water (e.g. grey and harbour seal).

The criteria used in the original assessment are summarised in **Table 4.3** and **Table 4.4**. It should be noted that the Southall *et al*. (2007) and Lucke *et al*. (2007) criteria presented in the NPL modelling, and here as a comparison, are only for single strike SEL (SEL_{ss}).

Table 4.3 Criteria and thresholds for assessing impacts on harbour porpoise in the original assessment and modelled by NPL, based on Lucke et al. (2009)

Potential Impact	Criteria	Harbour porpoise
PTS	SPL_{peak} (dB re 1 µPa)	200
	Unweighted SEL_{ss} (dB re 1 µPa^{2}s	179
TTS	SPL_{peak} (dB re 1 µPa)	194
	Unweighted SEL_{ss} (dB re 1 µPa^{2}s)	164
Possible avoidance	SPL_{peak} (dB re 1 µPa	168
	Unweighted SEL_{ss} (dB re 1 µPa^{2}s)	145

Table 4.4 Criteria and thresholds for assessing impacts on mid-frequency (MF) cetaceans (e.g. dolphin species), low-frequency (LF) cetaceans (e.g. minke whale) and pinnipeds in water (e.g. grey and harbour seal) in the original assessment and modelled by NPL, based on Southall et al. (2007)

Potential Impact	Criteria	Dolphin species	Minke whale	Seals
PTS	SPL_{peak} (dB re 1 µPa)	230	230	218
	weighted SEL_{ss} (dB re 1 µPa^{2}s)	198	198	186
TTS	SPL_{peak} (dB re 1 µPa)	224	224	212
	weighted SEL_{ss} (dB re 1 µPa^{2}s)	183	183	171
Likely avoidance from area	Unweighted SEL_{ss} (dB re 1 µPa^{2}s)	170	152	N/A
Possible avoidance from area	Unweighted SEL_{ss} (dB re 1 µPa^{2}s)	160	142	N/A

4.1.6.2 Updated modelling

The current criteria (Southall *et al*., 2019) for single strike unweighted peak Sound Pressure Level criteria (SPL_{peak}), single strike weighted Sound Exposure Level (SEL_{ss}) and cumulative (i.e. more than a single impulsive sound) weighted sound exposure criteria (SEL_{cum}) for PTS and TTS used in the updated modelling are provided in **Table 4.5**.

It should be noted that these cannot be compared like-for-like with criteria in the original assessment as cumulative SELs were not considered for marine mammals. Instead, comparisons between the cumulative SELs for the maximum energy of 3,000 kJ and likely worst-case of 2,000 kJ (which is considered suitably comparable to the original assessment of 1,900 kJ) have been made.

Table 4.5 PTS and TTS thresholds for marine mammals from Southall et al. (2019) criteria for impulsive noise

Marine Mammal hearing group	**PTS threshold**			**TTS threshold**		
	SPL_{peak} (unweighted) dB re 1 μPa	**SEL_{ss} (weighted) dB re 1 μPa²s**	**SEL_{cum} (weighted) dB re 1 μPa²s**	**SPL_{peak} (unweighted) dB re 1 μPa**	**SEL_{ss} (weighted) dB re 1 μPa²s**	**SEL_{cum} (weighted) dB re 1 μPa²s**
Low-frequency cetaceans (e.g. minke whale)	219	183	183	213	168	168
High-frequency cetaceans (e.g. dolphin species)	230	185	185	224	170	170
Very high-frequency cetaceans (e.g. harbour porpoise)	202	155	155	196	140	140
Pinnipeds in water (e.g. grey and harbour seal)	218	185	185	212	170	170

4.2 Density estimates and reference populations

Since the ES was completed, updated information on the density estimates and reference populations for marine mammals in the Dogger Bank area has become available. **Table 4.6** and

Table 4.7 provide the density estimates and reference populations, respectively, used in the original assessment and the updated assessment.

The most recent density estimates have been based on the SCANS-IV survey for cetaceans (Gilles *et al*., 2023) and the Carter *et al*. (2022) data for seals. These have been used for the updated assessment.

Since the original assessment, the following changes have been made:

1. Harbour porpoise density estimate has increased from 0.7161 to 0.8034 harbour porpoise per km^2, based on the SCANS-IV survey (Gilles *et al*., 2023). This increased density estimate has been used as a worst-case scenario, e.g. highest density estimate, in the updated assessment.
2. White-beaked dolphin density estimate has lowered from 0.01487 to 0.007 individuals per km^2, based on Waggit *et al*., 2019 data.
3. Minke whale density estimate has increased slightly from 0.00866 to 0.0153 individuals per km^2, based on the SCANS-IV survey (Gilles *et al*., 2023).
4. Grey seal density estimate has decreased from 0.2132 to 0.0001 individuals per km^2. The most recent Carter *et al*. (2022) data is the most appropriate density estimate to use in the updated assessment.
5. In the original assessment harbour seals were not included, however, the density estimate from Carter *et al*. (2022) has been used for the updated assessment, with a density of 0.00002 per km^2.

Since the original assessment, the reference population for:

1. Harbour porpoise in the North Sea Management Unit (MU) has increased. With the previous population reference of 227,298 (Inter-Agency Marine Mammal Working Group (IAMMWG), 2013) increasing to the updated reference population of 346,601 within the CGNS MU (IAMMWG, 2023).
2. A higher reference population for white-beaked dolphin has been published in IAMMWG (2023), with a population estimate of 43,951 within the Celtic and Greater North Sea (CGNS) MU (28,056 higher than the population used originally in the ES). The updated CGNS MU population will be used as a worst case scenario in the updated assessment.
3. More recent data has been published for minke whale, with a reference population of 20,118 within the CGNS MU (IAMMWG, 2023); this has been used in the updated assessment.
4. The most recent counts for South-East (SE) and North-East (NE) MU (Special Committee on Seals (SCOS), 2022) have been used for the grey seal reference population in the updated assessment. The haul out counts have also been corrected to take into account the number of seals not available to count during the surveys. For grey seals the correction factor 0.2515 was applied to give the total population number used in this assessment.

5. Harbour seals were not previously included in the ES assessments, however the most recent SE and NE MU reference population from SCOS (2022) have been used in the updated assessment. As for grey seals, harbour seals also had a correction factor applied to gain the population number, the correction factor applied was 0.72.

Table 4.6 Marine mammal density estimates used in the original assessment and updated assessments).

Species	**Original assessment**		**Updated assessment**	
	Density estimate used in ES	**ES data source**	**Updated density estimate (number of individuals per km2)**	**Updated data source**
Harbour porpoise	0.7161/km^2 (95% CI = 0.52284-0.97333/km^2)	Site specific surveys; ES (Forewind, 2014a)	0.8034/km^2 (CV = 0.241)	SCANS-IV survey block NS-H (Gilles *et al*., 2023)
White-beaked dolphin	0.01487/km^2 (95% CI = 0.00663-0.02813/km^2)	Site specific surveys; ES (Forewind, 2014a)	0.007/km^2	Waggitt *et al.*, 2019
Minke whale	0.00866/km^2 (95% CI = 0-0.02391/km^2).	Site specific surveys; ES (Forewind, 2014a)	0.0153/km^2 (CV = 0.552)	SCANS-IV survey block NS-H (Gilles *et al*., 2023)
Grey seal	0.02131/km^2 (95% CI = 0.01571-0.03257)	SMRU (2013); ES (Forewind, 2014a)	0.0001/km^2	Seal at-sea usage maps (Carter *et al*., 2022)
Harbour seal	N/A	N/A	0.00002/km^2	Seal at-sea usage maps (Carter *et al*., 2022)

Table 4.7 Marine mammal reference populations used in the original assessment and updated assessments (consented parameters shown in the grey rows)

Species	**Reference population**		
	Extent	**Size**	**Data source**
Harbour porpoise	North Sea MU	346,601 (CV = 0.09; 95% CI = 289,498-419,967) [used in updated assessment]	IAMMWG (2023)
		227,298 (95% CI = 176,360-292,948) [used in original assessment]	IAMMWG (2013) based on SCANS-II (Hammond *et al*., 2013
White-beaked dolphin	Celtic and Greater North Seas (CGNS) MU	43,951 (CV=0.22; 95% CI=28,439-67,924) [used in updated assessment]	IAMMWG (2023)
	All UK waters (British Isles; BI) MU	15,895 (95% CI=9,107-27,743) [used in original assessment]	IAMMWG (2013) based on SCANS-II (Hammond *et al*., 2013)
Minke whale	Celtic and Greater North Seas (CGNS) MU	20,118 (CV=0.18; 95% CI=14,061-28,786) [used in updated assessment]	IAMMWG (2023)
	(a) BI MU (b) Central and north east Atlantic	(a) 23,168 (95% CI=13,772-38,958) [used in original assessment] (b) 174,000 (125,000-245,000)	IAMMWG (2013) based on SCANS-II (Hammond *et al*., 2013) and CODA (Macleod *et al*., 2009) (b) 1996 – 2001 IWC
Grey seal	South-east England MU; North-east England MU	56,505 = 30,592 + 25,913 [used in updated assessment]	SCOS (2022)
	North Sea (South-east England,	28,989 = 24,950 + 4,039	UK North Sea (IAMMWG, 2013)

Species	Reference population		
	Extent	Size	Data source
	Northeast England and East coast MU + Waddenzee)	[used in original assessment]	and Mainland Europe (Waddenzee Secretariat)
Harbour seal	South-east England MU; North-east England MU	4,991= 4,868 + 123 [used in updated assessment]	SCOS (2022)
	South-east England MU	4,868 [used in updated assessment]	SCOS (2022)
		3,567 (minimum population size) [used in original assessment]	IAMMWG (2013)

5 Outcome of Assessments

5.1 Updated assessments and comparisons

Each assessment is based on the latest Southall *et al*. (2019) criteria (see **Section 4.1.6.2**) and considers:

- The increase in predicted impact range and area for maximum OSP hammer energy of 3,000 kJ compared to 2,000 kJ (see note below for use of 2,000 kJ);
- A comparison of the level of magnitude of the proposed hammer energy results compared to those reported in the ES; and
- The maximum number of individuals and percentage of the reference population that could potentially be impacted.

The assessment outcome and conclusion is based on the number of individuals and percentage of the reference population that may be impacted.

The updated underwater noise modelling (Subacoustech, 2023) was undertaken for an absolute maximum hammer energy of 3,000 kJ as well as a likely worst-case of 2,000 kJ, against the previous 1,900 kJ maximum hammer energy. Therefore, the results for the 2,000 kJ and 3,000 kJ hammer energies are used in the assessments and compared against each other in this section, as well as against the original ES assessments levels of magnitude.

It is important to note that this is not a ‘like for like’ comparison; as previously outlined, there have been changes to the modelling, threshold criteria, species density estimates and reference populations since the ES. It is more relevant, especially in determining whether there are any new or materially different significant effects in relation to marine mammals between the proposed maximum hammer energy and the currently consented maximum hammer energy, for the NMC to provide a comparison of the impact significance and overall outcomes of the original assessments in the ES (Forewind, 2013), on which the DCO was based, with the impact significance and overall outcomes of the updated assessments for the increase in hammer energy. This has been provided in the following sections.

It is also important to note that although an increase in maximum hammer energy is being applied for it will not be required for all pile locations, and if used would only be a very small proportion of the total piling time. For example, at the Beatrice Offshore Wind Farm, it was estimated in the ES that the maximum hammer energy would be 2,300 kJ (Beatrice Offshore Wind Farm Ltd, 2018). However, during construction, the maximum hammer energy actually used ranged between 435 kJ and 2,299 kJ, with an average across the site of 1,088 kJ (Beatrice Offshore Wind Farm Ltd, 2018).

5.1.1 *Harbour porpoise*

5.1.1.1 PTS

5.1.1.1.1 PTS from single strike and cumulative exposure

The modelling of instantaneous PTS in harbour porpoise for a single strike of the maximum hammer energy of 2,000 kJ, based on the unweighted SPL_{peak} Southall *et al*. (2019) criteria, predicted a maximum potential impact range of 390 m. The maximum number of harbour porpoise that could be at risk of PTS is 0.4 harbour porpoise. This represents 0.0001% of the NS MU reference population that could be impacted. Therefore, the magnitude of effect is assessed as negligible (less than 0.001% of the reference population anticipated to be exposed to permanent effect). See **Annex 2** for impact assessment methodology.

In the updated assessment, for the maximum 3,000 kJ hammer energy the maximum predicted impact range is 450 m (0.64 km^2) for the unweighted SPL_{peak} criteria for a single strike. The maximum number of harbour porpoise that could be at risk of PTS is 0.5 harbour porpoise (

Table *5.1*). This represents 0.0002% of the current North Sea MU reference population, therefore, without mitigation, the magnitude of effect would be negligible.

There is no significant difference between the number of harbour porpoise and percentage of the NS MU that could be at risk of PTS based on the maximum predicted SPL_{peak} ranges for single strike of the maximum hammer energy of 2,000 kJ or 3,000 kJ (

Table *5.1*). The magnitude of effect for the maximum predicted PTS ranges, based on the SPL_{peak} thresholds, for the 2,000 kJ and 3,000 kJ maximum hammer energies, are both negligible (

Table *5.1*). Therefore, there is no difference in the magnitude of effect in increasing the OSP maximum hammer energy to 3,000 kJ.

The original assessment in the ES (Forewind, 2014a) determined the potential magnitude of effect for harbour porpoise for a single strike of the maximum hammer energy of 1,900 kJ to also have a negligible residual effect, and therefore **there is no difference in the overall magnitude of effect between the originally assessed 1,900 kJ hammer energy, and the proposed increase to 3,000 kJ.**

As outlined in **Section 6.1**, effective mitigation will be put in place to reduce the risk of PTS from underwater noise during piling.

For harbour porpoise there is no difference in magnitude of effect between the maximum predicted PTS cumulative SEL ranges for the maximum hammer energy of 2,000 kJ and 3,000 kJ (

Table *5.1*).

In the updated assessment for the 2,000 kJ hammer energy, the maximum predicted impact range is 2,100 m for the weighted SEL_{cum} criteria. The maximum number of harbour porpoise that could be at risk of PTS is 8.8 (

Table *5.1*). This represents 0.003% of the current North Sea MU reference population, therefore, without mitigation, the magnitude of effect would be low, with less than 0.01% of the reference population anticipated to be exposed to effect.

In the updated assessment for the 3,000 kJ hammer energy, the maximum predicted impact range is than 2,500 m for the weighted SEL_{cum} criteria. The maximum number of harbour porpoise that could be at risk of PTS is 24.9 (

Table *5.1*). This represents 0.007% of the current North Sea MU reference population, therefore, without mitigation, the magnitude of effect would be low, with less than 0.01% of the reference population anticipated to be exposed to effect.

As outlined in **Section 6.1**, effective mitigation will be put in place to reduce the risk of PTS from underwater noise during piling.

Table 5.1 Maximum predicted impact ranges (areas) and maximum number of harbour porpoise (% of reference population) that could be at risk of PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}), based on Southall et al. (2019) impulsive criteria for harbour porpoise (very high frequency cetacean)

PTS threshold	Maximum predicted impact ranges (areas) and Maximum number of individuals (% reference population)		
	Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	**Maximum hammer energy of 3,000 kJ for pin-piles (proposed amendment)**	**Difference between 2,000 kJ and 3,000 kJ**
Single strike			
Unweighted SPL_{peak} Single strike 202 dB re 1 µPa (very high frequency cetacean)	390 m (0.47 km^2)	450 m (0.64 km^2)	+60 m +0.17 km^2
	0.4 harbour porpoise (0.0001% NS MU)	0.5 harbour porpoise (0.0002% NS MU)	+0.1 harbour porpoise (+0.0001% NS MU)
	Magnitude of effect = negligible	Magnitude of effect = negligible	No difference in magnitude of effect
Cumulative SEL			
Weighted SEL_{cum} Cumulative 155 dB re 1 µPa^2s (very high frequency cetacean)	2,100 m (11 km^2)	2,500 m (31 km^2)	+400 m (+20 km^2)
	8.8 harbour porpoise (0.003% NS MU)	24.9 harbour porpoise (0.007% NS MU)	+16.1 harbour porpoise (+0.004% NS MU)
	Magnitude of effect = low	Magnitude of effect = low	No difference in magnitude of effect

5.1.1.1.2 PTS Impact Significance

There is no difference in the impact significance for PTS in harbour porpoise (without mitigation) for the proposed increased maximum hammer energy to 3,000 kJ compared to 2,000 kJ (consented maximum hammer energy was 1,900 kJ) (**Table 5.2**).

The Marine Mammal Mitigation Protocol (MMMP), as outlined in **Section 6.1**, will detail the proposed mitigation measures to reduce the risk of PTS to marine mammals as a result of underwater noise during piling.

With effective mitigation in the MMMP, the residual impact is expected to be negligible for maximum hammer energy of 2,000 kJ (1,900 kJ consented) and increase in maximum hammer to 3,000 kJ (**Table 5.2**).

Table 5.2 Impact significance for PTS in harbour porpoise from maximum hammer energy of 2,000 kJ (1,900 kJ consented) and increase to maximum of 3,000 kJ

Impact significance for PTS in harbour porpoise	**Maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)**	**Maximum hammer energy of 3,000 kJ (proposed amendment)**	**Magnitude of effect reported in ES (1,900 kJ)**
PTS from single strike without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Minor adverse
PTS from single strike with mitigation (residual impact)	No impact / negligible	No impact / negligible	Negligible
PTS from cumulative exposure without mitigation	Moderate adverse (high sensitivity x permanent impact with low magnitude (<=0.01% ref. pop.)*)	Moderate adverse (high sensitivity x permanent impact with low magnitude (<=0.01% ref. pop.)*)	N/A
PTS from cumulative exposure with mitigation (residual impact)	Minor adverse	Minor adverse	N/A

*see **Annex 2** for definitions of sensitivity, magnitude and impact significance matrix

5.1.1.2 TTS

5.1.1.2.1 TTS from single strike and cumulative exposure

In the updated assessment of instantaneous TTS in harbour porpoise for a single strike of the maximum pin-pile hammer energy of 2,000 kJ, based on the unweighted Southall *et al*. (2019) criteria SPL_{peak} 196 dB re 1 µPa), predicted a potential impact range of 3.2-4.2 km. The maximum number of harbour porpoise that could be at risk of TTS / fleeing response in the ES assessment was 53 harbour porpoise, based on a density of 0.7161 harbour porpoise per km^2. The ES assessment determined that 0.02% of the 227,298 reference population could be impacted and that the magnitude of effect was medium, with less than 1% of the reference population anticipated to be temporarily exposed to effect. The impact significance, without mitigation, was assessed as moderate (medium sensitivity x temporary impact with medium magnitude).

The maximum difference between the predicted TTS range for the 1,900 kJ and 3,000 kJ maximum hammer energies, based on the Southall *et al*. (2019) unweighted SPL_{peak} criteria for single strike, is 130 m (1 km^2). The difference in the number of harbour porpoise that could be temporarily impacted by the 3,000 kJ compared to the 2,000 kJ hammer energy is 0.8 (0.0002% of the North Sea MU) (**Table 5.3**).

There is no adverse significant difference in the potential temporary impacts assessed in the ES for the risk of TTS to harbour porpoise from a single strike at a maximum hammer energy of 3,000 kJ compared to the potential risk from a single strike at a maximum hammer energy of 1,900 kJ, without any mitigation. The magnitude of effect is assessed as negligible for all hammer energies.

In the updated assessment, the potential for any temporary auditory injury (TTS) / fleeing response, the Southall *et al*. (2019) criteria for unweighted SPL_{peak} for single strike, weighted SEL for single strike and TTS from cumulative exposure (SEL_{cum}) have been modelled for the proposed increased pin-pile hammer energy (up to 3,000 kJ), as well as the 1,900 kJ hammer energy for pin-piles. Cumulative SEL assessments have been based on the worst-case soft-start and ramp-up scenario.

Table 5.3 Maximum predicted impact ranges (areas) and maximum number of harbour porpoise (% of reference population) that could be at risk of temporary auditory injury (TTS) / fleeing response from a single strike (SPL_{peak} and SEL_{ss}) and from cumulative exposure (SEL_{cum}), based on Southall et al. (2019) impulsive criteria for harbour porpoise (very high frequency cetacean)

TTS threshold	**Maximum predicted impact ranges (areas) and Maximum number of individuals (% reference population)***		
	Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	**Maximum hammer energy of 3,000 kJ for pin-piles (proposed amendment)**	**Difference between 2,000 kJ and 3,000 kJ**
Single strike			
Unweighted SPL_{peak} Single strike 196 dB re 1 µPa (very high frequency cetacean)	970 m ($2.9\ km^2$)	1,100 m ($3.9\ km^2$)	+130 m ($+1\ km^2$)
	2.3 harbour porpoise (0.0007% NS MU)	3.1 harbour porpoise (0.0009% NS MU)	+0.8 harbour porpoise (+0.0002 % NS MU)
	Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Cumulative SEL			
Weighted SEL_{cum} Cumulative 140 dB re 1 $µPa^2s$ (very high frequency cetacean)	21,000 m ($1,100\ km^2$)	25,000 m ($1,400\ km^2$)	+4,000 m ($+300\ km^2$)
	884 harbour porpoise (0.3% NS MU)	1125 harbour porpoise (0.3% NS MU)	+241 harbour porpoise (+0.0% NS MU)
	Magnitude of effect = medium	Magnitude of effect = medium	No difference in magnitude of effect

5.1.1.2.2 TTS Impact significance

There is no difference in the impact significance for TTS in harbour porpoise for the proposed increased maximum hammer energy to 3,000 kJ compared to the maximum hammer energy of 2,000 kJ (Table 5.4).

Table 5.4 Impact significance for TTS in harbour porpoise from maximum hammer energy of 1,900 kJ and 3,000 kJ*

Impact significance for TTS in harbour porpoise	Updated modelling for maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)	Updated modelling for maximum hammer energy of 3,000 kJ (proposed amendment)	Magnitude of effect reported in ES (1,900 kJ)
TTS from single strike without mitigation	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.))	Negligible
TTS from cumulative exposure without mitigation	Moderate adverse (medium sensitivity x temporary impact with medium magnitude (≤1% ref. pop.))	Moderate adverse (medium sensitivity x temporary impact with medium magnitude (≤1% ref. pop.))	N/A
TTS from cumulative exposure with mitigation (residual impact)	Minor adverse	Minor adverse	N/A

5.1.1.3 Disturbance

The latest Southall *et al*. (2019) criteria do not currently provide any thresholds for any behavioural response or disturbance. However, the ES used Lucke *et al*., 2009 for harbour porpoise behaviour assessments. Subacoustech have modelled potential behavioural impact ranges and areas using Lucke *et al*., 2009 as well enabling a comparison to be made between the previous and updated assessment.

In the updated assessment for the hammer energy 2,000 kJ, the potential for any avoidance response, based on the unweighted Lucke *et al*. (2009) criteria (pulse SEL 145 dB re 1 μPa^{2}s), predicted a potential impact area of 2,300 km^2. The impact significance, without mitigation, was assessed as moderate adverse (medium sensitivity x temporary impact with medium magnitude).

In the updated assessment for the hammer energy 3,000 kJ, the potential for any avoidance response, based on the unweighted Lucke *et al*. (2009) criteria (pulse SEL 145 dB re 1 μPa^{2}s), predicted a potential impact area of 2,600 km^2.

The maximum difference between the predicted avoidance impact area for the lower hammer energy of 2,000 kJ and the proposed hammer energy of 3,000 kJ, based on the Lucke *et al*. (2009) thresholds, is up to 300 km^2. The difference in the number of harbour porpoise that could be impacted is 241 (**Table 5.5**).

There is no adverse significant difference in the potential avoidance impacts assessed for the risk of avoidance to harbour porpoise from a single strike at a maximum hammer energy of 3,000 kJ compared to the potential risk from a single strike at a maximum hammer energy of 2,000 kJ, without any mitigation. The magnitude of effect is assessed as medium for all hammer energies. When assessing the possible avoidance due to piling, the sensitivity is assessed as low for harbour porpoise. A medium magnitude of effect and low sensitivity gives an overall minor adverse impact significance.

In the ES, using Lucke *et al*., (2009) the impact range of the behavioural response to 1,900 kJ hammer energy for harbour porpoise was between 20 to 28 km. With the updated assessments using Lucke *et al*., (2009) for 3,000 kJ the impact range was between 25 to 33 km.

The current advice from the Statutory Nature Conservation Bodies (SNCBs) is that a potential disturbance range (Effective Deterrence Range (EDR)) of 15 km (706.86 km^2) for pin piles (with and without noise abatement) is used to determine the area that harbour porpoise may be disturbed from in relevant Special Areas of Conservation (SAC) (JNCC et al., 2020). When carrying out an assessment for the potential for disturbance using an EDR 15 km range, there was the potential for 568 (0.15% of the NS MU population) harbour porpoise to be potentially impacted. Using this disturbance range results in a decrease of 1,280 number of individuals impacted compared to the results for the 2,000 kJ hammer energy using Lucke *et al*., (2009) thresholds

Table 5.5 Maximum predicted impact areas and maximum number of harbour porpoise (% of reference population) that could be at risk of avoidance from a single strike (SEL_{ss}), based on Lucke et al. (2009) impulsive criteria for harbour porpoise (very high frequency cetacean)

Avoidance threshold	**Maximum predicted impact areas** **Maximum number of individuals (% reference population)***		
	Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	**Maximum hammer energy of 3,000 kJ for pin-piles (proposed amendment)**	**Difference between 2,000 kJ and 3,000 kJ**
Unweighted pulse SEL 145 dB re 1 μPa²s (very high frequency cetacean)	30,000 m (2,300 km²)	33,000 (2,600 km²)	+3,000 m (+300 km²)
	1,848 harbour porpoise (0.5% NS MU)	2,089 harbour porpoise (0.6% NS MU)	+241 harbour porpoise (+0.1 % NS MU)
	Magnitude of effect = medium	Magnitude of effect = medium	No adverse difference in magnitude of effect

5.1.2 *White-beaked dolphin*

5.1.2.1 PTS

5.1.2.1.1 PTS from single strike and cumulative exposure

For white-beaked dolphin there is no difference between the predicted single strike PTS ranges for the 2,000 kJ and 3,000 kJ maximum hammer energies, based on the Southall *et al*. (2019) criteria for high-frequency cetaceans (dolphin species) (**Table 5.6**). Both hammer energies modelled had a potential impact range of less than 50 m, with 0.00007 white-beaked dolphin potentially impacted (<0.00001% of the CGNS MU). There is no difference in the impact significance for PTS in dolphin species for the proposed increased maximum hammer energy, both hammer energies had negligible magnitudes of effect.

The original assessment in the ES (Forewind, 2014a) determined the potential magnitude of effect for white-beaked dolphin for a single strike of the maximum hammer energy of 1,900 kJ to also be negligible.

For white-beaked dolphin there is no difference between the predicted cumulative PTS ranges for the 2,000 kJ and 3,000 kJ maximum hammer energies, based on the Southall *et al*. (2019) criteria for high-frequency cetaceans (dolphin species) (**Table 5.6**). There is no difference in the impact significance for PTS in dolphin species for the proposed increased maximum hammer energy to 3,000 kJ.

Table 5.6 Maximum predicted impact ranges (and areas) for PTS from a single strike (SPL_{peak} and SEL_{ss}) and from cumulative exposure (SEL_{cum}) based on Southall et al. (2019) impulsive criteria for high-frequency cetaceans (dolphin species)

Receptor	Threshold	Maximum predicted impact range and area		Difference
		Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	**Maximum hammer energy of 3,000 kJ for pin-piles (proposed amendment)**	**Difference between 2,000 kJ and 3,000 kJ**
Single strike				
White-beaked dolphin (high frequency cetacean)	Unweighted SPL_{peak} 230 dB re 1 µPa	<50 m (<0.01 km^2)	<50 m (<0.01 km^2)	No difference
		0.00007 white-beaked dolphin (<0.00001% CGNS MU)	0.00007 white-beaked dolphin (<0.00001% CGNS MU)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Cumulative SEL				
White-beaked dolphin (high frequency cetacean)	SEL_{cum} Weighted 185 dB re 1 µPa^{2}s	<100 m (<0.1 km^2)	<100 m (<0.1 km^2)	No difference
		0.0007 white-beaked dolphin (<0.00001% CGNS MU)	0.0007 white-beaked dolphin (<0.00001% CGNS MU)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect

5.1.2.1.2 PTS Impact significance

There is no difference in the impact significance for PTS in white-beaked dolphin (without mitigation) for the proposed increased maximum hammer energy to 3,000 kJ compared to 2,000 kJ (consented maximum hammer energy was 1,900 kJ) (**Table 5.7**).

The MMMP, as outlined in **Section 6.1**, will detail the proposed mitigation measures to reduce the risk of PTS to marine mammals as a result of underwater noise during piling.

With effective mitigation in the MMMP, the residual impact is expected to be negligible for the maximum hammer energy of 2,000 kJ (1,900 kJ consented) and the increase in maximum hammer to 3,000 kJ (**Table 5.7**).

Table 5.7 Impact significance for PTS in white-beaked dolphin from maximum hammer energy of 2,000 kJ (1,900 kJ consented) and increase to maximum of 3,000 kJ

Impact significance for PTS in white-beaked dolphin	**Maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)**	**Maximum hammer energy of 3,000 kJ (proposed amendment)**	**Magnitude of effect reported in ES (1,900 kJ)**
PTS from single strike without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Minor adverse
PTS from single strike with mitigation (residual impact)	No impact / negligible	No impact / negligible	Negligible
PTS from cumulative exposure without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	N/A
PTS from cumulative exposure with mitigation (residual impact)	No impact / negligible	No impact / negligible	N/A

see **Annex 2 for definitions of sensitivity, magnitude and impact significance matrix*

5.1.2.2 TTS

5.1.2.2.1 TTS from single strike and cumulative exposure

In the updated assessment of instantaneous TTS in white-beaked dolphin for a single strike of the pin-pile hammer energy of 2,000 kJ and 3,000 kJ, there is no difference between the predicted TTS ranges based on Southall *et al*. (2019) criteria for high-frequency cetaceans (dolphin species) (**Table 5.8**). Both hammer energies modelled had a potential impact range of less than 50 m, with 0.00007 white-beaked dolphin potentially impacted (<0.00001% of the CGNS MU). There is no difference in the impact significance for TTS in dolphin species for the proposed increased maximum hammer energy to 3,000 kJ.

For white-beaked dolphin there is no difference between updated noise modelling results for the predicted cumulative TTS ranges for the 2,000 kJ and 3,000 kJ hammer energies, based on the Southall *et al*. (2019) criteria for high-frequency cetaceans (dolphin species) (**Table 5.8**). Both hammer energies modelled had a potential impact range of less than 100 m, with 0.0007 white-beaked dolphin potentially impacted (<0.00001% of the CGNS MU). There is no difference in the impact significance for TTS in dolphin species for the proposed increased maximum hammer energy to 3,000 kJ.

Table 5.8 Maximum predicted impact ranges (and areas) for TTS from a single strike (SPL_{peak} and SEL_{ss}) and from cumulative exposure (SEL_{cum}) based on Southall et al. (2019) impulsive criteria for high-frequency cetaceans (dolphin species)

Receptor	Threshold	Maximum predicted impact range and area		Difference
		Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	**Maximum hammer energy of 3,000 kJ for pin-piles (proposed amendment)**	**Difference between 2,000 kJ and 3,000 kJ**
Single strike				
Dolphin species (high frequency cetacean)	Weighted SPL_{peak} 224 dB re 1 µPa	<50 m (0.01 km^2)	<50 m (0.01 km^2)	No difference
		0.00007 white-beaked dolphin (<0.00001%)	0.00007 white-beaked dolphin (<0.00001%)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Cumulative SEL				
Dolphin species (high frequency cetacean)	SEL_{cum} Weighted 170 dB re 1 µPa^{2}s	<100 m (<0.1 km^2)	<100 m (<0.1 km^2)	No difference
		0.0007 white-beaked dolphin (<0.00001%)	0.0007 white-beaked dolphin (<0.00001%)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect

5.1.2.2.2 TTS Impact Significance

There is no difference in the impact significance for TTS in white-beaked dolphin for the proposed increased maximum hammer energy to 3,000 kJ compared to the hammer energy of 2,000 kJ (Table 5.9).

Table 5.9 Impact significance for TTS in white-beaked dolphin from maximum hammer energy of 1,900 kJ and 3,000 kJ*

Impact significance for TTS in white-beaked dolphin	Updated modelling for maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)	Updated modelling for maximum hammer energy of 3,000 kJ (proposed amendment)	Magnitude of effect reported in ES (1,900 kJ)
TTS from single strike without mitigation	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.))	Negligible
TTS from cumulative exposure without mitigation	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.))	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.))	N/A

5.1.2.3 Disturbance

The ES used Southall *et al*., (2007) for white-beaked dolphin behaviour assessments, and for a hammer energy of 1,900 kJ, the possible avoidance of an area (pulse SEL 160 dB re 1 μPa^2s) was shown to be between 5 to 7 km. The predicted impact range for disturbance was also modelled for the hammer energy of 3,000 kJ, with possible avoidance of an area (pulse SEL 160 dB re 1 μPa^2s) being between 6 and 8.5 km (impact area of 209 km^2). The ES reported that with a worst case of 3,000 kJ hammer energy, the number of white-beaked dolphin that may be impacted was 3 (0.02% of the reference population). Using the same impact range but with the updated density estimate and reference population, a hammer energy of 3,000 kJ would impact 1.5 individuals (0.003% of CGNS MU). However, it must be noted that the impact ranges and areas provided within the ES were for monopiling as a worst case scenario, so these results are highly precautionary and are expected to be lower for the pin-piling OSP hammer energies. It also should be noted that the updated underwater noise modelling results have not used the same threshold from Southall *et al*., 2007, and therefore a direct comparison is not possible.

The ES reported the impact significance of the 3,000 kJ hammer energy for possible avoidance as negligible for white-beaked dolphin. With the updated density estimate and reference population for the same impact area, the impact significance would be minor adverse for white-beaked dolphin.

5.1.3 *Minke whale*

5.1.3.1 PTS

5.1.3.1.1 PTS from single strike and cumulative exposure

For minke whale, there is no difference between the predicted PTS range for the 2,000 kJ and 3,000 kJ hammer energies, based on the SPL_{peak} criteria for single strike (**Table 5.10**).

Both hammer energy results indicated the impact area is predicted to be less than 0.01 km^2. Up to 0.0002 minke whale (less than 0.00001% CGNS MU) could be at risk of PTS from a single strike for the proposed increased hammer energy of 3,000 kJ compared to 2,000 kJ hammer energy, based on Southall *et al*. (2019) impulsive criteria (**Table 5.10**).

Without mitigation, the magnitude of effect for PTS from a single strike would be negligible for a maximum hammer energy of 3,000 kJ with less than 0.001% of the reference population anticipated to be exposed to any permanent effect (see **Annex 2**). The impact significance, without mitigation, is assessed as minor adverse (high sensitivity x permanent impact with negligible magnitude; see **Annex 2**).

The original assessment in the ES (Forewind, 2014a) determined the potential magnitude of effect for minke whale for a single strike of the maximum hammer energy of 1,900 kJ to be negligible.

There is no significant difference in the potential impacts assessed in the ES for the risk of PTS to minke whale from a single strike at a maximum hammer energy of 1,900 kJ compared to the potential risk from a single strike at a maximum hammer energy of 3,000 kJ, with mitigation. The magnitude of effect is assessed as negligible for all hammer energies with mitigation, which is the same as in the original ES assessment for the consented maximum hammer energy of 1,900 kJ.

Effective mitigation will be put in place to reduce the risk of any physical or permanent auditory injury (PTS) from underwater noise during piling.

For the cumulative SEL assessments, the difference in predicted impact areas for the 2,000 kJ and 3,000 kJ hammer energies was 22.3 km^2. An additional 0.34 minke whale was predicted to be impacted (0.0017% CGNS MU). The 2,000 kJ hammer energy had a magnitude of effect of negligible and the 3,000 kJ had a magnitude of effect of low.

Table 5.10 Maximum predicted impact ranges (impact area) and maximum number of minke whale (% of reference population) for PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on Southall et al. (2019) impulsive criteria for low-frequency cetaceans (minke whale)

Threshold	Maximum predicted impact range and area		Difference
	Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	**Maximum hammer energy of 3,000 kJ for pin-piles (proposed amendment)**	**Difference between 2,000 kJ and 3,000 kJ**
Single strike			
Unweighted SPL_{peak} 219 dB re 1 µPa (low frequency cetacean)	<50 m (<0.01 km^2)	<50 m (<0.01 km^2)	No difference
	0.0002 minke whale (<0.00001% CGNS MU)	0.0002 minke whale (<0.00001% CGNS MU)	No difference
	Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Cumulative SEL			
SEL_{cum} Weighted 183 dB re 1 µPa^{2}s (low frequency cetacean)	1,500 m (3.7 km^2)	3,400 m (26 km^2)	+1,900 m (+22.3 km^2)
	0.06 minke whale (0.0003% CGNS MU)	0.4 minke whale (0.002% CGNS MU)	+0.34 minke whale (+0.0017% CGNS MU)
	Magnitude of effect = negligible	Magnitude of effect = low	No adverse difference in magnitude of effect

5.1.3.1.2 Mitigation

The MMMP will detail the proposed mitigation measures to reduce the risk of any permanent auditory injury (PTS) to marine mammals as a result of underwater noise during piling.

During the 30 minute soft-start and ramp-up (**Section 6.1**) and based on a constant speed of 3.25 m/s for minke whale (Blix and Folkow, 1995), minke whale would move at least 5.85 km from the pile location. If acoustic deterrent devices (ADDs) were activated, for example, for up to 20 minutes before the soft-start, minke whale would move an additional 3.6 km. Therefore, there should be no minke whale in the potential impact area and at risk of instantaneous or cumulative PTS from the maximum hammer energy of 3,000 kJ.

5.1.3.1.3 PTS Impact significance

There is no difference in the impact significance for PTS for a single strike for minke whale (with and without mitigation) for the proposed increased maximum hammer energy to 3,000 kJ compared to the consented hammer energy of 1,900 kJ (**Table 5.11**). There is an increase in impact for the 3,000 kJ PTS cumulative exposure, however with mitigation the significance of this impact is reduced to minor adverse.

Table 5.11 Impact significance for PTS in minke whale from maximum hammer energy of 1,900 kJ, 3,000 kJ*

Impact significance for PTS in minke whale	Maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)	Maximum hammer energy of 3,000 kJ (proposed amendment)	Magnitude of effect reported in ES (1,900 kJ)
PTS from single strike without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.))	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.))	Minor adverse
PTS from single strike with mitigation (residual impact)	No impact / negligible	No impact / negligible	Negligible
PTS from cumulative exposure without mitigation	Minor adverse (high sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.))	Moderate adverse (high sensitivity x permanent impact with low magnitude (<=0.01% ref. pop.))	N/A
PTS from cumulative exposure with mitigation	No impact / negligible	Minor adverse	N/A

see **Annex 2 for definitions of sensitivity, magnitude and impact significance matrix*

5.1.3.2 TTS

5.1.3.2.1 TTS from single strike and cumulative exposure

The difference between the predicted TTS / fleeing response range for the maximum hammer energy of 2,000 kJ and 3,000 kJ, based on the SPL_{peak} criteria for single strike, is up to 10 m, for minke whale (**Table 5.12**). However, there is no difference between the impact area itself, and **therefore no difference in the maximum predicted number of minke whale impacted by TTS single strike for the maximum hammer energy of 2,000 kJ or 3,000 kJ** (**Table 5.12**).

The original assessment in the ES (Forewind, 2014a) determined the potential TTS magnitude of effect for minke whale for a single strike of the maximum hammer energy of 1,900 kJ to be negligible. This level of magnitude has stayed the same with the updated modelling results for the increase in hammer energy to 3,000 kJ.

The difference between the predicted TTS / fleeing response range for the maximum hammer energy of 2,000 kJ and 3,000 kJ, based on the SEL_{cum} criteria for single strike, is up to 4,000 m (impact area of 400 km^2), for minke whale (**Table 5.12**). The predicted increase in number affected by TTS is 7 minke whale (no change in percentage of CGNS MU impacted). However, both hammer energies had a medium magnitude of effect, **therefore there is no adverse difference between the hammer energies.**

Table 5.12 Maximum predicted impact ranges (impact area) and maximum number of minke whale (% of reference population) for TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on Southall et al. (2019) criteria for minke whale

Receptor	Threshold	Maximum predicted impact range and area		Difference
		Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	Maximum hammer energy of 3,000 kJ for pin-piles (proposed amendment)	Difference between 2,000 kJ and 3,000 kJ
Single strike				
Minke whale	SPL_{peak} unweighted 213 dB re 1 µPa	70 m (0.02 km^2)	80 m (0.02 km^2)	+10 m (+0.0 km^2)
		0.0003 minke whale (<0.00001% CGNS MU)	0.0003 minke whale (<0.00001% CGNS MU)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Cumulative SEL				
Minke whale	SEL_{cum} Weighted 168 dB re 1 µPa^{2}s	26,000 m (1,400 km^2)	30,000 m (1,800 km^2)	+4,000 m (+400 km^2)
		21 minke whale (0.1% CGNS MU)	28 minke whale (0.1% CGNS MU)	+7 minke whale (+0.0% CGNS MU)
		Magnitude of effect = medium	Magnitude of effect = medium	No adverse difference in magnitude of effect

5.1.3.2.2 TTS Impact Significance

There is no difference in the impact significance for TTS in minke whale for the proposed increased maximum hammer energy to 3,000 kJ compared to the hammer energy of 2,000 kJ and the level of magnitude reported in the ES (**Table 5.13**).

Table 5.13 Impact significance for TTS in minke whale from maximum hammer energy of 1,900 kJ, 3,000 kJ*

Impact significance for TTS in minke whale	Updated modelling for maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)	Updated modelling for maximum hammer energy of 3,000 kJ (proposed amendment)	Magnitude of effect reported in ES (1,900 kJ)
TTS from single strike without mitigation	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.)*)	Negligible (medium sensitivity x temporary impact with negligible magnitude (≤0.001% ref. pop.)*)	Negligible
TTS from cumulative exposure without mitigation	Moderate adverse (medium sensitivity x permanent impact with medium magnitude (<=1% ref. pop.)*)	Moderate adverse (medium sensitivity x permanent impact with medium magnitude (<=1% ref. pop.)*)	N/A
TTS from cumulative exposure with mitigation (residual impact)	Minor adverse	Minor adverse	N/A

see **Annex 2 for definitions of sensitivity, magnitude, and impact significance matrix*

5.1.3.3 Disturbance

The ES used Southall *et al*., (2007) for minke whale behaviour assessments, and for the hammer energy of 1,900 kJ, the possible avoidance of an area (pulse SEL 142 dB re 1 μPa^{2}s) was between 23 to 35.5 km. The predicted impact range for disturbance was also modelled for the hammer energy 3,000 kJ, with the results showing a possible avoidance of an area (pulse SEL 142 dB re 1 μPa^{2}s) of between 26.5 to 41 km (impact area of 3,940 km^2). The ES reported that with a worst case of 3,000 kJ hammer energy, the number of minke whale that may be impacted was 34 (0.02% of the reference population). Using the same impact range but with the updated density estimate and reference population, a hammer energy of 3,000 kJ would impact 60 individuals (0.3% of CGNS MU).

The ES reported the impact significance of the 3,000 kJ hammer energy for possible avoidance as negligible for minke whale. With the updated density estimate and reference population for the same impact area, the impact significance would be minor adverse for minke whale (low sensitivity x medium magnitude of effect). However, it must be noted that the impact ranges and areas provided within the ES were for monopiling as a worst case scenario, so these results are highly precautionary and are expected to be lower for the pin-piling OSP hammer energies. It also should be noted that the updated underwater noise modelling results have not used the same threshold from Southall *et al*., 2007, and therefore a direct comparison is not possible.

5.1.4 *Grey and harbour seal*

5.1.4.1 PTS

5.1.4.1.1 PTS from single strike and cumulative exposure

There is no difference between the predicted PTS range for the 2,000 kJ and 3,000 kJ hammer energies, based on the SPL_{peak} criteria for single strike. For both grey seal and harbour seal there is no predicted difference in the potential impact area or number of individuals affected (**Table 5.14**). All hammer energies in both scenarios had a negligible magnitude of effect.

The original assessment in the ES (Forewind, 2014a) determined the potential magnitude of effect for grey seal for a single strike of the maximum hammer energy of 1,900 kJ to also be of a negligible residual effect. Harbour seal impacts were not assessed within the original assessment in the ES.

There is no difference between the predicted PTS range for the 2,000 kJ and 3,000 kJ hammer energies, based on the SEL_{cum} criteria for cumulative strikes. For both grey seal and harbour seal there is no predicted difference in the potential impact area or number of individuals affected (**Table 5.14**). With both hammer energies, the potential impact area was assessed as 0.1 km^2 with 0.00001 grey seal being impacted (<0.00001% of total population and SE MU) and 0.000002 harbour seal (<0.00001% of total population and SE MU) impacted. All hammer energies in both scenarios had a negligible magnitude of effect.

Table 5.14 Maximum predicted impact ranges (and areas) for PTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on Southall et al. (2019) criteria for seals

Receptor	Threshold	Maximum predicted impact range and area		Difference
		Maximum hammer energy of 2,000 kJ for pin-piles (1,900 kJ was consented parameter)	**Maximum hammer energy of 3,000 kJ for pin-piles**	**Difference between 2,000 kJ and 3,000 kJ**
Single strike				
Grey seal	SPL_{peak} unweighted 218 dB re 1 µPa	<50 m (<0.01 km^2)	<50 m (<0.01 km^2)	No difference
		0.000001 grey seal (<0.00001% total population; <0.00001% SE MU)	0.000001 grey seal (<0.00001% total population; <0.00001% SE MU)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Harbour seal		<50 m (<0.01 km^2)	<50 m (<0.01 km^2)	No difference
		0.0000002 harbour seal (<0.00001% total population; <0.00001% SE MU)	0.0000002 harbour seal (<0.00001% total population; <0.00001% SE MU)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Cumulative SEL				
Grey seal	SEL_{cum} Weighted	<100 m (0.1 km^2)	<100 m (0.1 km^2)	No difference

Receptor	**Threshold**	**Maximum predicted impact range and area**		**Difference**
		Maximum hammer energy of 2,000 kJ for pin-piles (1,900 kJ was consented parameter)	**Maximum hammer energy of 3,000 kJ for pin-piles**	**Difference between 2,000 kJ and 3,000 kJ**
	185 dB re 1 µPa^{2}s	0.00001 grey seal (<0.00001% total population; <0.00001% SE MU)	0.00001 grey seal (<0.00001% total population; <0.00001% SE MU)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Harbour seal		<100 m (0.1 km^2)	<100 m (0.1 km^2)	No difference
		0.000002 harbour seal (<0.00001% total population and SE MU)	0.000002 harbour seal (<0.00001% total population and SE MU)	No difference
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect

5.1.4.1.2 PTS Impact Significance

There is no difference in the impact significance for PTS in grey seal and harbour seal (without mitigation) for the proposed increased maximum hammer energy to 3,000 kJ compared to the consented hammer energy of 1,900 kJ (Table 5.15).

Table 5.15 Impact significance for PTS in grey seal and harbour seal from maximum hammer energy of 1,900 kJ, 2,000 kJ and 3,000 kJ*

Impact significance for PTS in grey seal and harbour seal	Maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)	Maximum hammer energy of 3,000 kJ (proposed amendment)	Magnitude of effect reported in ES (1,900 kJ)
PTS from single strike without mitigation	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Negligible
PTS from cumulative exposure without mitigation	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	N/A

see **Annex 2 for definitions of sensitivity, magnitude and impact significance matrix*

5.1.4.2 TTS

5.1.4.2.1 TTS from single strike and cumulative exposure

For the TTS SPL_{peak} criteria, the difference between the maximum predicted range for hammer energies of 2,000 kJ and 3,000 kJ is up to 20 m (impact area of 0.01 km^2) for both seals. The increase in number of individuals affected by TTS single strikes were assessed as up to 0.000001 for grey seal and 0.0000002 for harbour seal. All scenarios had a negligible magnitude of effect, see **Table 5.16**.

There is no significant difference in the impact significance for TTS single strike on grey and harbour seal for the proposed increased maximum hammer energy to 3,000 kJ compared to the hammer energy of 2,000 kJ, and the level of magnitude reported in the ES.

For the TTS cumulative assessments, the difference in impact range was up to 1,600 m (impact are of 70 km^2). The difference in number of individuals affected was assessed as up to 0.007 grey seal and 0.002 harbour seal. For both grey seal and harbour seal the magnitude of effect with both hammer energies was negligible. **There is no adverse difference in magnitude of effect for either grey and harbour seal and the hammer energies 2,000 kJ and 3,000 kJ.**

Table 5.16 The maximum number of grey and harbour seal (and % of reference population) that could be at risk of TTS from a single strike (SPL_{peak}) and from cumulative exposure (SEL_{cum}) based on Southall et al. (2019) criteria

Receptor	Threshold	Maximum predicted impact range and area		Difference
		Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	Maximum hammer energy of 3,000 kJ for pin-piles	Difference between 2,000 kJ and 3,000 kJ
Single strike				
Grey seal	SPL_{peak} unweighted 212 dB re 1 µPa	80 m (0.02 km^2)	100 m (0.03 km^2)	+20 m (+0.01 km^2)
		0.000002 grey seal (<0.00001% of total population; 0.00001% SE MU.)	0.000003 grey seal (<0.00001% of total population; 0.00001% SE MU.)	+0.000001 grey seal
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Harbour seal		80 m (0.02 km^2)	100 m (0.03 km^2)	+20 m (+0.01 km^2)
		0.0000004 grey seal (<0.00001% of total population and SE MU)	0.0000006 grey seal (<0.00001% of total population and SE MU)	+0.0000002 grey seal
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Cumulative SEL				
Grey seal	SEL_{cum} Weighted 170 dB re 1 µPa^{2}s	9,400 m (210 km^2)	11,000 m (280 km^2)	+1,600 m (+70 km^2)
		0.021 grey seal (0.00004% of total population; 0.00007% SE MU)	0.028 grey seal (0.00005% of total population; 0.00009% SE MU)	+0.007 grey seal (+0.00001% of ref. pop.)

Receptor	**Threshold**	**Maximum predicted impact range and area**		**Difference**
		Maximum hammer energy of 2,000 kJ for pin-piles (consented parameter was 1,900 kJ)	**Maximum hammer energy of 3,000 kJ for pin-piles**	**Difference between 2,000 kJ and 3,000 kJ**
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect
Harbour seal		9,400 m (210 km^2)	11,000 m (280 km^2)	+1,600 m (+70 km^2)
		0.004 harbour seal (0.00008% of total population; 0.00009% of SE MU)	0.006 harbour seal (0.0001% of total population and SE MU.)	+0.002 (+0.0%)
		Magnitude of effect = negligible	Magnitude of effect = negligible	No adverse difference in magnitude of effect

5.1.4.2.2 TTS Impact Significance

There is no difference in the impact significance for TTS in grey seal and harbour seal for the proposed increased maximum hammer energy to 3,000 kJ compared to the hammer energy of 2,000 kJ (Table 5.17). The magnitude of effect reported in the ES were also of the same magnitude as these updated assessments.

Table 5.17 Impact significance for TTS in grey seal and harbour seal from maximum hammer energy of 1,900 kJ, 3,000 kJ*

Impact significance for TTS in grey seal and harbour seal	Updated modelling for maximum hammer energy of 2,000 kJ (consented parameter was 1,900 kJ)	Updated modelling for maximum hammer energy of 3,000 kJ (proposed amendment)	Magnitude of effect reported in ES (1,900 kJ)
TTS from single strike without mitigation	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Negligible
TTS from cumulative exposure without mitigation	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	Negligible (medium sensitivity x permanent impact with negligible magnitude (<=0.001% ref. pop.)*)	N/A

see **Annex 2 for definitions of sensitivity, magnitude and impact significance matrix*

5.1.4.3 Disturbance

For pinnipeds, several of the studies reviewed by Southall *et al*. (2007) indicate that fleeing and avoidance only occur at noise levels which are considered sufficient to cause the TTS (M_{pw} weighted 171dB re 1 μPa^{2}s). Based on this information, the previous assessments in the ES assumed the magnitude of effect is the same as outlined for TTS, which was negligible.

Data from tagged harbour seals in the Wash indicated clear evidence of avoidance during pile driving events (Russell *et al*., 2017). Seal activity was significantly reduced at ranges of up to 25 km from piling sites, although within two hours of cessation of piling, seal distribution returned to pre-piling levels (Russell *et al.,* 2017).

When using a 25 km disturbance range it is estimated that the number of grey seals impacted is 0.2 (0.0003% of the total reference population; 0.0006% of SE MU). For harbour seal the number estimated to be impacted was 0.04 (0.0008% of total reference population; 0.0008% of SE MU). However, the 25 km disturbance range set by Russell *et al*., 2017 was based on monopiles therefore these results are highly precautionary. Based on these results the magnitude of effect is negligible, with no significant impact. **This indicates there is no**

significant difference between consented 1,900 kJ hammer energy and the proposed 3,000 kJ hammer energy magnitudes of effect.

5.2 Comparison with the ES results

Due to the differing underwater noise models, threshold criteria, density estimates, and reference populations used for the ES results, and for the updated assessments, it is difficult to make a 'like for like' comparison.

It is more relevant, especially in determining whether there are any new or materially different significant effects in relation to marine mammals between the proposed maximum hammer energy and the currently consented maximum hammer energy, for the NMC, to provide a comparison of the level of magnitude and overall outcomes of the original assessments in the ES (Forewind, 2014a), on which the DCO was based, with the level of magnitude and overall outcomes of the updated assessments for the increase in hammer energy.

The comparison with the impact significance (without mitigation) based on assessments for the consented maximum hammer energy with the updated assessments for the proposed increases in maximum hammer energy, indicate that for harbour porpoise the impact significance for PTS and avoidance is slightly higher than ES assessment with a minor adverse effect rather than negligible. For white-beaked dolphin, grey seal and harbour seal all impact significance assessments are the same level as ES assessments. For minke whale, the updated assessments for PTS and avoidance, have a worst-case of minor adverse which reflects updates to modelling, density estimates and reference population.

However, as previously outlined, the MMMP would be implemented to reduce the risk of PTS in marine mammals, based on the greatest potential impact range for PTS. Therefore, the residual impacts for PTS (with mitigation) would be the same as assessed in the ES; negligible (**Table 5.18**). **Therefore, there are no new or materially different significant effects in relation to marine mammals between using the proposed maximum hammer energy of 3,000 kJ for OSP pin-piles compared to the currently consented maximum hammer energy of 1,900 kJ for OSP pin-piles.**

Table 5.18 Summary of residual impacts for the ES findings and updated non-material change findings

Species	Potential impact	ES findings	Updated NMC findings	Overall conclusion
Harbour porpoise	PTS	Minor adverse	Minor adverse	No significant difference
	TTS	Negligible	Minor adverse	No significant difference
	Disturbance	Negligible	Minor adverse	No significant difference
White-beaked dolphin	PTS	Minor adverse	Negligible	No significant difference
	TTS	Negligible	Negligible	No significant difference
	Disturbance	Negligible	Minor adverse	No significant difference

Minke whale	PTS	Minor adverse	Minor adverse	No significant difference
	TTS	Negligible	Minor adverse	No significant difference
	Disturbance	Negligible	Minor adverse	No significant difference
Grey and harbour seal	PTS	Minor adverse	Negligible	No significant difference
	TTS	Negligible	Negligible	No significant difference
	Disturbance	Not assessed	Negligible	No significant difference

5.3 Comparison with HRA

As demonstrated, there is no significant difference in the potential impacts on marine mammals from increasing the maximum pin-pile hammer energy to 3,000 kJ compared to the maximum pin-pile hammer energy of 1,900 kJ in the original assessment. As a result, the conclusions of the HRA which underpin the DCO (DECC, 2015) are not affected and the proposed change itself **does not have the potential to give rise to likely significant effects on any European site** (including the Southern North Sea Special Area of Conservation (SAC)).

It is important to note that it is the impacts of the proposed change that should be assessed rather than the Project as a whole. The increase in hammer energy compared to the consented Project has been considered in relation to the Southern North Sea SAC. This has been undertaken by considering the impacts on harbour porpoise as predicted in the ES and the additional impacts that may be caused by the increase in hammer energy, taking into account the potential increase in impact ranges with a comparison of the assessments in the ES, and for the latest Southall *et al*. (2019) criteria. For the latest criteria, the potential change in impacts has then been considered in relation to the effects on the North Sea MU population of harbour porpoise. This demonstrates that there is no significant difference in the impacts due to the increase in hammer energy and therefore supports a conclusion that the proposed change would not give rise to likely significant effects on the Southern North Sea SAC. In addition, it is important to note that hammer energy has no bearing on the results of the potential for disturbance to harbour porpoise of the Southern North Sea SAC, as that is based on the EDRs.

5.3.1 *Permanent Auditory Injury and Requirements for Mitigation*

As outlined in **Section 5.1.1.1**, up to an additional 0.1 harbour porpoise (0.00001% North Sea MU), based on the SCANS-IV density estimate, could be at increased risk of PTS from a single strike of the maximum hammer energy of 3,000 kJ compared to 1,900 kJ hammer energy, based on Southall et al. (2019) unweighted criteria for SPL_{peak}. Therefore, there is no significant difference (i.e. the additional difference is less than 0.001% of the North Sea MU reference population) between the consented hammer energy of 1,900 kJ and the proposed increase to a maximum hammer energy of 3,000 kJ.

The potential for any auditory injury (PTS), associated with underwater noise will be mitigated through the MMMP (such as establishing mitigation zone based on the maximum potential range for PTS, soft-start and ramp-up, activation of Acoustic Deterrent Devices (ADDs) prior to soft-start) will ensure this is not a risk for harbour porpoise in the Southern North Sea SAC. The overriding purpose of the MMMP is to provide mitigation for the potential to kill or injure marine mammals during construction.

5.3.2 *Disturbance and Requirements for Mitigation and Management*

A DBC SNS SAC Site Integrity Plan (SIP) (LF700013-CST-DOG-MEM-0003; submitted 3rd November 2023 and approved on 27th November 2023) has been produced to set out the approach to deliver any potential mitigation measures for DBC, and to ensure the avoidance of significant disturbance of harbour porpoise in relation to the SNS SAC site Conservation Objectives.

This SIP reflects the commitment of the DBC project to undertake required measures to reduce the potential for any significant disturbance of harbour porpoise in the SNS SAC. This will be achieved through installing the foundations with the potential to overlap with the SAC in the winter season, thereby having no impact on the site.

5.3.3 *In-Combination Effects*

As demonstrated, there is no significant difference in the potential impacts on harbour porpoise from increasing the maximum pin-pile hammer energy to 3,000 kJ compared to the maximum pin-pile hammer energy of 1,900 kJ in the original assessment, **therefore there will be no significant difference to the outcome of any in-combination effect scenarios**, this includes the BEIS (now DESNZ) (2020) RoC HRA, as outlined in **Section 5.4.**

5.3.4 *Southern North Sea Conservation Objectives*

The Conservation Objectives for the site are (JNCC and Natural England, 2019):

To ensure that the integrity of the site is maintained and that it makes the best possible contribution to maintaining Favourable Conservation Status (FCS) for the harbour porpoise in UK waters.

In the context of natural change, this will be achieved by ensuring that:

1. Harbour porpoise is a viable component of the site;
2. There is no significant disturbance of the species; and
3. The condition of supporting habitats and processes, and the availability of prey is maintained.

The specific conversation objectives are considered below in relation to the proposed non-material amendment to the DCO.

5.3.4.1 Assessments against the Conservation Objectives

Conservation Objective 1: Harbour porpoise is a viable component of the site

The intent of this Conservation Objective is to minimise the risk of injury and killing or other factors that could restrict the survivability and reproductive potential of harbour porpoise within the site. Specifically, this objective is concerned with operations within the site that would result in unacceptable levels of impact upon individuals using the site. Unacceptable levels are defined as those that would have an impact upon the Favourable Conservation Status (FCS) of the population. The Conservation Objectives state that, with regard to assessing impacts, 'the reference population for assessments against this objective is the MU population in which the SAC is situated (IAMMWG, 2015)".

Harbour porpoise are considered to a viable component of the site if they are able to live successfully within it. PTS has been used to determine the area where harbour porpoise could be at increased risk of any physical or permanent auditory injury. The assessment indicates a potential increase in range of 60 m (from 390 m to 450 m), based on the latest Southall *et al*. (2019) criteria. In relation to the proposed amendment, this equates to 0.0001% North Sea MU population that could be at increased risk of any physical injury or permanent auditory injury. As outlined above, any impact at these ranges would be mitigated by the MMMP, as secured through the existing deemed Marine Licences. As such, the proposed NMC would not result in an adverse effect on integrity for either the Project alone or in-combination with other plans, projects or proposals.

Conservation Objective 2: There is no significant disturbance of the species

Disturbance is considered to be significant if it leads to the exclusion of harbour porpoise from a significant portion of the site for a significant period of time. Draft SNCB guidance for assessing the significance of noise disturbance to a site suggests:

"Noise disturbance within an SAC from a plan/project individually or in combination is significant if it excludes harbour porpoise from more than:

1. 20% of the relevant area of the site in any given day, and
2. an average of 10% of the relevant area of the site over a season".

The current SNCB advice is that the assessments for potential disturbance of harbour porpoise in the Southern North Sea SAC is based on an area of EDR of 15 km (or an area of 706.86 km^2) for pin-piles (with and without noise abatement). Based on the 15 km EDR, there would be no difference in the disturbance to harbour porpoise within the Southern North Sea SAC, as a result of piling at DBC, for any hammer energy used, and given the distance of the DBC project to the SAC, there would no potential for any adverse effect on the Southern North Sea SAC.

Conservation Objective 3: The condition of supporting habitats and processes, and the availability of prey is maintained.

Within this Conservation Objective, supporting habitats relates to the characteristics of the seabed and water column, and supporting processes encompass the movements and physical properties of the habitat. The maintenance of supporting habitats and processes contributes to ensuring that prey is maintained and available to individuals within the site. Harbour porpoise are strongly reliant on the availability of prey species due to their high energy demands and are highly dependent on being able to access prey species year-round. The densities of harbour porpoise within a site are therefore highly dependent on the availability of key prey species.

This Conservation Objective is designed to ensure that harbour porpoise are able to access food resources year round, and that activities occurring in the Southern North Sea SAC will not affect this. As set out in the Environmental Report submitted in support of the NMC application, the proposed increase in hammer energy does not alter the worst case assessed for fish and will not result in a physical change in habitat in addition to that already considered for the consented Project. In addition, there would be no additional displacement of harbour porpoise as a result of any changes in prey resources during piling, as harbour porpoise would already be potentially disturbed as a result of underwater noise during piling and the potential area of any disturbance of prey species would be the same or less as those assessed for directly for harbour porpoise. Therefore, the proposed amendment would not give rise to any additional impacts in relation to this Conservation Objective compared to the consented Project.

In considering the Conservation Objectives of the Southern North Sea SAC it can be concluded that the increase in hammer energy would not result in an adverse effect on the integrity of the site for either the project alone or in-combination with other projects.

5.4 Comparison with BEIS (now DESNZ) (2020) RoC HRA

The RoC HRA (BEIS, 2020) reviewed eleven offshore wind farm consents, including DBC. The conclusion of the RoC HRA was that the consented offshore wind farms considered will not have an adverse effect on the Southern North Sea SAC either alone or in combination with other plans and projects, provided that the parameters of each wind farm as assessed by the HRA are not exceeded.

The maximum predicted PTS impact ranges for the updated noise modelling for a maximum hammer energy of 3,000 kJ are within the maximum predicted PTS ranges in the BEIS (2020) RoC HRA.

6 Mitigation

6.1 MMMP

The Marine Mammal Mitigation Protocol (MMMP) at the time of writing is still being drafted. However, it will cover the installation of both the monopile foundations for the Wind Turbine Generators, and pin-pile foundations for the OSP at DBC. The MMMP will detail the mitigation measures required to reduce the risk of underwater noise causing permanent auditory injury / permanent shift in hearing sensitivity (PTS), in all marine mammal species in and around DBC.

Mitigation in the MMMP will include:

- The establishment of a Monitoring Area (MA);
- The activation of an Acoustic Deterrent Device (ADD) prior to piling;
- Soft-start procedure prior to operational piling; and
- Procedure for breaks in operational piling and during soft-start.

6.1.1 *Monitoring Area*

The MA is the area around each pile location which is monitored by the Marine Mammal Observers (MMObs) and Passive Acoustic Monitoring (PAM).

The Joint Nature Conservation Committee (JNCC) (2010) guidelines state that the minimum MA should be 500 m in all directions, from the pile location, but that this should be increased to cover the potential injury zones if they are larger. The MA is therefore to be increased to at least 600 m, to ensure it is greater than the maximum predicted impact range for PTS from a single strike of the maximum hammer energy (of up to 530 m for harbour porpoise for 3,000 kJ for OSP pin-piles). This area will be monitored during the pre-piling watch.

At least two MMObs will conduct visual surveys to cover a full 360° view of the entire MA around each pile location. Marine mammal observations will be carried out from vantage points to allow unobstructed observations of the entire MA.

6.1.2 *Acoustic Deterrent Device*

The ADD will be deployed and ready to be activated following;

- any breaks in piling of more than two hours;
- any breaks during soft-start; and
- when the piling mitigation procedures will be required.

ADD will be activated to reduce the risk of instantaneous PTS from the first strike of the starting hammer energy and single strike of the maximum hammer energy, but also to reduce the risk of PTS from cumulative exposure due to the installation of one pile.

6.1.3 *Soft-start*

Throughout this step, there are two stages to the soft-start procedure:

- Low-energy blows for a minimum of 10 minutes, within the starting hammer energies of 320 kJ for OSP pin-piles, followed by:
- Ramp-up in piling energy for a minimum of 10 minutes until the maximum hammer energy required to install the pile is reached (up to maximum of 3,000 kJ for OSP pin-piles).

If a marine mammal enters the MA during soft-start, where possible there will be no increase in the hammer energy until the marine mammal is observed to move out of the MA.

6.1.4 *Breaks in piling*

Monitoring of the MA during any breaks in piling will be conducted by MMObs during daylight hours and suitable visibility, or by PAM during poor visibility or at night.

Breaks during operational piling:

- If break is less than 10 minutes – continue operational piling at the required hammer energy after the break.
- If break is between 10 minutes and 2 hours – restart piling with 5 – 6 hammer blows at maximum 320 kJ before continuing operational piling.
- If break more than 2 hours – the full piling mitigation procedure needs to be restarted.

7 Conclusions

This marine mammal technical report has reviewed and re-modelled the impacts on marine mammals which could arise from the proposed amendment to DBC to compare to the modelling that informed the ES and HRA which underpin the DCO. In addition, due to the change in noise thresholds and criteria that have occurred since the project was consented, an assessment of the potential impacts based on these has also been undertaken.

The modelling carried out to compare with the original consent showed that there was no significant difference between the potential impact for a maximum hammer energy of 1,900 kJ compared to 3,000 kJ for permanent auditory injury (PTS), temporary auditory injury (TTS) and disturbance for all species. Therefore, the proposed increase in maximum hammer energy from 1,900 kJ to 3,000 kJ would not alter the outcomes of the original assessment made within the ES, including the cumulative impact assessment and, where relevant, the HRA.

It is therefore concluded that as there is no material difference between the impacts assessed in the ES and those resulting from the proposed amendment to the Project; the conclusions of the ES and its associated documents are not affected by the proposed change and that the recommendations of the Examining Authority and the conclusions of the HRA which underpin the DCO, are similarly not affected. The proposed change does not have the potential to give rise to likely significant effects on any European sites (including the Southern North Sea SAC). Therefore, the proposed amendment to the DCO will not give rise to any new or materially different likely significant effects in relation to marine mammals and no further assessment is required for marine mammals in support of the proposed amendment to the DCO.

As such, it is appropriate for the application to amend the maximum hammer energy to be consented as an NMC to the DCO.

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Annex 2 – Impact Assessment Methodology

A.1.1 Value

All marine mammals are considered to have high value in the assessments.

A1.2 Sensitivity

A 1 Sensitivity of marine mammals to noise impacts from pile driving

Species	PTS	TTS	Disturbance / fleeing response	Possible avoidance / behavioural reaction
Harbour porpoise	High	Medium	Medium	Low
White-beaked dolphin	High	Medium	Medium	Low
Minke whale	High	Medium	Medium	Low
Grey seal	Medium	Medium	Medium	N/A
Harbour seal	Medium	Medium	Medium	N/A

A 2 Definition of sensitivity for a marine mammal receptor

Sensitivity	Definition
High	Individual receptor has very limited capacity to avoid, adapt to, tolerate or recover from the anticipated impact.
Medium	Individual receptor has limited capacity to avoid, adapt to, tolerate or recover from the anticipated impact.
Low	Individual receptor has some tolerance to avoid, adapt to, tolerate or recover from the anticipated impact.
Negligible	Individual receptor is generally tolerant to and can tolerate or recover from the anticipated impact.

A1.3 Magnitude

A 3 Definitions of magnitude levels for marine mammals

Magnitude	Definition
High	Permanent irreversible change to exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that more than 1% of the reference population are anticipated to be exposed to the effect. OR Temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor.

Magnitude	Definition
	Assessment indicates that more than 10% of the reference population are anticipated to be exposed to the effect.
Medium	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that between 0.01% and 1% of the reference population anticipated to be exposed to effect. OR Temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that between 5% and 10% of the reference population anticipated to be exposed to effect.
Low	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that between 0.001% and 0.01% of the reference population anticipated to be exposed to effect. OR Intermittent and temporary effect (e.g. limited to the construction phase of development) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor.
Negligible	Permanent irreversible change to exposed receptors or feature(s) of the habitat of particular importance to the receptor. Assessment indicates that less than 0.001% of the reference population anticipated to be exposed to effect. OR Intermittent and temporary effect (limited to the construction phase of development or Project timeframe) to the exposed receptors or feature(s) of the habitat which are of particular importance to the receptor. Assessment indicates that less than 1% of the reference population anticipated to be exposed to effect.

A1.4 Impact Significance

A 4 Impact significance matrix

Impact significance		Sensitivity			
		High	**Medium**	**Low**	**Negligible**
Magnitude	**High**	Major	Major	Moderate	Minor
	Medium	Major	Moderate	Minor	Negligible
	Low	Moderate	Minor	Minor	Negligible
	Negligible	Minor	Minor	Negligible	Negligible

Potential impacts identified within the assessment as major or moderate are regarded as significant in terms of the EIA regulations.