NORTH FALLS

Offshore Wind Farm

ENVIRONMENTAL STATEMENT

Appendix 12.4 Underwater Noise Technical Assessment

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NORTH FALLS
Offshore Wind Farm

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Glossary of Acronyms

Acronym	Meaning
ADD	Acoustic Deterrent Device
dB	Decibel
EMODnet	European Marine Observation and Data Network
HF	High-Frequency
Hz	Hertz
kJ	kilojoule
LF	Low-Frequency
m	metre
m/s	Metres per Second
NMFS	National Marine and Fisheries Service
PCW	Phocid Carnivores in Water
PTS	Permanent Threshold Shift
RMS	Root Mean Square
SEL	Sound Exposure Level
SPL	Sound Pressure Level
TTS	Temporary Threshold Shift
VHF	Very High-Frequency
WTG	Wind Turbine Generator

Glossary of Terminology

Array area	The offshore wind farm area, within which the wind turbine generators, array cables, platform interconnector cable, offshore substation platform(s) and/or offshore converter platform will be located.
Array cables	Cables which link the wind turbine generators with each other and the offshore substation platform(s) and / or the offshore converter platform.
Decibel (dB)	A customary scale commonly used (in various ways) for reporting levels of sound. A difference of 10 dB corresponds to a factor of 10 in sound power. The actual sound measurement is compared to a fixed reference level and the “decibel” value is defined to be 10 $\log_{10}$(actual/reference) where (actual/reference) is a power ratio. Because sound power is usually proportional to sound pressure squared, the decibel value for sound pressure is 20 $\log_{10}$(actual pressure/reference pressure). The standard reference for underwater sound is 1 micropascal (μPa). The dB symbol is followed by a second symbol identifying the specific reference value (e.g., re 1 μPa).
Offshore cable corridor	The corridor of seabed from array areas to the landfall within which the offshore export cables will be located.
Offshore converter platform	Should an offshore connection to an HVDC interconnector cable be selected, an offshore converter platform would be required. This is a fixed structure located within the array area, containing HVAC and HVDC electrical equipment to aggregate the power from the wind turbine generators, increase the voltage to a more suitable level for export and convert the HVAC power generated by the wind turbine generators into HVDC power for export to shore via a third party HVDC interconnector cable.

Offshore export cables	The cables which bring electricity from the offshore substation platform(s) to the landfall, as well as auxiliary cables.
Offshore project area	The overall area of the array area and the offshore cable corridor.
Offshore substation platform(s)	Fixed structure(s) located within the array area, containing HVAC electrical equipment to aggregate the power from the wind turbine generators and increase the voltage to a more suitable level for export to shore via offshore export cables.
Peak pressure	The highest pressure above or below ambient that is associated with a sound wave.
Peak-to-peak pressure	The sum of the highest positive and negative pressures that are associated with a sound wave.
Permanent Threshold Shift (PTS)	A permanent total or partial loss of hearing caused by acoustic trauma. PTS results in irreversible damage to the sensory hair cells of the air, and thus a permanent reduction of hearing acuity.
Platform interconnector cable	Cable connecting the offshore substation platforms (OSP); or the OSP and offshore converter platform (OCP)
Root Mean Square (RMS)	The square root of the arithmetic average of a set of squared instantaneous values. Used for presentation of an average sound pressure level.
Scour protection	Protective materials to avoid sediment being eroded away from the base of the wind turbine generator foundations and offshore substation platform (OSP) or / and offshore converter platform (OCP) foundations as a result of the flow of water.
Soft-start	Procedure through which the pilling activity begins at lower hammer energy increasing gradually (ramp-up) before reaching maximum hammer energy. Assumes marine mammals will move away out of the area as the hammer energy is increased.
Sound Exposure Level (SEL)	The constant sound level acting for one second, which has the same amount of acoustic energy, as indicated by the square of the sound pressure, as the original sound. It is the time-integrated, sound-pressure-squared level. SEL is typically used to compare transient sound events having different time durations, pressure levels, and temporal characteristics.
Sound Exposure Level, cumulative (SEL_{cum})	Single value for the collected, combined total of sound exposure over a specified time or multiple instances of a noise source.
Sound Exposure Level, single strike (SEL_{ss})	Calculation of the sound exposure level representative of a single noise impulse, typically a pile strike.
Sound Pressure Level (SPL)	The sound pressure level is an expression of sound pressure using the decibel (dB) scale; the standard frequency pressures of which are 1 μPa for water and 20 μPa for air.
Sound Pressure Level Peak (SPL_{peak})	The highest (zero-peak) positive or negative sound pressure, in decibels.
Temporary Threshold Shift (TTS)	Temporary reduction of hearing acuity because of exposure to sound over time. Exposure to high levels of sound over relatively short time periods could cause the same level of TTS as exposure to lower levels of sound over longer time periods. The mechanisms underlying TTS are not well understood, but there may be some temporary damage to the sensory cells. The duration of TTS varies depending on the nature of the stimulus.
The Applicant	North Falls Offshore Wind Farm Limited (NFOW).
The Project Or 'North Falls'	North Falls Offshore Wind Farm, including all onshore and offshore infrastructure.
Unweighted sound level	Sound levels which are "raw" or have not been adjusted in any way, for example to account for the hearing ability of a species.

Weighted sound level	A sound level which has been adjusted with respect to a "weighting envelope" in the frequency domain, typically to make an unweighted level relevant to a particular species. Examples of this are the dB(A), where the overall sound level has been adjusted to account for the hearing ability of humans in air, or the filters used by Southall *et al*. (2019) for marine mammals.
Wind turbine generator	Power generating device that is driven by the kinetic energy of the wind

1 Underwater noise technical assessment

1.1 Introduction

1. This Appendix details the underwater noise modelling that has been undertaken for North Falls Offshore Wind Farm, and the resultant assessment of effect to each of the marine mammal populations assessed.

1.2 Underwater noise modelling

2. Underwater noise modelling was carried out by Subacoustech Environmental Ltd to estimate the noise levels likely to arise during noisy activities, and determine the potential impacts on marine mammals using the INSPIRE v5.1 (Impulsive Noise Propagation and Impact Estimator) subsea noise propagation model (ES Appendix 12.3 (Document Reference: 3.3.8)). The INSPIRE model is a semi-empirical noise propagation model based on the use of a combination of numerical modelling and actual measured underwater noise data. It was designed to calculate the propagation of noise in shallow, mixed water, typical of both conditions around the UK. The INSPIRE model has been validated against over 80 datasets of underwater noise propagation from the monitoring of underwater noise at offshore piling activities. See Section 3 of ES Appendix 12.3 (Document Reference: 3.3.8) for more information on the validation process.
3. The modelling for piling considers a wide array of input parameters, including variations in bathymetry and source frequency content to ensure accurate results for the North Falls site. It should also be noted that the results presented in this assessment are precautionary, as the worst-case parameters have been selected for all relevant parameters, including;
   - Piling hammer energies;
   - Soft-start, ramp-up profiles, and strike rate;
   - The duration of piling; and
   - Receptor swim speeds.
4. The modelling for other noisy activities (including other construction activities, operation and maintenance activities, UXO clearance, and vessels) uses a simple modelling approach.

1.2.1 Methodology of underwater noise modelling

5. The key parameters used within the underwater noise modelling are described in detail below. More information can be found within ES Appendix 12.3 (Document Reference: 3.3.8).

1.2.1.1 Underwater noise

6. Sound measurements underwater are usually expressed using the decibel (dB) scale, which is a logarithmic measure of sound.
7. The sound pressure level (SPL) is normally used to characterise noise and vibration of a continuous nature. The variation in sound pressure can be measured

over a specific time period to determine the root mean square (RMS) level of the time varying acoustic pressure, therefore SPL (i.e. SPL_{RMS}) can be considered as a measure of the average unweighted level of the sound over the measurement period. Peak SPLs (SPL_{peak}) are often used to characterise sound transients from impulsive sources, such as percussive impact piling. A peak SPL is calculated using the maximum variation of the pressure from positive to zero within the wave. This represents the maximum change in positive pressure (differential pressure from positive to zero) as the transient pressure wave propagates.

8. The sound exposure level (SEL) sums the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound source and the duration for which the sound is present in the acoustic environment (further details are provided in Es Appendix 12.3 (Document Reference: 3.3.8)). SEL_{ss} is the potential sound exposure level from a single strike of the hammer, e.g. one hammer strike at the starting hammer energy or maximum hammer energy applied. SEL_{cum} is the cumulative sound exposure level during the total duration of piling, including the soft-start, and time required to complete the installation of the pile.

1.2.1.2 Piling locations

9. Modelling has been undertaken at three representative locations, covering the extent of the North Falls array area. These modelling locations include the deepest point of the sites (typically the worst-case location; i.e. the deepest location where piling can take place, which tends to give the greatest noise propagation) (; ES Appendix 12.3 (Document Reference: 3.3.8));

- East location;
    - Showing noise propagation to the east into the wider North Sea, with a water depth of 34.7m.
- South location;
    - At the most southern point of North Falls, with a water depth of 34m.
- West location;
    - At the north west corner of North Falls, with a water depth of 31.2m.

10. The assessments are based on the largest impact ranges modelled at any of these three locations (which was the East location in all cases), and was used to inform the assessment of the maximum potential impacts on receptor groups, in order to provide a conservative assessment.

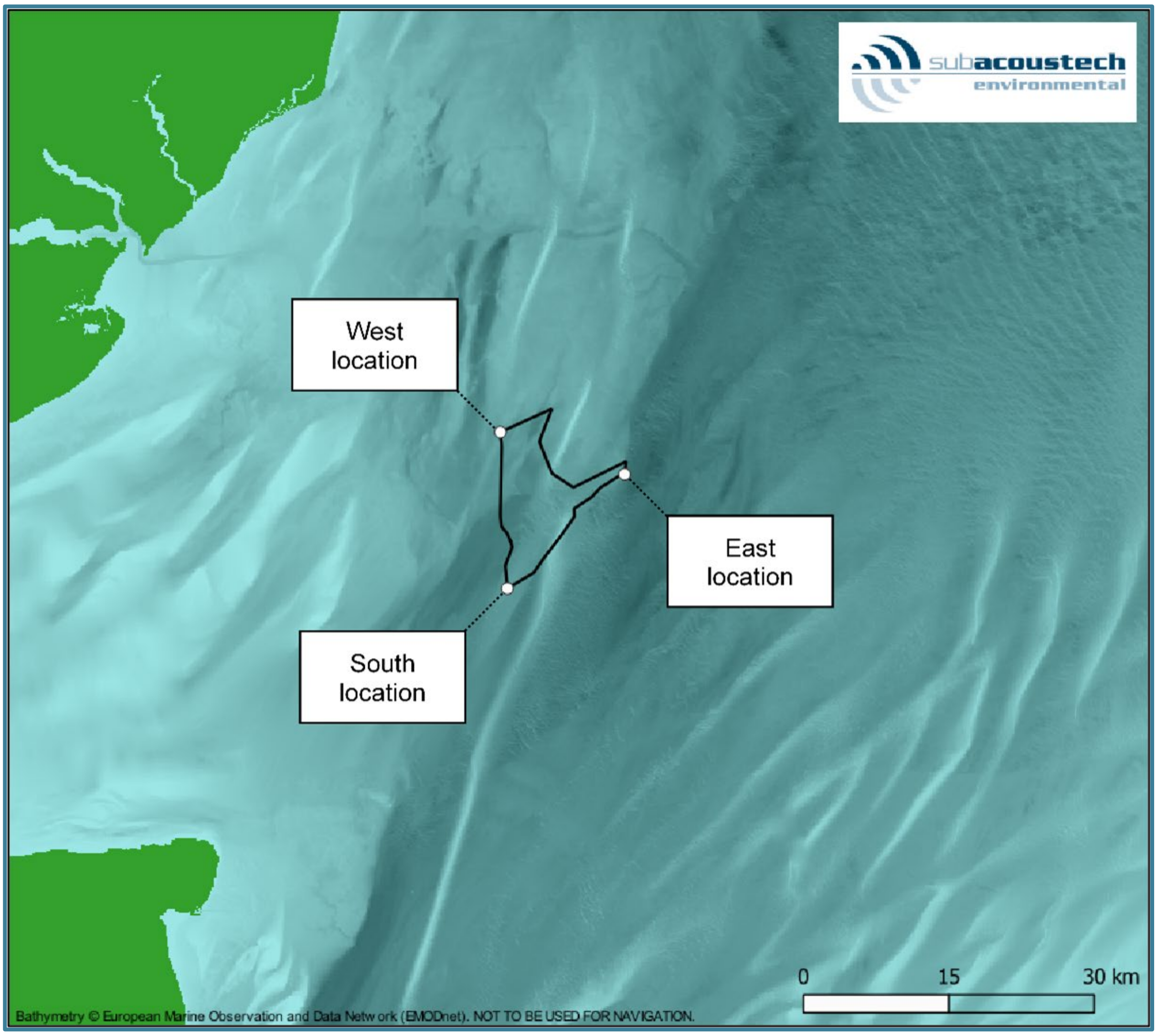

Plate 1.1 Underwater noise modelling locations (ES Appendix 12.3 (Document Reference: 3.3.8))

1.2.1.3 Soft-start and hammer energy profiles

11. The underwater noise modelling was based on the following worst-case scenarios for monopiles and pin piles;

- Monopile with a maximum diameter of up to 17m, a maximum hammer energy of up to 6,000 kilojoule (kJ), and a maximum starting hammer energy of 900kJ.
- Pin pile with a maximum diameter of up to 6m, a maximum hammer energy of up to 4,400kJ, and a maximum starting hammer energy of 660kJ.

12. To determine the potential for permanent auditory injury (Permanent Threshold Shift (PTS)) or temporary auditory injury (Temporary Threshold Shift (TTS)) from SEL_{cum}, the soft-start, hammer energy profile, total active piling duration, and strike rate are taken into account. The soft-start takes place over the first 10 minutes of piling, which includes low-energy blows (at the starting hammer energy), followed by a gradual increase (ramp-up) to the maximum hammer energy required to safely install the pile.

13. As a worst-case scenario, it is assumed that all piles installed will require 100% of the maximum hammer energy, however, maximum hammer energy is only likely to be required at a few of the piling installation locations, and for short periods of time.

14. The low-energy blows, ramp-up, and piling duration used to assess SEL_{cum} for both monopiles and pin piles are summarised in Table 1.1 and Table 1.2.

Table 1.1 Hammer energy, ramp-up and piling duration for monopiles

Hammer energy / piling parameters	900kJ	1,800 kJ	2,700 kJ	3,700kJ	4,800kJ	6,000 kJ	Total for pile
Hammer energy profile for monopiles							
Number of hammer strikes	100	600	600	600	600	10,880	13,380 strikes over a total duration of 7.5 hours [Or 40,140 strikes over a total duration of 22.5 hours for the maximum of 3 piles per 24 hours].
Duration of piling at each stage	10 minutes	30 minutes	30 minutes	30 minutes	30 minutes	320 minutes	
Strike rate	10 strikes / minute	20 strikes / minute				Approx. 34 strikes / minute	

Table 1.2 Hammer energy, ramp-up and piling duration for pin piles

Hammer energy / piling parameters	660kJ	1,320 kJ	1,980 kJ	2,640 kJ	3,520 kJ	4,400 kJ	Total for pile
Hammer energy profile for pin piles							
Number of hammer strikes	100	400	400	400	400	6,120	7,820 strikes over a total duration of 4.5 hours [Or 46,920 strikes over a total duration of 27 hours for 6 piles]*
Duration of piling at each stage	10 minutes	20 minutes	20 minutes	20 minutes	20 minutes	180 minutes	
Strike rate	10 strikes / minute	20 strikes / minute				Approx. 34 strikes / minute	

**As the underwater noise modelling is based on the cumulative noise over a 24 hour period, the jacket pin pile modelling is based on 24 hours of exposure*

1.2.1.4 Noise source levels

15. Underwater noise modelling requires knowledge of the source level, which is the theoretical noise level at 1m from the noise source. The INSPIRE noise propagation model assumes that the noise acts as a single point source. The source level is estimated based on the pile diameter and the hammer energy imparted on the pile by the hammer. This is then adjusted depending on the water

depth at the modelling location to allow for the length of pile in contact with the water, which can affect the amount of noise that is transmitted from the pile into its surroundings (further information is provided in ES Appendix 12.3 (Document Reference: 3.3.8)).

16. The unweighted SPL_{peak} and SEL_{ss} source levels estimated for this assessment are summarised in Table 1.3.

Table 1.3 Unweighted SPL_{peak} and SEL_{ss} source levels used in underwater noise modelling for monopiles and pin piles

Type of source levels	Modelling location	Monopile worst-case noise source level	Pin pile worst-case noise source level
Unweighted SPL_{peak}	East, South & West	243.0 dB re 1 μPa @ 1m	242.5 dB re 1 μPa @ 1m
Unweighted SEL_{ss}	East, South & West	224.2 dB re 1 $μPa^2s$ @ 1m	223.6 dB re 1 $μPa^2s$ @ 1m

1.2.1.5 Environmental conditions

17. The inclusion of measured data for similar offshore piling operations in UK waters allows the INSPIRE model to intrinsically account for various environmental conditions. This includes the differences that can occur with the temperature and salinity of water as well as the sediment type surrounding the site. Data from the European Marine Observation and Data Network (EMODnet) geology study show that the seabed surrounding North Falls is generally made up of sandy gravel.

18. Digital bathymetry, also from the EMODnet, has been used for this modelling, and mean tidal depth has been used throughout (ES Appendix 12.3 (Document Reference: 3.3.8)).

1.2.1.6 Sequential piling

19. Underwater noise modelling has been undertaken to cover the possible option for more than one pile to be installed, one after the other, in the same 24 hour period. The modelling was based on the worst-case for three monopiles installed sequentially, or six pin piles installed sequentially at each modelling location.

20. Due to the uncertainty of what a receptor will do between piling operations it has been assumed that any additional piling will occur immediately after the previous installation, with no pause.

21. A fleeing receptor, such as marine mammals, will have travelled away from the noise source by the time the second pile installation starts, and as such increases in noise level compared to a single installation are not as pronounced when compared to simultaneous piling (see ES Appendix 12.3 (Document Reference: 3.3.8) for further information).

1.2.1.7 Multiple location piling

22. To take into account the possibility of two piling vessels to be used for the construction of North Falls (and the potential for two simultaneous piling events to occur), underwater noise modelling has been undertaken, based on the following worst-case scenarios:

    - Three sequential monopile installations at the East location, at the same time as three monopile installations at the South location (six piles per day in total); and

- Six sequential pin pile installations at the East location, at the same time as six pin pile installations at the South location (twelve piles per day in total).

23. The multiple location piling modelling uses the East and South locations as the piling locations as they are the furthest apart, and would represent the worst-case in terms of potential cumulative exposure effect areas.

24. All modelling assumes that the piling operations start at the same time.

25. When considering SEL_{cum} modelling, piling from multiple sources has the ability to increase impact ranges and areas significantly, as it doubles the number of pile strikes (see ES Appendix 12.3 (Document Reference: 3.3.8) for further information).

1.2.1.8 Baseline noise levels

26. Ambient noise measurements for UK coastal waters indicates that noise levels are generally 95 to 120 dB re 1μPa (maximum third-octave band), with the peak noise levels occurring in the tens of Hertz (Hz), to 100s of Hz (Nedwell *et al.,* 2007; Theobald *et al.,* 2010; Robinson *et al.,* 2011).

27. During the piling operations at the Greater Gabbard Offshore Wind Farm (adjacent to the North Falls site) in 2009 and 2010, the ambient noise levels were also recorded (Theobald *et al.*, 2010). In 2009, the ambient noise levels were highest at less than 100Hz, at approximately 104 dB re 1 μPa^2 (Plate 1.2; Robinson *et al.,* 2009 *cited in* Theobald *et al*., 2013). The measurements taken therefore show noise levels that are of the same order as baseline noise levels sampled elsewhere in the North Sea, and so are considered to be typical and realistic.

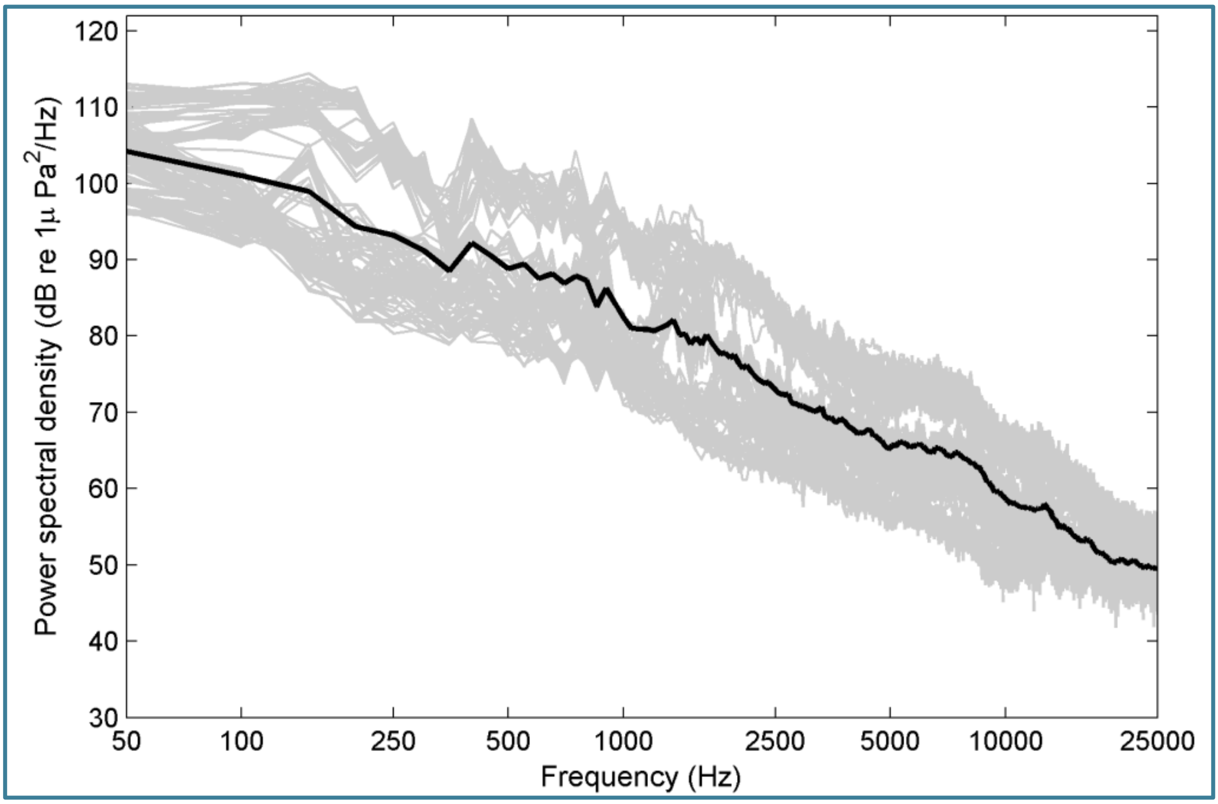

Plate 1.2 Ambient noise levels recorded at Greater Gabbard in July 2009 (Robinson *et al.*, 2009 *cited in* Theobald *et al.*, 2013)

1.2.1.9 Marine mammal impact thresholds

28. The metrics and criteria that have been used to assess the potential impact of underwater noise on marine mammals are based on, at the time of writing, the most up to date publications and recommended guidance.

29. Southall *et al.* (2019) present unweighted peak criteria (SPL_{peak}) for single strike, weighted sound exposure criteria for single strike (SEL_{ss}) and cumulative (i.e. more than a single sound impulse) weighted sound exposure criteria (SEL_{cum}) for both permanent auditory injury (PTS), where unrecoverable reduction in hearing sensitivity may occur, and for temporary auditory injury (TTS), where a temporary reduction in hearing sensitivity may occur.

30. Southall *et al.* (2019) categorises marine mammal species into hearing groups and applies filters to the unweighted noise to approximate for the specific hearing abilities and sensitivities of each group. This provided the weighted SEL criteria, which corrects the sound level based on the sensitivity of the receiver, for example, harbour porpoise *Phocoena phocoena* are less sensitive to low frequency sound than minke whales.

31. Southall *et al.* (2019) also includes criteria based on SPL_{peak}, which are unweighted and do not take species sensitivity into account. It is important to note that they are different criteria and as such they should not be compared directly. All decibel SPL values are referenced to 1µPa and all SEL values are referenced to $1µPa^2s$. Assessments have been based on the criteria with the greatest predicted impact ranges.

32. Note that the Southall *et al.* (2019) Marine Mammal Noise Exposure Criteria are the same as the National Marine and Fisheries Service (NMFS) (2018) criteria, although the names of the species groupings are different. The species groupings used in Southall *et al.* (2019), and therefore referred to in the underwater noise modelling report (ES Appendix 12.3 (Document Reference: 3.3.8)) are;

- LF = low-frequency cetaceans;
  - Including all baleen whales (such as minke whale *Balaenoptera acutorostrata*).
- HF = high-frequency cetaceans;
  - Including all dolphin species, toothed whales, beaked whales, and bottlenose whales.
- VHF = very high-frequency cetaceans; and
  - Including porpoise species (such as harbour porpoise).
- PCW = phocid carnivores in water;
  - Including all true seals (such as grey seal *Halichoerus grypus* and harbour seal *Phoca vitulina*).

33. The Southall *et al.* (2019) thresholds and criteria used in the assessments are summarised in Table 1.4.

Table 1.4 Southall *et al.* (2019) thresholds and criteria used in the underwater noise modelling and assessments

Marine mammal species group	Impulsive thresholds		Non-impulsive thresholds	
	PTS	TTS	PTS	TTS
Unweighted SPL_{peak} (dB re 1 µPa)				
LF	219	213	-	-
HF	230	224	-	-
VHF	202	196	-	-
PCW	218	212	-	-
Weighted SEL_{cum} (dB re 1 µPa^{2}s)				
LF	183	168	199	179
HF	185	170	198	178
VHF	155	140	173	153
PCW	185	170	201	181

34. The Southall *et al*. (2019) criterion are based on whether the noise source is considered to be impulsive or non-impulsive. Impulsive noises are defined as having high peak sound pressure, a short duration, fast rise-time and broad frequency content at source, and non-impulsive sources as steady-state noise. Explosives, impact piling and seismic airguns are considered impulsive noise sources, while sonars, vibro-piling, drilling and other low-level continuous noises are considered non-impulsive. However, a non-impulsive noise does not necessarily have to have a long duration.

35. As sound pulses propagate through the environment and dissipate, they lose their most injurious characteristics (e.g. rapid pulse rise time and high peak sound pressure) and become more like a “non-pulse” at greater distances. Active research is currently underway into the identification of the distance at which the pulse can be considered effectively non-impulsive (see ES Appendix 12.3 (Document Reference: 3.3.8)), with one study finding that most impulsive noise signals analysed were considered to be impulsive at 3.5km form the source (Hastie *et al*., 2019). Both impulsive and non-impulsive criteria from Southall *et al.* (2019) have been included in the underwater noise modelling, however assessments have been based on the criteria with the greatest predicted impact ranges. While work in this field is ongoing, when reviewing the results of this underwater noise modelling, it should be considered that where impulsive noise ranges are considerably higher than 3.5km, the non-impulsive impact range is likely to be more appropriate.

1.2.1.10 Fleeing receptors

36. To determine SEL_{cum} ranges for marine mammals, a fleeing animal model has been used. This assumes that the animal exposed to high noise levels will swim away from the noise source.

37. For this, a constant swimming speed of 3.25 metres per second (m/s) has been assumed for minke whale (Blix and Folkow, 1995), and as a precautionary approach for all other species a constant swimming speed of 1.5m/s has been used, based on the average swimming speed for harbour porpoise mother calf pairs (Otani *et al.,* 2000). This is considered a ‘worst-case’ scenario as marine mammals are expected to be able to swim faster. Further details on how SEL_{cum} is modelled is provided in ES Appendix 12.3 (Document Reference: 3.3.8).

38. For the results of the SEL_{cum} modelling, the impact ranges presented can be considered to be a starting position that the animal would have to be (at the onset of piling) to not be exposed to the relevant impact. For example, if the animal began to flee in a straight line (and at the fleeing speeds as outlined above) from the noise source, the impact range would represent the range at which that animal would need to be exposed to noise levels to induce the relevant impact as per the thresholds as outlined in Section 1.2.1.9. Further explanation is provided in ES Appendix 12.3 (Document Reference: 3.3.8), and Plate 1.3 illustrates this effect.

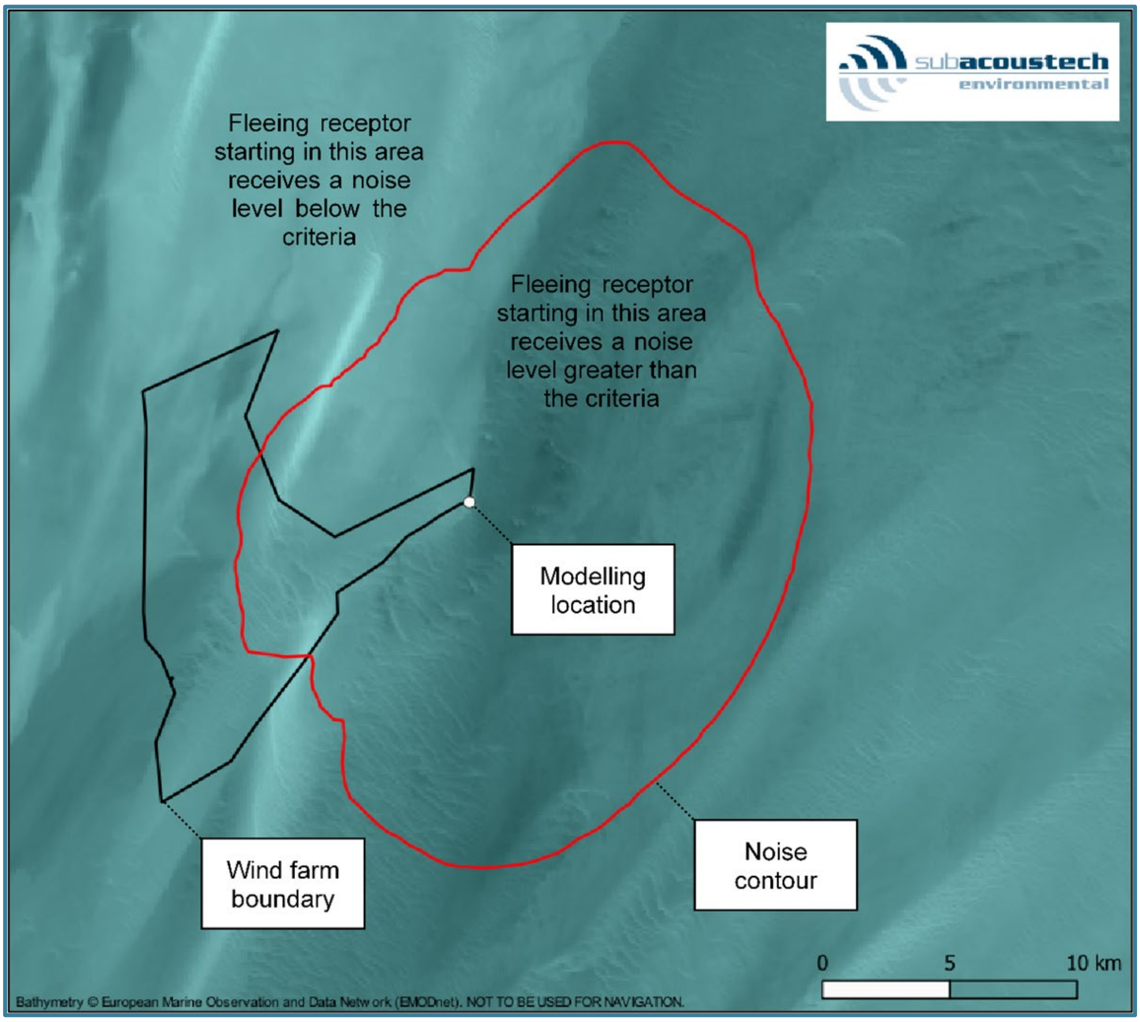

Plate 1.3 Example of the effect of fleeing on the exposure to cumulative underwater noise (ES Appendix 12.3 (Document Reference: 3.3.8))

1.2.2 Assumptions and limitations

39. It should be noted and taken into account that the underwater noise modelling and assessment is based on 'worst-case' scenarios and precautionary approaches, this includes, but is not limited to:

- The maximum hammer energy to be applied and maximum piling duration is assumed for all piling locations; however, it is unlikely that maximum hammer energy applied and duration will be required at the majority of piling locations.
- The maximum predicted impact ranges are based on the location with the greatest potential noise propagation range and this was assumed as the worst-case for each piling location.
- Impact ranges modelled for a single strike are from the piling location and do not take into account (i) the distance marine mammals could move away from the piling location during mitigation measures, such as the use of Acoustic Deterrent Devices (ADDs) to move marine mammals out of the area where there could be a risk of physical or auditory injury; or (ii) the

potential disturbance and movement of marine mammals away from the site as a result of the vessels and set-up prior to mitigation.

- The assumption that fleeing animals (harbour porpoise, grey seal and harbour seal) are swimming at a constant speed of 1.5m/s (based on swimming speed of harbour porpoise mother calf pairs; Otani *et al.,* 2000), however, marine mammals are expected to swim much faster.
    - For example, harbour porpoise have been recorded swimming at speeds of up to 4.3m/s (Otani *et al.,* 2000), and the swimming speed of a harbour porpoise during playbacks of pile driving sounds (SPL of 154 dB re 1µPa) was 1.97m/s (7.1km/h), and during quiet baseline periods the mean swimming speed was 1.2m/s (4.3km/h; Kastelein *et al.,* 2018).
- The assumption that animals are submerged 100% of the time, which does not account for any time that an individual may spend at the surface or the reduced SELs near the surface where the animal would not be exposed to such high levels, or for seals having their head out of the water.

40. Underwater noise modelling assumes that marine mammals will travel in the mid-water column where sound pressure levels are greatest. However, in reality animals would not be subjected to these high sound pressure levels at all times since they are likely to move up and down through the water column, and surface to breathe, where the sound pressure would drop to zero. A study by Teilmann *et al.* (2007) on diving behaviour of harbour porpoise in Danish waters suggests that animals spent 55% of their time in the upper 2m of the water column from April to August, and over the whole year they spent 68% of their time in less than 5m depth. However, it should be noted that this study was conducted for “undisturbed” animals, which could show a different behaviour.

41. The swimming patterns of harbour porpoise undertaking direct travel are typically characterised by short submergence periods, compared to feeding animals (Watson and Gaskin, 1983). These short duration dives with horizontal travel suggest that travelling animals, such as harbour porpoise moving away from pile driving noise, would swim in the upper part of the water column. It would be anticipated, that during a fleeing response, from a loud underwater noise, such as piling, that their swimming behaviour may change with a reduction in deep dives. For example, during pile driving playback sounds to examine TTS, harbour porpoise showed behaviour response during the exposure periods, which included increased swimming speeds and jumping out of the water more (Kastelein *et al.,* 2016).

42. Noise impact assessments assume that all animals within the noise contour may be affected to the same degree for the maximum worst-case scenario. For example, that all animals exposed to noise levels that induce behavioural avoidance will be displaced, or all animals exposed to noise levels that are predicted as inducing PTS or TTS will suffer permanent or temporary auditory injury, respectively. However, a study looking at the proportion of trials at different SELs that result in TTS in exposed bottlenose dolphins suggests that to induce TTS in 50% of animals, it would be necessary to extrapolate well beyond the range of measured SEL levels (Finneran *et al.,* 2005). This suggests that for a given species, the likely significant effects follow a dose-response curve such that the

probability of inducing TTS will decrease moving further away from the SEL threshold required to induce TTS. Further work by Thompson *et al.* (2013) has adopted this dose-response curve to produce a theoretical dose-response for PTS in harbour seal by scaling up Finneran *et al.* (2005) dose response curve for changes in levels of TTS at different SEL, where the probability of seals experiencing PTS increases from an SEL of 186 up to 240 dB re 1 μPa^{2}s; the point at which all animals are predicted to have PTS.

43. The soft-start and ramp-up is included as embedded mitigation. The soft-start begins with a lower hammer energy before reaching maximum hammer energy, with the assumption that marine mammals will move out of the area as the hammer energy is increased, and before there is the increased risk of PTS from the maximum hammer energy. However, research around the installation of jacket foundations in the Moray Firth found that received levels at any given distance were highest at low hammer energies (Thompson *et al.,* 2020). Modelling highlighted that this was because noise from pin pile installations was dominated by the strong negative relationship with pile penetration depth, with only a weak positive relationship with hammer energy (Thompson *et al.,* 2020). Although the responses to ADD play-back indicated that disturbance was beyond that required to mitigate injury (Thompson *et al.,* 2020).

1.3 Assessment of underwater noise effects from piling

44. The following sections provide the results of the underwater noise modelling (ES Appendix 12.3 (Document Reference: 3.3.8)), and the subsequent assessment for each marine mammal species. All assessments are undertaken based on the area of effect for permanent auditory injury (PTS) and temporary auditory injury (TTS), the density of each species (as outlined in ES Appendix 12.2 (Document Reference: 3.3.7) and Section 12.4 of ES Chapter 12 Marine Mammals (Document Reference: 3.1.14)), and the percentage of the reference populations with the potential to be affected. The potential magnitudes of effect (as outlined in Section 12.3 of ES Chapter 12 Marine Mammals (Document Reference: 3.1.14)) are then applied, to produce the overall magnitude of effect for each underwater noise impact and receptor.

45. The following sections include the assessments for all species densities estimates.

1.3.1 Assessment for a permanent auditory injury (PTS)

1.3.1.1 Assessment of the potential for permanent auditory injury (PTS) from monopiles at a single piling location

46. Table 1.5 to Table 1.9 below provide the assessments for the potential of PTS onset due to monopile installation.

47. Table 1.5 provides the assessment for potential for PTS onset at the starting hammer energy of 900kJ for monopiles, and

48. Table 1.6 includes the assessment of the potential for PTS onset of a single monopile strike at the maximum hammer energy of 6,000kJ.

49. Table 1.7 includes an assessment of the potential for PTS onset due to the cumulative exposure of one monopile installation, and Table 1.8 includes the assessment for the potential for PTS onset due to the cumulative exposure of three monopile installations in one 24 hour period.

Table 1.5 Underwater noise assessment for the potential of PTS onset from a single strike from the starting hammer energy of a monopile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.31	0.29	0.7 harbour porpoise (0.0002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.31**	**0.29**	**0.9 harbour porpoise (0.0003% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.31	0.29	0.5 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.31	0.29	0.09 harbour porpoise (0.00003% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.05**	**0.01**	**0.0002 minke whale (0.000001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.05	0.01	0.00001 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.05	0.01	0.00002 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.05**	**0.01**	**0.0007 grey seal (0.000002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.05**	**0.01**	**0.0007 grey seal (0.000001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.05**	**0.01**	**0.000005 harbour seal (0.0000001% of the SE E MU reference population)**	**Negligible**

Table 1.6 Underwater noise assessment for the potential of PTS onset from a single strike from the maximum hammer energy of a monopile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km²)	Reference population	Impact range (km)	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.68	1.4	4 harbour porpoise (0.001% of the NS MU reference population)	Low
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.68**	**1.4**	**5 harbour porpoise (0.001% of the NS MU reference population)**	**Low**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.68	1.4	3 harbour porpoise (0.0007% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.68	1.4	0.4 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.05**	**0.01**	**0.0002 minke whale (0.000001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.,* 2019 annual density estimate for array area)	0.0011	20,118	0.05	0.01	0.00001 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.,* 2019 summer density estimate for array area)	0.0015	20,118	0.05	0.01	0.00002 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.06**	**0.01**	**0.0007 grey seal (0.000002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.06**	**0.01**	**0.0007 grey seal (0.000001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.06**	**0.01**	**0.000005 harbour seal (0.0000001% of the SE E MU reference population)**	**Negligible**

Table 1.7 Underwater noise assessment for the potential of PTS onset from the cumulative exposure from the installation of one monopile in a 24 hour period (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	3.3	22.0	54 harbour porpoise (0.02% of the NS MU reference population)	Medium
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**3.3**	**22.0**	**71 harbour porpoise (0.02% of the NS MU reference population)**	Medium
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	3.3	22.0	37 harbour porpoise (0.01% of the NS MU reference population)	Medium
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	3.3	22.0	7 harbour porpoise (0.002% of the NS MU reference population)	Low
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**7.0**	**94.0**	**2 minke whale (0.0099% of the CGNS MU reference population)**	**Low**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	7.0	94.0	0.1 minke whale (0.0005% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array areas)	0.0015	20,118	7.0	94.0	0.1 minke whale (0.0007% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.1**	**0.1**	**0.007 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.1**	**0.1**	**0.007 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.1**	**0.1**	**0.00005 harbour seal (0.000001% of the SE E MU reference population)**	**Negligible**

Table 1.8 Underwater noise assessment for the potential of PTS onset from the cumulative exposure from the installation of three monopiles in a 24 hour period (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	3.3	22.0	54 harbour porpoise (0.02% of the NS MU reference population)	Medium
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**3.3**	**22.0**	**71 harbour porpoise (0.02% of the NS MU reference population)**	**Medium**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	3.3	22.0	37 harbour porpoise (0.01% of the NS MU reference population)	Medium
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	3.3	22.0	7 harbour porpoise (0.002% of the NS MU reference population)	Low
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**7.0**	**94.0**	**2 minke whale (0.0099% of the CGNS MU reference population)**	**Low**
Minke whale (Waggitt *et al.,* 2019 annual density estimate for array area)	0.0011	20,118	7.0	94.0	0.1 minke whale (0.0005% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.,* 2019 summer density estimate for array area)	0.0015	20,118	7.0	94.0	0.1 minke whale (0.0007% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.1**	**0.1**	**0.007 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.1**	**0.1**	**0.007 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.1**	**0.1**	**0.00005 harbour seal (0.000001% of the SE E MU reference population)**	**Negligible**

1.3.1.2 Assessment of the potential for permanent auditory injury (PTS) from monopiles at due to simultaneous piling at multiple pile locations

50. This section outlines the effect of simultaneous monopile installations (at the same time), at the East and South modelling locations. Plate 1.4 shows the results of the modelling, and Table 1.9 provides the assessment of the potential for PTS onset due to the cumulative exposure of three monopile installations at the same time.

51. The simultaneous piling scenario assumes that animals that are within potential impact ranges for a much longer period (i.e. they would be travelling from one pile location to another), and therefore cumulative effect ranges are much larger than for the cumulative exposure ranges of one monopile at a time.

52. The potential impact ranges are not possible to model under this scenario, as there are two starting points for receptors, and it is not possible to determine the potential range at which they need to be in order to not be at risk of effect. Therefore, the following assessment is based on the potential areas of effect.

53. Where the potential impact areas are not large enough to interact with each other, they have not been included in the results of the modelling (as the results for the respective locations and scenarios can be used).

54. The potential for PTS onset due to simultaneous monopile installations did not interact for seal species (Plate 1.4), and therefore they have not been included in Table 1.9.

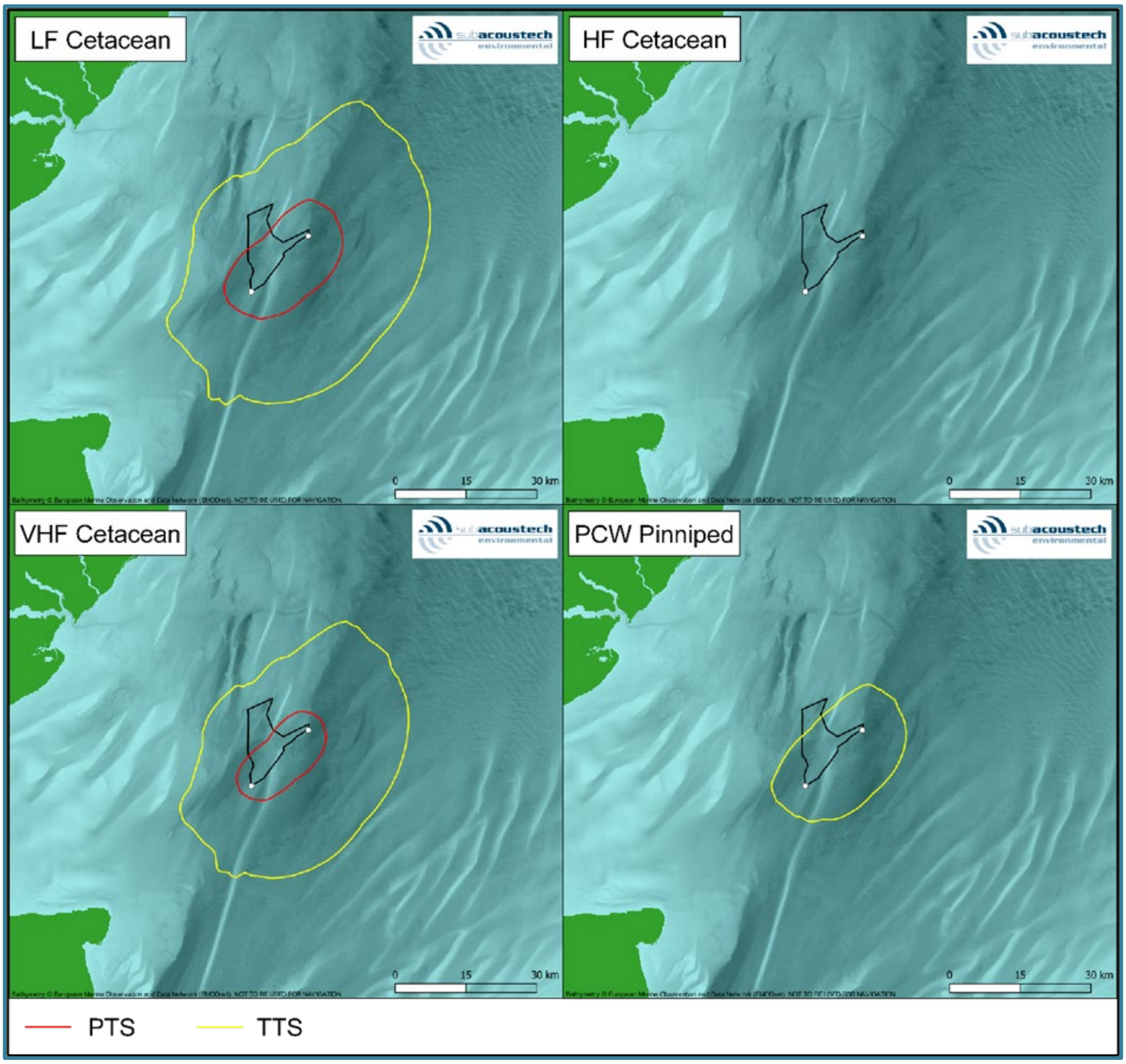

Plate 1.4 Contour plots for PTS (shown in red) and TTS onset (shown in yellow) due to the simultaneous installation of three sequential monopiles at the East and South modelling locations (ES Appendix 12.3 (Document Reference: 3.3.8))

Table 1.9 Underwater noise assessment for the potential of PTS onset from cumulative exposure of the installation of three sequential monopiles, at two simultaneous locations (SEL_{cum}) at the furthest apart modelling locations (East and South), for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	210.0	**513** harbour porpoise (0.2% of the NS MU reference population)	Medium
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**210.0**	**676 harbour porpoise (0.2% of the NS MU reference population)**	**Medium**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	210.0	350 harbour porpoise (0.1% of the NS MU reference population)	Medium
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	210.0	65 harbour porpoise (0.02% of the NS MU reference population)	Medium
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**390.0**	**6 minke whale (0.03% of the CGNS MU reference population)**	**Medium**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	390.0	0.4 minke whale (0.002% of the CGNS MU reference population)	Low
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	390.0	0.6 minke whale (0.003% of the CGNS MU reference population)	Low

1.3.1.3 Assessment of the potential for permanent auditory injury (PTS) from pin piles at a single piling location

55. Table 1.10 to Table 1.13 below provide the assessments for the potential of PTS onset due to pin pile installation.

56. Table 1.10 provides the assessment of the potential for PTS onset for a single strike at the start hammer energy of 660kJ for pin piles, and Table 1.11 includes the assessment of the potential for PTS onset of a single pin pile strike at the maximum hammer energy of 4,400kJ.

57. Table 1.12 includes an assessment of the potential for PTS onset due to the cumulative exposure of one pin pile installation, and Table 1.13 includes the assessment for the potential for PTS onset due to the cumulative exposure of six pin pile installations in one 24 hour period.

Table 1.10 Underwater noise assessment for the potential of PTS onset from a single strike from the starting hammer energy of a pin pile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.24	0.17	0.4 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.24**	**0.17**	**0.5 harbour porpoise (0.0002% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.24	0.17	0.3 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.24	0.17	0.05 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.05**	**0.01**	**0.0002 minke whale (0.000001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.05	0.01	0.00001 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.05	0.01	0.00002 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.05**	**0.01**	**0.0007 grey seal (0.000002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.05**	**0.01**	**0.0007 grey seal (0.000001% of the wider reference population)**	**Negligible**

Species scenario	Density (/km²)	Reference population	Impact range (km)	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.05**	**0.01**	**0.000005 harbour seal (0.0000001% of the SE E MU reference population)**	**Negligible**

Table 1.11 Underwater noise assessment for the potential of PTS onset from a single strike from the maximum hammer energy of a pin pile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km²)	Reference population	Impact range (km)	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.63	1.2	3 harbour porpoise (0.001% of the NS MU reference population)	Low
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.63**	**1.2**	**4 harbour porpoise (0.001% of the NS MU reference population)**	**Low**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.63	1.2	2 harbour porpoise (0.001% of the NS MU reference population)	Low
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.63	1.2	0.4 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.05**	**0.01**	**0.0002 minke whale (0.000001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.05	0.01	0.00001 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.05	0.01	0.00002 minke whale (0.00000001% of the CGNS MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.05**	**0.01**	**0.0007 grey seal (0.000002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.05**	**0.01**	**0.0007 grey seal (0.000001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.05**	**0.01**	**0.000005 harbour seal (0.000001% of the SE E MU reference population)**	**Negligible**

Table 1.12 Underwater noise assessment for the potential of PTS onset from the cumulative exposure from the installation of one pin pile in a 24 hour period (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	3.3	22.0	54 harbour porpoise (0.02% of the NS MU reference population)	Medium
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**3.3**	**22.0**	**71 harbour porpoise (0.02% of the NS MU reference population)**	Medium
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	3.3	22.0	37 harbour porpoise (0.01% of the NS MU reference population)	Medium
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	3.3	22.0	7 harbour porpoise (0.002% of the NS MU reference population)	Low
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**6.9**	**85.0**	**2 minke whale (0.0099% of the CGNS MU reference population)**	**Low**
Minke whale (Waggitt *et al.,* 2019 annual density estimate for array area)	0.0011	20,118	6.9	85.0	0.09 minke whale (0.0005% of the CGNS MU reference population)	Negligible

Species scenario	Density (/km²)	Reference population	Impact range (km)	Impact area (km²)	Assessment of effect	Magnitude of effect
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	6.9	85.0	0.1 minke whale (0.0006% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.1**	**0.1**	**0.007 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.1**	**0.1**	**0.007 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.1**	**0.1**	**0.00005 harbour seal (0.000001% of the SE E MU reference population)**	**Negligible**

Table 1.13 Underwater noise assessment for the potential of PTS onset from the cumulative exposure from the installation of six pin piles in a 24 hour period (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km²)	Reference population	Impact range (km)	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	3.4	23.0	57 harbour porpoise (0.02% of the NS MU reference population)	Medium
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**3.4**	**23.0**	**74 harbour porpoise (0.02% of the NS MU reference population)**	**Medium**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	3.4	23.0	39 harbour porpoise (0.01% of the NS MU reference population)	Medium
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	3.4	23.0	8 harbour porpoise (0.002% of the NS MU reference population)	Low
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**6.9**	**85.0**	**2 minke whale (0.009% of the CGNS MU reference population)**	**Low**

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Minke whale (Waggitt *et al.,* 2019 annual density estimate for array area)	0.0011	20,118	6.9	85.0	0.09 minke whale (0.0005% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.,* 2019 summer density estimate for array area)	0.0015	20,118	6.9	85.0	0.1 minke whale (0.0006% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.1**	**0.1**	**0.007 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.1**	**0.1**	**0.007 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.1**	**0.1**	**0.00005 harbour seal (0.000001% of the SE E MU reference population)**	**Negligible**

1.3.1.4 Assessment of the potential for permanent auditory injury (PTS) from pin piles at multiple pile locations

58. This section outlines the effect of simultaneous pin pile installations (at the same time), at the East and South modelling locations. Plate 1.5 shows the results of the modelling for pin piles, and Table 1.14 provides the assessment of the potential for PTS onset due to the cumulative exposure of six pin pile installations at the same time.

59. The potential for PTS onset due to simultaneous pin pile installations did not interact for seal species (Plate 1.5), and therefore they have not been included in Table 1.14.

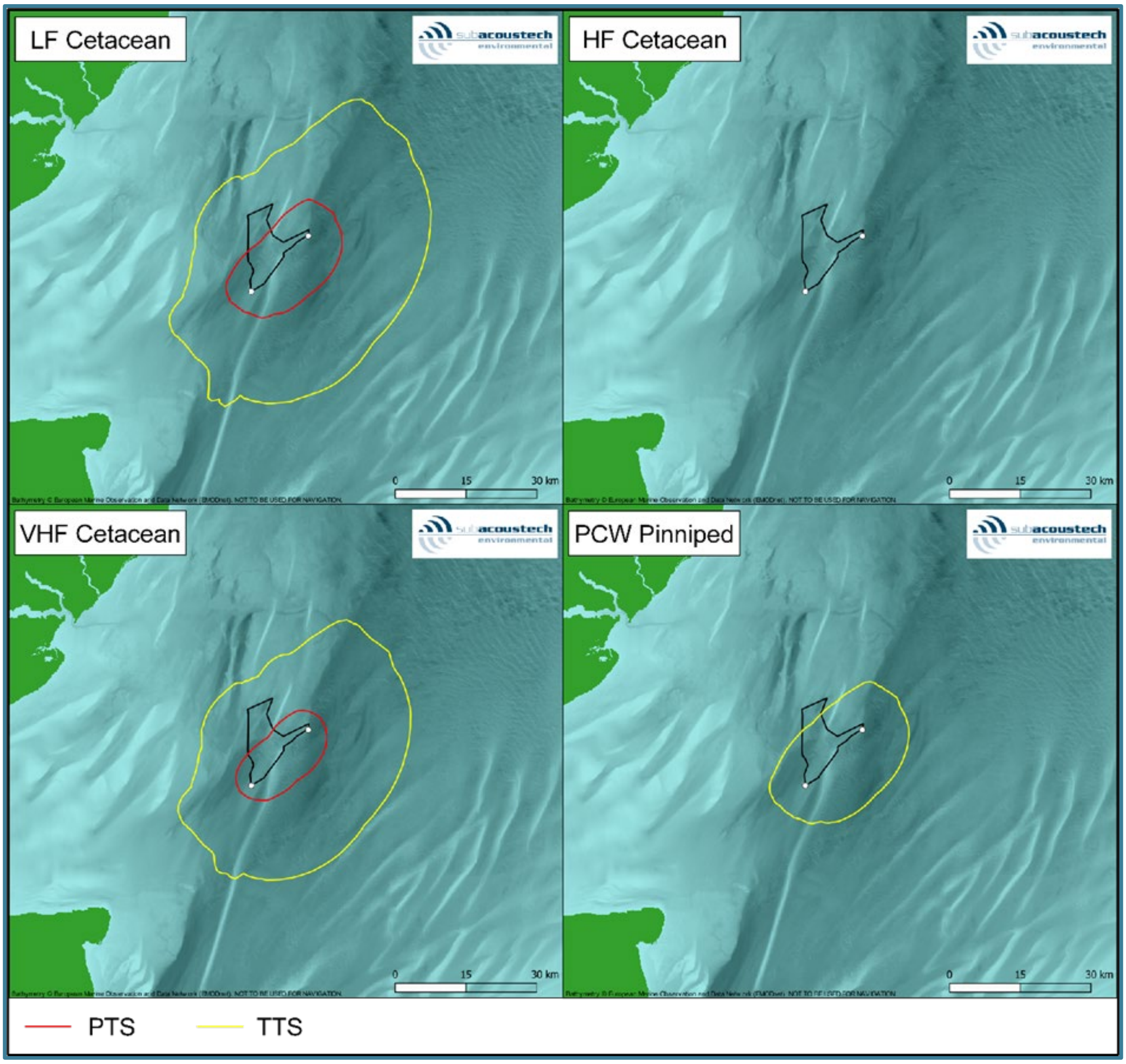

Plate 1.5 Contour plots for PTS (shown in red) and TTS onset (shown in yellow) due to the simultaneous installation of six pin piles at both the East and South modelling locations (Appendix 12.3 (Document Reference: 3.3.8))

Table 1.14 Underwater noise assessment for the potential of PTS onset from the cumulative exposure of six sequential pin piles installed at two simultaneous locations (SEL_{cum}) at the furthest apart modelling locations (East and South) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km²)	Reference population	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	230.0	562 harbour porpoise (0.2% of the NS MU reference population)	Medium
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**230.0**	**740 harbour porpoise (0.2% of the NS MU reference population)**	**Medium**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	230.0	383 harbour porpoise (0.1% of the NS MU reference population)	Medium
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	230.0	72 harbour porpoise (0.02% of the NS MU reference population)	Medium
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**380.0**	**6 minke whale (0.03% of the CGNS MU reference population)**	**Medium**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	380.0	0.4 minke whale (0.002% of the CGNS MU reference population)	Low
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	380.0	0.6 minke whale (0.003% of the CGNS MU reference population)	Low

1.3.2 Assessment for a temporary auditory injury (TTS)

1.3.2.1 Assessment of the potential for temporary auditory injury (TTS) from monopiles at a single piling location

60. Table 1.15 to Table 1.18 below provide the assessments for the potential of TTS onset due to monopile installation.

61. Table 1.15 provides the assessment for the potential for TTS onset due to a single strike of the starting hammer energy for a monopile, and Table 1.16 includes the assessment of the potential for TTS onset of a single monopile strike at the maximum hammer energy of 6,000kJ.

62. Table 1.17 includes an assessment of the potential for TTS onset due to the cumulative exposure of one monopile installation, and Table 1.18 includes the assessment for the potential for TTS onset due to the cumulative exposure of three monopile installations in one 24 hour period.

Table 1.15 Underwater noise assessment for the potential of TTS onset from a single strike from the starting hammer energy of a monopile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in Es Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.79	1.9	5 harbour porpoise (0.001% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.79**	**1.9**	**7 harbour porpoise (0.002% of the NS MU reference population)**	Negligible
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.79	1.9	4 harbour porpoise (0.001% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.79	1.9	0.6 harbour porpoise (0.0002% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.06**	**0.01**	**0.0002 minke whale (0.000001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.06	0.01	0.00001 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.06	0.01	0.00002 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.07**	**0.01**	**0.0007 grey seal (0.000002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.07**	**0.01**	**0.0007 grey seal (0.000001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.07**	**0.01**	**0.000005 harbour seal (0.0000001% of the SE E MU reference population)**	**Negligible**

Table 1.16 Underwater noise assessment for the potential of TTS onset from a single strike from the maximum hammer energy of a monopile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	1.7	8.2	21 harbour porpoise (0.006 of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**1.7**	**8.2**	**27 harbour porpoise (0.01% of the NS MU reference population)**	Negligible
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	1.7	8.2	14 harbour porpoise (0.004% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	1.7	8.2	3 harbour porpoise (0.001% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.12**	**0.05**	**0.0008 minke whale (0.000004% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.12	0.05	0.00006 minke whale (0.0000003% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.12	0.05	0.00008 minke whale (0.0000004% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.14**	**0.06**	**0.004 grey seal (0.00001% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.14**	**0.06**	**0.004 grey seal (0.000007% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.14**	**0.06**	**0.00003 harbour seal (0.0000006% of the SE E MU reference population)**	**Negligible**

Table 1.17 Underwater noise assessment for the potential of TTS onset from the cumulative exposure of one monopile installation in a 24 hour period (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	24.0	1,000.0	2,441 harbour porpoise (0.7% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**24.0**	**1,000.0**	**3,217 harbour porpoise (0.9% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	24.0	1,000.0	1,665 harbour porpoise (0.5% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	24.0	1,000.0	310 harbour porpoise (0.09% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**30.0**	**1,600.0**	**25 minke whale (0.12% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	30.0	1,600.0	2 minke whale (0.01% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	30.0	1,600.0	3 minke whale (0.01% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**9.0**	**160.0**	**12 grey seal (0.04% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**9.0**	**160.0**	**12 grey seal (0.02% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**9.0**	**160.0**	**0.08 harbour seal (0.002% of the SE E MU reference population)**	**Negligible**

Table 1.18 Underwater noise assessment for the potential of TTS onset from the cumulative exposure of three monopile installations in a 24 hour period (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	24.0	1,000.0	2,441 harbour porpoise (0.7% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**24.0**	**1,000.0**	**3,217 harbour porpoise (0.9% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	24.0	1,000.0	1,665 harbour porpoise (0.5% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	24.0	1,000.0	310 harbour porpoise (0.09% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**30.0**	**1,600.0**	**25 minke whale (0.12% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.,* 2019 annual density estimate for array area)	0.0011	20,118	30.0	1,600.0	2 minke whale (0.01% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.,* 2019 summer density estimate for array area)	0.0015	20,118	30.0	1,600.0	3 minke whale (0.01% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**9.0**	**160.0**	**12 grey seal (0.04% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**9.0**	**160.0**	**12 grey seal (0.02% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**9.0**	**160.0**	**0.08 harbour seal (0.002% of the SE E MU reference population)**	**Negligible**

1.3.2.2 Assessment of the potential for temporary auditory injury (TTS) from monopiles at multiple pile locations

63. This section outlines the effect of simultaneous monopile installations (at the same time), at the East and South modelling locations. Plate 1.4 shows the results of the modelling for monopiles, and Table 1.19 provides the assessment of the potential for TTS onset due to the cumulative exposure of three monopile installations at the same time.

Table 1.19 Underwater noise assessment for the potential of TTS onset from the cumulative exposure of three sequential monopile installations at two simultaneous locations (SEL_{cum}) at the furthest apart modelling locations (East and South) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	1,800.0	4,394 harbour porpoise (1.3% of the NS MU reference population)	Low
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**1,800.0**	**5,791 harbour porpoise (1.7% of the NS MU reference population)**	**Low**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	1,800.0	2,997 harbour porpoise (0.9% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	1,800.0	558 harbour porpoise (0.16% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**2,400.0**	**37 minke whale (0.18% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	2,400.0	3 minke whale (0.01% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	2,400.0	4 minke whale (0.02% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**530.0**	**38 grey seal (0.12% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**530.0**	**38 grey seal (0.07% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**530.0**	**0.3 harbour seal (0.005% of the SE E MU reference population)**	**Negligible**

1.3.2.3 Assessment of the potential for temporary auditory injury (TTS) from pin piles at a single piling location

64. Table 1.20 to Table 1.23 below provide the assessments for the potential of TTS onset due to pin pile installation.

65. Table 1.20 provides the assessment for TTS onset due to a single strike of the starting hammer energy of pin piles, and Table 1.21 includes the assessment of the potential for TTS onset of a single pin pile strike at the maximum hammer energy of 4,400kJ.

66. Table 1.22 includes an assessment of the potential for TTS onset due to the cumulative exposure of one pin pile installation, and Table 1.23 includes the assessment for the potential for TTS onset due to the cumulative exposure of three monopile installations in one 24 hour period.

Table 1.20 Underwater noise assessment for the potential of TTS onset from the single strike at the starting hammer energy of a pin pile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in Es Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.61	1.1	**3** harbour porpoise (0.0008% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.61**	**1.1**	**4 harbour porpoise (0.001% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.61	1.1	2 harbour porpoise (0.0005% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.61	1.1	0.3 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.05**	**0.01**	**0.0002 minke whale (0.000001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.05	0.01	0.00001 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.05	0.01	0.00002 minke whale (0.0000001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.05**	**0.01**	**0.0007 grey seal (0.000002% of the SE E MU reference population)**	**Negligible**

Species scenario	Density (/km²)	Reference population	Impact range (km)	Impact area (km²)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.05**	**0.01**	**0.0007 grey seal (0.000001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.05**	**0.01**	**0.000005 harbour seal (0.0000001% of the SE E MU reference population)**	**Negligible**

Table 1.21 Underwater noise assessment for the potential of TTS onset from the single strike at the maximum hammer energy of a pin pile (SPL_{peak}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km²)	Reference population	Impact range (km)	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	1.6	7.1	18 harbour porpoise (0.005% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**1.6**	**7.1**	**23 harbour porpoise (0.007% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	1.6	7.1	12 harbour porpoise (0.003% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	1.6	7.1	3 harbour porpoise (0.0009% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.11**	**0.04**	**0.006 minke whale (0.000003% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.11	0.04	0.00004 minke whale (0.0000002% of the CGNS MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.11	0.04	0.00006 minke whale (0.0000003% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.13**	**0.05**	**0.004 grey seal (0.00001% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.13**	**0.05**	**0.004 grey seal (0.000006% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.13**	**0.05**	**0.0002 harbour seal (0.0000005% of the SE E MU reference population)**	**Negligible**

Table 1.22 Underwater noise assessment for the potential of TTS onset from the cumulative exposure of the installation of one pin pile (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	24.0	1,100.0	2,686 harbour porpoise (0.8% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**24.0**	**1,100.0**	**3,539 harbour porpoise (1.04% of the NS MU reference population)**	**Low**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	24.0	1,100.0	1,832 harbour porpoise (0.5% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	24.0	1,100.0	341 harbour porpoise (0.10% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**31.0**	**1,500.0**	**23 minke whale (0.11% of the CGNS MU reference population)**	**Negligible**

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	31.0	1,500.0	2 minke whale (0.01% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	31.0	1,500.0	3 minke whale (0.01% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**9.3**	**180.0**	**13 grey seal (0.04% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**9.3**	**180.0**	**13 grey seal (0.02% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**9.3**	**180.0**	**0.09 harbour seal (0.002% of the SE E MU reference population)**	**Negligible**

Table 1.23 Underwater noise assessment for the potential of TTS onset from the cumulative exposure of the installation of six pin piles (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	24.0	1,100.0	**2,686** harbour porpoise (0.**8**% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**24.0**	**1,100.0**	**3,539 harbour porpoise (1.04% of the NS MU reference population)**	**Low**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	24.0	1,100.0	1,832 harbour porpoise (0.5% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	24.0	1,100.0	341 harbour porpoise (0.10% of the NS MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**31.0**	**1,500.0**	**23 minke whale (0.11% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	31.0	1,500.0	2 minke whale (0.01% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	31.0	1,500.0	3 minke whale (0.01% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**9.5**	**180.0**	**13 grey seal (0.04% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**9.5**	**180.0**	**13 grey seal (0.02% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area (Northern array area), and the SE MU)	**0.00048**	**4,868**	**9.5**	**180.0**	**0.09 harbour seal (0.002% of the SE E MU reference population)**	**Negligible**

1.3.2.4 Assessment of the potential for temporary auditory injury (TTS) from pin piles at multiple pile locations

67. This section outlines the effect of simultaneous pin pile installations (at the same time), at the East and South modelling locations. Plate 1.5 shows the results of the modelling for pin piles, and Table 1.24 provides the assessment of the potential for TTS onset due to the cumulative exposure of six pin pile installations at the same time.

Table 1.24 Underwater noise assessment for the potential of TTS onset from the cumulative exposure of six sequential pin pile installations at two simultaneous locations (SEL_{cum}) at the furthest apart modelling locations (East and South) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	1,800.0	4,394 harbour porpoise (1.3% of the NS MU reference population)	Low
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**1,800.0**	**5,791 harbour porpoise (1.7% of the NS MU reference population)**	**Low**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	1,800.0	2,997 harbour porpoise (0.8% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	1,800.0	558 harbour porpoise (0.16% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**2,400.0**	**37 minke whale (0.18% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	2,400.0	3 minke whale (0.01% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	2,400.0	4 minke whale (0.02% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**580.0**	**41 grey seal (0.13% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**580.0**	**41 grey seal (0.07% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**580.0**	**0.3 harbour seal (0.006% of the SE E MU reference population)**	**Negligible**

1.4 Assessment of underwater noise effects from other construction activities

1.4.1 Underwater noise modelling

68. Subacoustech Environmental Ltd undertook underwater noise modelling for other sources of underwater noise associated with North Falls. The other sources of noise include;

- Cable laying;
  - Underwater noise associated with the cable laying vessel and activities during offshore cable installation.
- Dredging;
  - Dredging as required for seabed preparation works, and for the export, array, and platform interconnector cable installation activities. Suction dredging has been modelled as represents the worst-case in terms of underwater noise.
- Trenching;
  - Plough trenching may be required during offshore construction works.
- Rock placement;
  - Rock placement is potentially required for cable and / or scour protections.

69. Underwater noise from vessels, and operational turbine noise were also modelled, and are assessed in Sections A.1.1 and 1.5.3 respectively.

70. A simple modelling approach has been used to determine the potential impact ranges associated with these activities. More detail on the approach used can be found in ES Appendix 12.3 (Document Reference: 3.3.8). This modelling approach does not take into account the site specific bathymetry or any other environmental conditions into account.

71. The predicted source levels of each of these activities has been derived based on Subacoustech Environmental Ltd's own underwater noise measurement database.

- Cable laying;
  - Underwater source level of 171 dB re 1 µPa @ 1m (RMS), based on 11 datasets of a pipe laying vessel of 300m in length.
- Suction dredging;
  - Underwater source level of 186 dB re 1 µPa @ 1m (RMS), based on five datasets of suction and cutter suction dredgers.
- Trenching;
  - Underwater source level of 172 dB re 1 µPa @ 1m (RMS), based on three datasets of a trenching vessel of more than 100m in length.
- Rock placement;

- Underwater source level of 172 dB re 1 µPa @ 1m (RMS), based on four datasets from a rock placement vessel.

72. To account for the frequency weightings within the Southall *et al.* (2019) thresholds, reductions in the source levels have been applied for each species grouping. See ES Appendix 12.3 (Document Reference: 3.3.8) for further detail, and for the corrected source noise levels for the above listed sound sources.
73. The results of the underwater noise modelling using this simple modelling approach does not define effect ranges of less than 100m, and therefore, where the effect ranges are less than that, the results show effect ranges of <100m (it is possible that the actual effect ranges are therefore considerably less than this).
74. For the cumulative exposure ranges for these noise sources it has been assumed that the noise will be present for 24 hours a day.

1.4.2 Assessment for auditory injury (PTS and TTS) for a single activity

75. Table 1.25 includes the assessment of the potential for PTS onset due to the cable laying, suction dredging, trenching, and rock placement activities that may occur in either the construction or operation and maintenance phases. The cumulative exposures are based on the noise source being present for 12 hours in any 24 hour period.
76. Table 1.26 includes an assessment of the potential for TTS onset for these other noisy activities.

Table 1.25 Underwater noise assessment for the potential of PTS onset due to cable laying, suction dredging, trenching and rock placement (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	0.031	0.08 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**0.031**	**0.1 harbour porpoise (0.00003% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	0.031	0.05 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	0.031	0.01 harbour porpoise (0.000003% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**0.031**	**0.0005 minke whale (0.00000002% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	0.031	0.00004 minke whale (0.000000002% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.1	0.031	0.00005 minke whale (0.000000002% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1	0.031	0.002 grey seal (0.00001% of the SE E MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 density for cable corridors, and the SE MU)	**0.19**	**30,592**	**0.1**	**0.031**	**0.006 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1	0.031	0.002 grey seal (0.000004% of the wider reference population)	Negligible
Grey seal (Carter *et al*., 2022 density for cable corridors, and the wider reference population)	**0.19**	**56,505**	**0.1**	**0.031**	**0.006 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1	0.031	0.00002 harbour seal (0.0000003% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al*., 2022 density for cable corridors, and the SE MU)	**0.11**	**4,868**	**0.1**	**0.031**	**0.003 harbour seal (0.00007% of the SE E MU reference population)**	**Negligible**

Table 1.26 Underwater noise assessment for the potential of TTS onset due to cable laying, suction dredging, trenching and rock placement (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Potential effect to harbour porpoise due to TTS onset from cable laying and trenching						
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	0.031	0.08 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**0.031**	**0.1 harbour porpoise (0.00003% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	0.031	0.05 harbour porpoise (0.00002% of the NS MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	0.031	0.01 harbour porpoise (0.000003% of the NS MU reference population)	Negligible
Potential effect to harbour porpoise due to TTS onset from suction dredging						
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.2	0.126	0.**3** harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.2**	**0.126**	**0.4 harbour porpoise (0.0001% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.2	0.126	0.2 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.2	0.126	0.04 harbour porpoise (0.00001% of the NS MU reference population)	Negligible
Potential effect to harbour porpoise due to TTS onset from rock placement						
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	1	3.14	8 harbour porpoise (0.002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**1**	**3.14**	**11 harbour porpoise (0.003% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	1	3.14	6 harbour porpoise (0.002% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	1	3.14	1 harbour porpoise (0.0003% of the NS MU reference population)	Negligible
Potential effect to minke whale due to TTS onset from cable laying, suction dredging, trenching and rock placement						
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**0.031**	**0.0005 minke whale (0.00000002% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	0.031	0.00004 minke whale (0.000000002% of the CGNS MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Minke whale (Waggitt *et al.,* 2019 summer density estimate for array area)	0.0015	20,118	0.1	0.031	0.00005 minke whale (0.000000002% of the CGNS MU reference population)	Negligible
Potential effect to grey seal and harbour due to TTS onset from cable laying, suction dredging, trenching and rock placement						
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1	0.031	0.002 grey seal (0.000007% of the SE E MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 density for cable corridors, and the SE MU)	**0.19**	**30,592**	**0.1**	**0.031**	**0.006 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1	0.031	0.002 grey seal (0.000004% of the wider reference population)	Negligible
Grey seal (Carter *et al*., 2022 density for cable corridors, and the wider reference population)	**0.19**	**56,505**	**0.1**	**0.031**	**0.006 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1	0.031	0.00002 harbour seal (0.0000003% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al*., 2022 density for cable corridors, and the SE MU)	**0.11**	**4,868**	**0.1**	**0.031**	**0.003 harbour seal (0.00007% of the SE E MU reference population)**	**Negligible**

1.4.3 Assessment for auditory injury (PTS and TTS) for multiple activities

77. There is the potential that more than one of these other construction activities could be underway at the array area, or within the offshore cable corridor, at the same time. As a worst-case and unlikely scenario, an assessment for all three activities being undertaken simultaneously has also been undertaken.

78. Table 1.27 includes the assessment of the potential for PTS onset due to the cable laying, suction dredging, trenching, and rock placement activities could occur at the same time. The cumulative exposures are based on the noise source being present for 12 hours in any 24 hour period.

79. Table 1.28 includes an assessment of the potential for TTS onset for these other noisy activities.

Table 1.27 Underwater noise assessment for the potential of PTS onset due to cable laying, suction dredging, trenching and rock placement being undertaken at the same time (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	4	0.126	0.**3** harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**4**	0.126	**0.4 harbour porpoise (0.0001% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	4	0.126	0.2 harbour porpoise (0.00006% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	4	0.126	0.04 harbour porpoise (0.00001% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**4**	**0.126**	**0.002 minke whale (0.00001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array areas)	0.0011	20,118	0.1	4	0.126	0.0001 minke whale (0.000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array areas)	0.0015	20,118	0.1	4	0.126	0.002 minke whale (0.00001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1	4	0.126	0.009 grey seal (0.00003% of the SE E MU reference population)	Negligible

Species scenario	Density (/km²)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km²)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al.*, 2022 density for cable corridor, and the SE MU)	**0.19**	**30,592**	**0.1**	**4**	**0.126**	**0.02 grey seal (0.00008% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1	4	0.126	0.009 grey seal (0.00002% of the wider reference population)	Negligible
Grey seal (Carter *et al.*, 2022 density for cable corridor, and the wider reference population)	**0.19**	**56,505**	**0.1**	**4**	**0.126**	**0.02 grey seal (0.00004% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1	4	0.126	0.0001 harbour seal (0.000001% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al.*, 2022 density for cable corridor, and the SE MU)	**0.11**	**4,868**	**0.1**	**4**	**0.126**	**0.01 harbour seal (0.0003% of the SE E MU reference population)**	**Negligible**

Table 1.28 Underwater noise assessment for the potential of TTS onset due to cable laying, suction dredging, trenching and rock placement being undertaken at the same time (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km²)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	4	3.33	9 harbour porpoise (0.002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**4**	**3.33**	**11 harbour porpoise (0.003% of the NS MU reference population)**	**Negligible**

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	4	3.33	6 harbour porpoise (0.002% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	4	3.33	2 harbour porpoise (0.0006% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**4**	**0.126**	**0.002 minke whale (0.00001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	4	0.126	0.0001 minke whale (0.000001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.1	4	0.126	0.0002 minke whale (0.000001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1 – 1.0	4	0.126	0.009 grey seal (0.00003% of the SE E MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 density for cable corridor, and the SE MU)	**0.19**	**30,592**	**0.1 – 1.0**	**4**	**0.126**	**0.02 grey seal (0.00008% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1 – 1.0	4	0.126	0.009 grey seal (0.00002% of the wider reference population)	Negligible
Grey seal (Carter *et al*., 2022 density for cable corridor, and the wider reference population)	**0.219**	**56,505**	**0.1 – 1.0**	**4**	**0.126**	**0.02 grey seal (0.00004% of the wider reference population)**	**Negligible**

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1 – 1.0	4	0.126	0.0001 harbour seal (0.000001% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al.*, 2022 density for cable corridors, and the SE MU)	**0.11**	**4,868**	**0.1 – 1.0**	**4**	0.126	**0.01 harbour seal (0.0003% of the SE E MU reference population)**	**Negligible**

1.5 Assessment of underwater noise effects from vessels (all phases)

1.5.1 Underwater noise modelling

80. Subacoustech Environmental Ltd undertook underwater noise modelling for the underwater noise associated with vessels at North Falls. This followed the same approach as outlined above for other noisy activities (Section 1.4).

81. The predicted source levels of the two vessel types (medium and large vessels) have been derived based on Subacoustech Environmental Ltd's own underwater noise measurement database.

- Medium vessels;
  - Underwater source level of 161 dB re 1 μPa @ 1m (RMS), based on three datasets of moderately sized vessels less than 100m in length, with an assumed vessel speed of 10 knots.
- Large vessels;
  - Underwater source level of 168 dB re 1 μPa @ 1m (RMS), based on five datasets of large vessels, including container ships, floating production storage and offloading platforms, and other vessels of more than 100m in length, with an assumed vessel speed of 10 knots.

82. To account for the frequency weightings within the Southall *et al.* (2019) thresholds, reductions in the source levels have been applied for each species grouping. See ES Appendix 12.3 (Document Reference: 3.3.8) for further detail, and for the corrected source noise levels for the vessel noise.

83. The results of the underwater noise modelling using this simple modelling approach does not define effect ranges of less than 100m, and therefore, where the effect ranges are less than that, the results show effect ranges of <100m (it is possible that the actual effect ranges are therefore considerably less than this).

84. For the cumulative exposure ranges for these noise sources it has been assumed that the noise will be present for 24 hours a day.

1.5.2 Assessment for auditory injury (PTS and TTS)

85. Table 1.29 includes the assessment of the potential for PTS onset due to the vessels that may be present in either the construction or operation and maintenance phases. The cumulative exposures are based on the noise source being present for 24 hours a day.

86. Table 1.30 includes an assessment of the potential for TTS onset for vessels.

Table 1.29 Underwater noise assessment for the potential of PTS onset due to vessel presence (large and medium vessels) (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	0.031	0.08 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**0.031**	**0.1 harbour porpoise (0.00003% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	0.031	0.05 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	0.031	0.01 harbour porpoise (0.000003% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**0.031**	**0.0005 minke whale (0.000002% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.,* 2019 annual density estimate for array area)	0.0011	20,118	0.1	0.031	0.00004 minke whale (0.0000002% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.,* 2019 summer density estimate for array area)	0.0015	20,118	0.1	0.031	0.00005 minke whale (0.0000002% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1	0.031	0.002 grey seal (0.000007% of the SE E MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 density for cable corridor, and the SE MU)	**0.19**	**30,592**	**0.1**	**0.031**	**0.006 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1	0.031	0.002 grey seal (0.000004% of the wider reference population)	Negligible
Grey seal (Carter *et al.*, 2022 density for cable corridor, and the wider reference population)	**0.19**	**56,505**	**0.1**	**0.031**	**0.006 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1	0.031	0.00002 harbour seal (0.0000003% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al.*, 2022 density for cable corridor, and the SE MU)	**0.11**	**4,868**	**0.1**	**0.031**	**0.003 harbour seal (0.00007% of the SE E MU reference population)**	**Negligible**

Table 1.30 Underwater noise assessment for the potential of TTS onset due to vessel presence (large and medium vessels) (SEL_{cum}) at the worst-case modelling location (East) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Potential effect to harbour porpoise due to TTS onset from large vessels						
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.2	0.126	0.3 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.2**	**0.126**	**0.4 harbour porpoise (0.0001% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.2	0.126	0.2 harbour porpoise (0.00006% of the NS MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.2	0.126	0.04 harbour porpoise (0.00001% of the NS MU reference population)	Negligible
Potential effect to harbour porpoise due to TTS onset from medium vessels						
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	0.031	0.08 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**0.031**	**0.1 harbour porpoise (0.00003% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	0.031	0.05 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	0.031	0.01 harbour porpoise (0.000003% of the NS MU reference population)	Negligible
Potential effect to minke whale, grey seal and harbour seal due to TTS onset from medium and large vessels						
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**0.031**	**0.0005 minke whale (0.00000002% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	0.031	0.00004 minke whale (0.000000002% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.1	0.031	0.00005 minke whale (0.000000002% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1	0.031	0.002 grey seal (0.000007% of the SE E MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al.*, 2022 density for cable corridor, and the SE MU)	**0.19**	**30,592**	**0.1**	**0.031**	**0.006 grey seal (0.00002% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1	0.031	0.002 grey seal (0.000004% of the wider reference population)	Negligible
Grey seal (Carter *et al.*, 2022 density for cable corridor, and the wider reference population)	**0.19**	**56,505**	**0.1**	**0.031**	**0.006 grey seal (0.00001% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1	0.031	0.00002 harbour seal (0.000003% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al.*, 2022 density for cable corridors, and the SE MU)	**0.11**	**4,868**	**0.1**	**0.031**	**0.003 harbour seal (0.00007% of the SE E MU reference population)**	**Negligible**

1.5.3 Assessment for auditory injury (PTS and TTS) for multiple vessels

87. There is the potential that up to 35 vessels may be present at North Falls at any one time. As a worst-case and unlikely scenario, an assessment for all construction vessels has also been undertaken.
88. Table 1.31 includes the assessment of the potential for PTS onset due to all construction vessels. The cumulative exposures are based on the noise source being present for 24 hours in a 24 hour period.
89. Table 1.32 includes an assessment of the potential for TTS onset for all construction vessels.

Table 1.31 Underwater noise assessment for the potential of PTS onset due to maximum of 35 construction vessels (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of vessels	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	35	1.1	**3** harbour porpoise (0.0009% of the NS MU reference population)	Low
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**35**	**1.1**	**4 harbour porpoise (0.001% of the NS MU reference population)**	**Low**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	35	1.1	2 harbour porpoise (0.0006% of the NS MU reference population)	Low
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	35	1.1	0.3 harbour porpoise (0.0001% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	0.1	**35**	**1.1**	**0.02 minke whale (0.0001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	35	1.1	0.001 minke whale (0.00001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.1	35	1.1	0.002 minke whale (0.00001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1	35	1.1	0.08 grey seal (0.0003% of the SE MU reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of vessels	Impact area (km^2)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al.*, 2022 density for cable corridors, and the SE MU)	**0.19**	**30,592**	0.1	**35**	**1.1**	**0.2 grey seal (0.0007% of the SE MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1	35	1.1	0.08 grey seal (0.0001% of the wider reference population)	Negligible
Grey seal (Carter *et al.*, 2022 density for cable corridors, and the wider reference population)	**0.19**	56,505	0.1	**35**	**1.1**	**0.2 grey seal (0.0004% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1	35	1.1	0.0005 harbour seal (0.00001% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al.*, 2022 density for cable corridor, and the SE MU)	**0.11**	**4,868**	0.1	**35**	**1.1**	**0.1 harbour seal (0.003% of the SE E MU reference population)**	**Low**

Table 1.32 Underwater noise assessment for the potential of TTS onset due to maximum of 35 construction vessels (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.2	35	4.4	11 harbour porpoise (0.003% of the NS MU reference population)	Negligible

Species scenario	Density (/km²)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.2**	**35**	**4.4**	**15 harbour porpoise (0.004% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.2	35	4.4	8 harbour porpoise (0.002% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.2	35	4.4	2 harbour porpoise (0.0006% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**35**	**1.1**	**0.02 minke whale (0.0001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	35	1.1	0.001 minke whale (0.00001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.1	35	1.1	0.002 minke whale (0.00001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al*., 2022 worst-case density for array area, and the SE MU)	0.07	30,592	0.1	35	1.1	0.08 grey seal (0.0003% of the SE E MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 density for cable corridor, and the SE MU)	**0.19**	**30,592**	**0.1**	**35**	**1.1**	**0.2 grey seal (0.0007% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter et al., 2022 worst-case density for array area, and the wider reference population)	0.07	56,505	0.1	35	1.1	0.08 grey seal (0.0001% of the wider reference population)	Negligible

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of activities at the same time	Impact area (km^2)	Assessment of effect	Magnitude of effect
Grey seal (Carter *et al.*, 2022 density for cable corridor, and the wider reference population)	**0.19**	**56,505**	**0.1**	**35**	**1.1**	**0.2 grey seal (0.0004% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	0.00048	4,868	0.1	35	1.1	0.0005 harbour seal (0.00001% of the SE E MU reference population)	Negligible
Harbour seal (Carter *et al.*, 2022 density for cable corridor, and the SE MU)	**0.11**	**4,868**	**0.1**	**35**	**1.1**	**0.1 harbour seal (0.003% of the SE E MU reference population)**	**Negligible**

1.6 Assessment of underwater noise effects from operational turbine noise

90. The main source of noise during operation of the turbines is from a mechanically generated vibration from the rotating machinery within the Wind Turbine Generator (WTG), which is transmitted into the water column through the WTG structure and foundations (Nedwell *et al*., 2003; Tougaard *et al.,* 2020). Underwater noise levels associated with turbines at the size included for North Falls is not currently available, and therefore noise levels are calculated based on a formula presented by Tougaard *et al.* 2020. See ES Appendix 12.3 (Document Reference: 3.3.8) for more detail on this process.
91. This data is used to predict the underwater noise levels, and therefore the potential impact ranges, of the operational turbines on marine mammal species groups. This modelling uses the same simple approach as described in Section 1.4.
92. The results of the underwater noise modelling using this simple modelling approach does not define effect ranges of less than 100m, and therefore, where the effect ranges are less than that, the results show effect ranges of <100m (it is possible that the actual effect ranges are therefore considerably less than this).
93. For the cumulative exposure ranges for operational turbines, it has been assumed that the noise will be present for 24 hours a day.
94. The reported PTS onset range of less than 100m (ES Appendix 12.3 (Document Reference: 3.3.8)) is likely an overestimation, as the modelling does not provide exact ranges at less than 100m. The TTS modelling results also show an effect range of 100m, indicating that the actual potential PTS ranges would be much lower than the reported 100m. Therefore, the potential for PTS onset due to operational WTG noise has not been quantitively assessed.

1.6.1 Assessment for temporary auditory injury (TTS) from a single WTG

95. Table 1.33 includes an assessment of the potential for TTS onset for one operational WTG.

Table 1.33 Underwater noise assessment for the potential for TTS onset from the operation of one WTG (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	0.031	0.08 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**0.031**	**0.1 harbour porpoise (0.00003% of the NS MU reference population)**	**Negligible**
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	0.031	0.05 harbour porpoise (0.00002% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	0.031	0.01 harbour porpoise (0.000003% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	**0.031**	**0.0005 minke whale (0.000002% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	0.031	0.00004 minke whale (0.0000002% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.1	0.031	0.00005 minke whale (0.0000002% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.1**	**0.031**	**0.002 grey seal (0.000007% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.1**	**0.031**	**0.002 grey seal (0.000004% of the wider reference population)**	**Negligible**
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.1**	**0.031**	**0.00002 harbour seal (0.0000003% of the SE E MU reference population)**	**Negligible**

1.6.2 Assessment for temporary auditory injury (TTS) for multiple WTGs

96. More than one WTG will be operating at the same time, and therefore an assessment of the potential for auditory injury, due to all operational WTGs, is required.
97. There is the potential for either 57 15MW WTGs, or 34 25MW WTGs to be installed for the Project. The potential auditory effect ranges are the same for either 15MW or 25MW WTGs, and therefore the worst-case would be for a total of 57 operational WTGs.
98. Table 1.34 includes the assessment of the potential for TTS onset due to 57 operational WTGs.

Table 1.34 Underwater noise assessment for the potential of TTS onset due to multiple operational WTGs (SEL_{cum}) for harbour porpoise, minke whale, grey seal, and harbour seal, including all potential density estimates and reference populations (density estimates and reference populations presented for assessment in ES Chapter 12 Marine Mammals (Document Reference: 3.1.14) are shown in bold) [where the number of individuals at risk is more than one, it has been rounded up to be biologically relevant]

Species scenario	Density (/km^2)	Reference population	Impact range (km)	Number of operational WTGs	Impact area (km^2)	Assessment of effect	Magnitude of effect
Harbour porpoise (site-specific worst-case aerial annual density estimate)	2.441	338,918	0.1	57	1.79	**5** harbour porpoise (0.001% of the NS MU reference population)	Negligible
Harbour porpoise (site-specific worst-case aerial winter density estimate)	**3.217**	**338,918**	**0.1**	**57**	**1.79**	**6 harbour porpoise (0.002% of the NS MU reference population)**	Negligible
Harbour porpoise (site-specific worst-case aerial summer density estimate)	1.665	338,918	0.1	57	1.79	3 harbour porpoise (0.0009% of the NS MU reference population)	Negligible
Harbour porpoise (SCANS-IV density estimate)	0.3096	338,918	0.1	57	1.79	0.6 harbour porpoise (0.0002% of the NS MU reference population)	Negligible
Minke whale (SCANS-IV density estimate)	**0.0153**	**20,118**	**0.1**	57	1.79	**0.03 minke whale (0.0001% of the CGNS MU reference population)**	**Negligible**
Minke whale (Waggitt *et al.*, 2019 annual density estimate for array area)	0.0011	20,118	0.1	57	1.79	0.002 minke whale (0.00001% of the CGNS MU reference population)	Negligible
Minke whale (Waggitt *et al.*, 2019 summer density estimate for array area)	0.0015	20,118	0.1	57	1.79	0.003 minke whale (0.00001% of the CGNS MU reference population)	Negligible
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.07**	**30,592**	**0.1**	**57**	**1.79**	**0.1 grey seal (0.0004% of the SE E MU reference population)**	**Negligible**
Grey seal (Carter *et al.*, 2022 worst-case density for array area, and the wider reference population)	**0.07**	**56,505**	**0.1**	**57**	**1.79**	**0.1 grey seal (0.0002% of the wider reference population)**	**Negligible**

Species scenario	Density (/km²)	Reference population	Impact range (km)	Number of operational WTGs	Impact area (km²)	Assessment of effect	Magnitude of effect
Harbour seal (Carter *et al.*, 2022 worst-case density for array area, and the SE MU)	**0.00048**	**4,868**	**0.1**	**57**	**1.79**	**0.0009 harbour seal (0.00002% of the SE E MU reference population)**	**Negligible**

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