Cerulean Winds

EPS and Protected Species Risk Assessment

EPS Licence Application Support – North Sea Renewable Grid

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Contents

List of Figures

List of Tables

1 Introduction

1.1 Purpose of the document

The North Sea Renewables Grid (NSRG), hereafter referred to as 'the Project', is a Floating Offshore Windfarm (OWF) being developed by Cerulean Winds (the Developer) and is made up of three Lease Areas (Aspen, Beech, and Cedar) all approximately 333 km^2, located 100 km apart in the Central North Sea, 100 km offshore. This European Protected Species (EPS) and Protected Species Risk Assessment has been produced to support an EPS licence application to the Marine Directorate - Licensing Operations Team (MD-LOT) specifically relating to the proposed geophysical, geotechnical and benthic survey campaigns undertaken within Aspen Survey Area and the Offshore Demand Cable (ODC) Corridor Search Area, hereafter collectively referred to as 'the Proposed Development'. Please see Appendix for coordinates and a supporting graphic of the Aspen Survey Area and ODC Corridor Search Area boundary. The EPS licence application covers equipment to be used in the geophysical, geotechnical, and benthic surveys for which a licence may be required. Geophysical, geotechnical and benthic surveys are planned for Aspen Survey Area and an ODC Corridor Survey Area, to be located with the ODC Corridor Search Area, in inshore and offshore waters (as shown in Figure 1).

1.2 Legislative background

The Proposed Development, which includes the Aspen Survey Area and the ODC Corridor Search Area , is known to support several EPS and protected species, including marine mammals, basking sharks, and leatherback turtles (see Section 4 for more information). EPS and protected species present in this area are sensitive to anthropogenic underwater noise and the geophysical, geotechnical, and benthic survey activities have the potential to generate disturbance or injury impacts to these hearing-sensitive species. All United Kingdom (UK) cetacean species are listed under marine megafauna of the European Habitats Directive and Schedule 2 of the Habitat Regulations 1994 as EPS, which has been transposed into Scottish Law through The Conservation (Natural Habitats, & c.) Regulations 1994 (as amended).

Within inshore waters, Regulation 39 (1) of the Conservation (Natural Habitats, &c.) Regulations 1994 (as amended), makes it an offence to deliberately or recklessly capture, kill, injure, disturb, or harass an EPS. Regulation 39 (2) makes further provision specifically for cetaceans, making it an offence to disturb any dolphin, porpoise, or whale. This provides protection to EPS within the inshore region, up to the 12 nm limit.

In the offshore region, beyond 12 nm, EPS are protected under the Conservation of Offshore Marine Habitats and Species Regulations 2017 (referred to as the 'Offshore Regulations'). Specifically, Regulation 45 (1) makes it an offence to deliberately capture, kill, injure, or disturb an EPS.

Pinnipeds are not listed as EPS species under the Habitats Directive however, both harbour and grey seals are included in Annex II, meaning that their core habitat must be protected under the European sites Network and managed in accordance with their ecological requirements. Under the Marine (Scotland) Act 2010, it is an offence to kill, injure, or take a seal, as well as to harass a seal, deliberately or recklessly, at a designated haul out site.

This document lays out the relevant information to support the licence application, including:

- Consideration of alternatives,
- The baseline information on EPS and protected species in the Proposed Development,
- The activities taking place which may cause injury and/or disturbance without mitigation,
- The likelihood of risk and potential impacts,
- The effects on EPS and protected species of concern without mitigation,
- The mitigation and management strategies implemented to minimise the potential impacts identified.

Basking shark is also considered as part of this risk assessment, as it is listed as a protected fish species, protected under Schedule 5 of the Wildlife and Countryside Act 1981. It may be affected by underwater noise.

Leatherback turtle is also considered as part of this risk assessment, as it is listed as an EPS under schedule 2 of the Habitats Regulations, 1994 (as amended in Scotland), and may be affected by underwater noise.

2 Scope of Work

2.1 Project information

Geophysical, geotechnical, and benthic surveys are required as a precursor to the Proposed Development and only these proposed activities are the subject of this assessment. The aim of the proposed activities is to understand the geological, hydrogeological, and geo-environmental conditions prevailing across the Proposed Development, as follows:

- To determine the composition of the overburden, seabed, depth to bedrock,
- To recover sediments and, if any, rock core for inspection, logging, and strength testing,
- To complete *in situ* testing to assess the strength and stiffness of the overburden and seabed,
- To complete geotechnical and geo-environmental laboratory testing on recovered sediments, rock core and groundwater samples,
- To complete geophysical survey works to determine the ground conditions between the intrusive geotechnical locations,
- To allow for design of the future site elements in accordance with relevant design codes (e.g., EC7) and provide information on engineering design and installation.

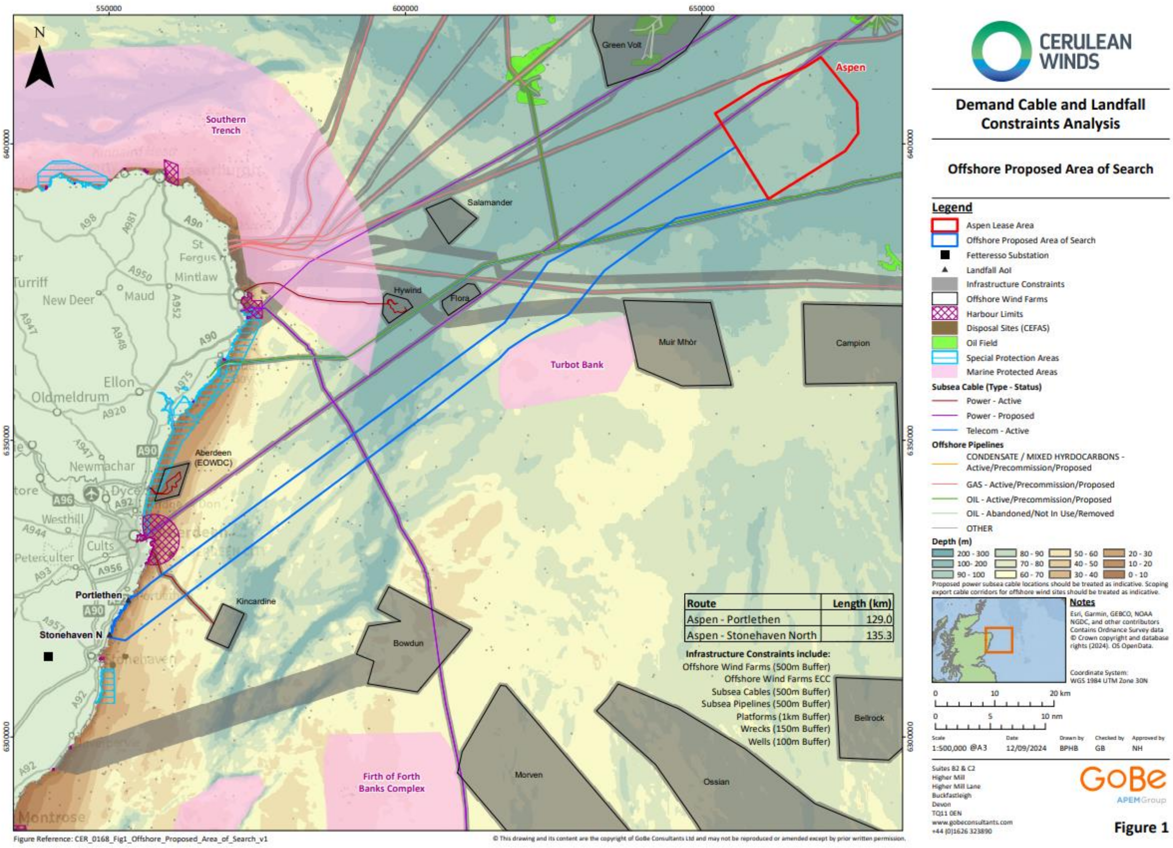

Figure 1 Proposed Development relevant to this risk assessment, which comprises Aspen Survey Area and the Offshore Demand Cable (ODC) Corridor Search Area within which the ODC Corridor Survey Area will be located.

2.2 Details of proposed survey activities

It is not appropriate to survey outside of the Proposed Development as the sediment and seabed structure may not be representative of the locations in which the windfarm and associated assets will be positioned. The locations presented in this risk assessment are placed to best inform the design and development of the windfarm, including micro-siting to minimise impacts on sensitive benthic habitats.

2.2.1 Aspen Survey Area

The Aspen Survey Area includes the footprint of Aspen Lease Area, totalling an area of approximately 333 km^2, with surveys to be carried out covering all of the Array.

2.2.2 Offshore Demand Cable Corridor Search Area

In order for the EPS application to be submitted in sufficient time to allow determination prior to survey, an ODC Corridor Search Area has been defined for the ODC. Surveys will however only take place within a 1 km maximum wide ODC Corridor Survey Area within the wider ODC Corridor Search Area.

2.3 Schedule of Proposed Activities

The exact dates for the geophysical, geotechnical, and benthic surveys are to be determined pending the granting of an EPS licence and the appointment of survey contractors. However, if an EPS licence is required for any element of the proposed activities, the geophysical, geotechnical, and benthic surveys shall not commence until this is in place. If necessary, additional surveys will be completed subsequently to fill in any data gaps.

Overall, it is estimated that the survey window for the geophysical, geotechnical and benthic survey campaign will be from 1st October 2024 to 1st October 2025 . Geophysical surveys which will include sub-bottom profiling (SBP), ultra-high resolution seismic (UHRS), side-scan sonar (SSS), ultra-short base line (USBL), and multi-beam echosounder (MBES). Geotechnical surveys will include borehole sampling and cone penetration testing (CPT); grab samples for benthic survey shall be taken concurrently during geophysical surveys. USBL will be used throughout geotechnical and benthic surveys for location positioning. Note these predicted days exclude visual assessments and adverse weather days when no geophysical, geotechnical, or benthic survey will be undertaken.

2.4 Physical Environment

The North Sea is a shallow sea surrounded by several land masses, including low-lying areas of northern Europe, the complex coastlines of western Norway and the eastern coast of the UK. Once a land bridge between Denmark and the UK, the North Sea has an average depth of 90 m and has a typically uniform bathymetry and substrate of fine mud and sand (Walday and Kroglund, 2008). It is open to the wider North Atlantic from the north and from the south where the English Channel opens into the Celtic Sea. The non-tidal current direction within the North Sea is anticlockwise.

3 Summary of proposed Survey Operations

The geophysical and geotechnical surveys will **comprise the survey equipment described in** Table 3.1:

Table 3.1 Summary of proposed geophysical and geotechnical survey techniques

Category	Survey Equipment	Purpose
Geophysical surveys	SBP (including sparkers and boomers)	SBP systems are used to identify and characterise layers of sediment or rock under the seafloor. The survey will utilise a parametric SBP. The parametric sound source ensures that the beam width of the sound is extremely spatially limited (the angle of the beam spread is approximately 2 degrees) and this combined with the high frequency of the generated sound (focused at 100 kHz) ensures that any propagation of the sound source is extremely limited.
	UHRS (including sparkers and boomers)	The use of an UHRS single or multi-channel system will be required to image the uppermost 50 – 100 m of the seabed, this is required to inform anchor designs for the floating turbines. The preferred system to be used is a sparker source, similar or equivalent to the GeoSparker 200 (Geo Marine Survey Systems). The UHRS survey will take place within the survey area and will not be required along cable survey routes. Sparkers emit an omnidirectional broadband acoustic pulse into the water column by first creating an electrical pulse between electrodes located on the tip of the device, and a grounding point located on the body. The resulting acoustic pulse penetrates into the seabed and is dispersed by the sediment. Dispersion varies with the thickness of sediment layers, grain size and position, and the energy reflected back to the sparker system hydrophones creates a profile of the seabed (Ruppel *et al.,* 2022). This method is useful for visualising the boundaries within marine sediment layers and the internal structures which can help inform design and placement of infrastructure. The GeoSparker 200 system has an operable frequency between 40 Hz and 1.5 kHz at a source level (SL) between 200 – 230 dB re 1µPa @ 1 m. Pulses are fired at 1 pulses per second (pps) with an energy output between 100 – 1000 J, with the sound level (SL) increasing non-linearly with the power level (Ruppel *et al*., 2022).
	MBES	MBES are used to obtain detailed 3-dimensional (3D) maps of the seafloor which show water depths. They measure water depth by recording the two-way travel time of a high frequency pulse emitted by a transducer. The beams produce a fanned arc composed of individual beams (also known as a swathe). MBES can, typically, carry out 200 or more simultaneous measurements. The frequencies used by shallow water MBES (<1000 m) are generally very high (70-100+ kHz; e.g., EM170: Source level = 232 dB re 1 µPa @ 1 m; Hildebrand, 2009) and

		outside the main hearing range of most marine mammal hearing groups (JNCC, 2017). This survey technique does not interact with the seabed.
	SSS	SSS is used to generate an accurate image of the seabed, which may include 3D imagery. An acoustic beam is used to obtain an accurate image of a narrow area of seabed to either side of the instrument by measuring the amplitude of back-scattered return signals. The instrument can either be towed behind a ship at a specified depth or mounted on to a ROV. The frequencies used by SSS are generally very high and outside of the main hearing range of all marine species (JNCC *et al.,* 2010; National Marine Fisheries Science (NMFS), 2018). The higher frequency systems provide higher resolution, but shorter-range measurements. This survey technique does not interact with the seabed.
	USBL	USBL will be used for the calibration of vessel positioning to be used in geotechnical and benthic surveys. The calibration process involves the temporary deployment of a Sonardyne 8370-1111 USBL transponder or similar on the seabed, at a depth of approximately 90-100 m. The Sonardyne 8370-1111 USBL unit has a primary operating frequency of 20 – 34 kHz and a SL of 184 dB re 1 µPa @ 1 m (as per the manufacturer's specifications). It is expected that the USBL will need to be calibrated per vessel and for each return to site.
Geotechnical and benthic surveys	Sampling at cable percussion boreholes	Boreholes by rotary drilling (to approximately 50 – 70 m below ground level or refusal) will be performed to collect seabed and overburden soil samples.
	CPT	CPT will be conducted to provide insight about the strength and behaviour characteristics of seabed sediments.
	Grab sampling for benthic survey	Grab sampling will be carried out for seabed sediment analysis and environmental testing, using a Van Veen type grab sampler or similar, depending on water depth, currents and sample size required. Grab samples are similar to grab buckets on land and tend to be either hydraulically or manually operated. The proposed sampling is not expected to contribute significantly to the acoustic profile of the area being sampled. It could potentially result in small-scale increases in the amount of sediment in the water column, albeit being highly localised.
	USBL	USBL will be used for the calibration of vessel positioning to be used in geotechnical and benthic surveys. The calibration process involves the temporary deployment of a Sonardyne 8370-1111 USBL transponder or similar on the seabed, at a depth of approximately 90-100 m. The Sonardyne 8370-1111 USBL unit has a primary operating frequency of 20 – 34kHz and a SL of 184 dB re 1 µPa @ 1 m (as per the manufacturer's specifications). Duration of the calibration exercise is expected

		to be less than one day and is only to take place as part of the initial geophysical survey planned for 2024.

4 Desk study

4.1 European Protected Species and protected species

Out of the 25 species of marine mammal observed in UK waters, 17 can be found within the North Sea (Reid, 2003). Both grey and harbour seals (*Haliochoerus grypus* and *Phoca vitulina*, respectively) are found within the region, while several species of odontocete (toothed whales) are also present. One mysticete species, the minke whale (*Balaenoptera acutorostrata*), is commonly observed in both coastal and more offshore areas within the North Sea. Basking sharks (*Cetorhinus maximus*) have been occasionally recorded on the east coast of Scotland and in offshore waters, as well as leatherback turtle (*Dermochelys coriacea*) in the North Sea (Langton *et al*., 1996).

For the purposes of the risk assessment, the available information on spatial and temporal distribution, abundance and density, and known behaviours of the most frequently observed cetacean species within the Proposed Development are reviewed. The Aspen Lease Area and the ODC Corridor Search Area straddle the Small Cetaceans in European Atlantic Waters and the North Sea (SCANS) IV survey block NS-D as detailed (Gilles *et al.,* 2023), and block R of the SCANS-III surveys (Hammond *et al*., 2017).

Cetacean species most likely to be encountered within the Proposed Development include harbour porpoise, bottlenose dolphin, white-beaked dolphin, and minke whale (Hammond *et al.,* 2017; Gilles *et al.,* 2023). While other species have been recorded in the region, the baseline data available indicate that their occurrences are considered infrequent (Hammond *et al.,* 2017; Gilles *et al.,* 2023). Some other species, such as sperm whales (*Physeter macrocephalus*), beaked whales, and other mysticete whales are occasional visitors, and as such are not considered in this risk assessment.

Pinnipeds have been included in this assessment as they are protected under the Marine Scotland Act, 2010, where it is an offence to hunt, injure or wilfully interfere with, disturb, or destroy the resting or breeding place of a protected (listed) species in Scottish territorial seas. Further legal protection of seals is provided by the EC Directive where they are listed as an Annex II species whose conservation requires the designation of Special Areas of Conservation (SACs), transposed into Scottish law via the Conservation Regulations, 1994. Two pinniped species, harbour and grey seal, are regularly seen within Scottish waters, and both occur regularly along the east coast of Scotland (SCOS, 2023; Carter *et al.*, 2022). Any proposed mitigation measures for the species included in this assessment will also be appropriate and/or relevant to seals, as well as any other species of cetacean and turtle not taken forward in this assessment.

Basking sharks have been recorded all around Scotland, primarily in the Sea of the Hebrides on the Scottish west coast (NatureScot, 2019; Witt *et al.,* 2016, 2019), and off Devon and Cornwall in southwest England (Fugro, 2021). Despite infrequent occurrences on the east of Scotland, the species will be taken forward in this assessment, following a precautionary approach.

There have been six species of marine turtle recorded in UK waters. Of these, the leatherback turtle is the only species that is considered resident (Botterell *et al.,* 2020). Therefore, only leatherback turtle will be taken forward in this assessment.

4.2 Marine mammals and sound

4.2.1 Potential effects, functional hearing groups and auditory weighting

It is widely documented that marine mammals are sensitive to underwater noise (e.g., Hildebrand, 2009; Nowacek *et al.*, 2007; OSPAR 2009; Richardson *et al.*, 1995; Southall *et al.*, 2019; Southall *et al.*, 2021), with a wealth of evidence that many anthropogenic sound sources, such as vessels and related construction activity (e.g. Culloch *et al.*, 2016; Dunlop, 2016; Pirotta *et al.*, 2012; Wisniewska *et al.*, 2018), impact pile driving (e.g. Brandt *et al.*, 2011; Graham *et al.*, 2019), seismic surveys (Pirotta *et al.*, 2014; Stone *et al.*, 2017) and acoustic deterrent devices (ADDs) (e.g. Basran *et al.*, 2020; Schaffeld *et al.*, 2019) do have impacts on marine mammals. Indirect impacts may also occur through direct impacts to prey species (e.g., Sivle *et al.*, 2021). These impacts have varying degrees of observed and/or predicted severity, ranging from changes in behaviour and masking (affecting communication and listening space, and/or locating prey) (Basran *et al.*, 2020; Dunlop, 2016; Erbe *et al.*, 2016; Heiler *et al.*, 2016; Pine *et al.*, 2019; Pirotta *et al.*, 2012; Wisniewska *et al.*, 2018), to displacement and disturbance (e.g. Brandt *et al.*, 2011; Culloch *et al.*, 2016; Graham *et al.*, 2019; Pirotta *et al.*, 2014; Stone *et al.*, 2017) to injury and even mortality (e.g., Reichmuth *et al.*, 2019; Schaffeld *et al.*, 2019). The severity of these potential impacts will depend, in part, on the hearing range of the species affected. These are divided into generalised hearing ranges across broad species categories, based on various data sources, such as captive studies (e.g., harbour porpoises) and anatomy-based predictions (NMFS, 2018; Table 4.1).

Table 4.1 Generalised hearing ranges for species groups (adapted from Popper et al. 2014, NMFS, 2018 and Southall et al., 2019)

Species Group Functional Hearing Group	Species examples	Generalised hearing ranges	Estimated region of peak sensitivity
Balaenoptera (Low Frequency)	Minke whale	7 Hz – 35 kHz	200 Hz – 19 kHz
Dephinidae (High Frequency)	Bottlenose dolphin, white-beaked dolphin	150Hz – 160 kHz	8.8 kHz – 110 kHz
Phocoenidae (Very High Frequency)	Harbour porpoise	275 Hz – 160 kHz	12 kHz – 140 kHz
Phocids (in water)	Harbour seal, grey seal	50 Hz – 86 kHz	1.9 kHz – 30 kHz
Marine turtles	Leatherback turtle	50 Hz – 800 Hz[1]	No information
Elasmobranch: Group 1 fish	Basking sharks	30 Hz – 210 Hz[2]	No information

To assess impacts of underwater noise, EPS and protected species are separated into functional hearing groups, which reflect the broad differences in hearing capabilities among the taxa (e.g., Southall *et al.*, 2019; Popper *et al.*, 2014). The classifications by Popper *et al.* (2014) and Southall *et al.* (2019) have used the most recent data on hearing of relevant taxa groups; it is considered current

[1] Derived from the audiogram of loggerhead sea turtle (*Caretta caretta*) in the absence of information on leatherback turtle hearing sensitivity (Popper *et al.*, 2014)

[2] Derived from the audiogram of plaice (*Pleuroncetes platessa*), which is also classed as a Group 1 fish species by Popper *et al.*, (2014)

best practice and supersedes previous works (e.g. Southall *et al.* (2007)). There are six functional hearing groups, with the harbour porpoise hearing group categorised as 'very high frequency (VHF)', bottlenose dolphin and white-beaked dolphin as 'high frequency (HF)', minke whale as 'low frequency (LF)', both seal (phocid) species covered by two groups (phocids in air and phocids in water), leatherback turtle as 'marine turtle', and basking shark as 'Group 1 fish' (Table 4.1). As the in-air thresholds for seals are not relevant to underwater noise assessments, these are not presented here. Southall *et al.* (2019) and Popper *et al.* (2014) applied weighting functions, which account for the frequency-dependent effects of noise, to each of the different functional hearing groups (see Southall *et al.,* 2019 and Popper *et al.* (2014) for more details on how weightings were derived).

4.2.2 Sound sources, exposure criteria, and temporary and permanent threshold shifts (TTS / PTS) in hearing

With respect to noise assessments using the criteria outlined in Southall *et al.* (2019), there are often two impacts assessed: a temporary threshold shift (TTS) in hearing and a permanent threshold shift (PTS) in hearing, the latter of which is typically regarded as injury. While for leatherback turtles and basking sharks, potential effects of noise are divided into five types by Popper *et al*. (2014), including mortality and mortal injury, recoverable injury[3], TTS, masking, and behavioural effects.

To assess these, sound sources are typically divided into two categories by Popper *et al.* (2014) and Southall *et al*. (2019), 'impulsive' and 'non-impulsive', based on attributes of the sound source:

- **Impulsive sound sources**, such as seismic airguns, are transient and brief (less than a second), broadband and typically consist of high peak pressure with rapid rise time and decay.
- **Non-impulsive sound sources**, such as shipping, CPT and rotary core borehole, can be broadband, narrowband or tonal, brief or prolonged, continuous or intermittent and typically do not have a high peak pressure with rapid rise time.

Consequently, the criteria used by Popper *et al.* (2014) and Southall *et al.* (2019) have different thresholds (see Table 4.2 and Table 4.3). The exposure metrics used are:

- frequency weighted Sound Exposure Level (SEL), to the reference value of 1 µPa2⁻s.
- unweighted peak Sound Pressure Level SPL, to the reference value of 1 µPa.

where the different exposure metrics are required to account for different aspects of exposure level and duration.

SEL is a measure of sound energy over multiple exposures and exposures accumulated over time and SPL is a measure of absolute exposure. In relation to the TTS and PTS thresholds, for impulsive sound sources, both metrics are used, and for non-impulsive sound sources only the SEL exposure metric is used. The rationale being, for non-impulsive sounds, given the very high peak SPL values required to

[3] This includes injuries such as hair cell damage, minor internal amd external bleeding. None of these injuries are likely to cause direct mortality.

induce TTS or PTS, the SEL criterion would be met before an exposure exceeding the peak SPL criteria (which are not presented by Southall *et al.* (2019) for this reason).

With respect to undertaking a quantitative assessment, should one be required, the SEL values would be calculated over the duration of a discrete noise exposure and would be cumulative over multiple repeated noise exposures occurring in relatively quick succession, and would be weighted for the relevant functional hearing group. For example, SEL could be calculated for impulsive sound sources; this could be multiple hammer strikes during installation of a monopile or several air guns firing on a transect line during seismic surveys, and for non-impulsive sound sources, this could be operational noise of vessels.

The VHF functional hearing group is the most sensitive to both impulsive and non-impulsive sound sources. We can conclude this because all the exposure criteria for this group are lower than those of the other functional hearing groups for the respective sound source and exposure criteria (**Error! Reference source not found.**). In the context of the proposed activities, the only VHF cetacean species in this region is the harbour porpoise, which is considered abundant in the North Sea (Evans *et al.*, 2003). Typically, a risk assessment would consider the most acoustically sensitive species first and, if it is concluded that the risk of TTS and PTS to VHF species is negligible, then the risk to less acoustically sensitive functional hearing groups would be reduced still.

In terms of instantaneous onset of TTS or PTS, the peak SPL exposure metric is used and as explained above, is applied to impulsive sound sources only. Loud instantaneous noises, particularly if the animals are close to the source, such as air guns firing on a seismic survey, or hammer strikes during pile driving, all have the potential to induce TTS or PTS instantaneously.

Table 4.2 Noise exposure criteria from Southall et al. (2019) for temporary threshold shift (TTS) and permanent threshold shift (PTS) in hearing by the respective functional groups

Functional hearing group	Species examples	Impulsive				Non-impulsive	
		TTS		PTS		TTS	PTS
		SEL	Peak SPL	SEL	Peak SPL	SEL	SEL
Low Frequency (LF)	Minke whale	168	213	183	219	179	199
High Frequency (HF)	Bottlenose dolphin, white-beaked dolphin	170	224	185	230	178	198
Very High Frequency (VHF)	Harbour porpoise	140	196	155	202	153	173
Phocids in water (PCW)	Harbour seal, grey seal	170	212	185	218	181	201

Table 4.3 Noise exposure criteria or relative effect risk from Popper et al. (2014) for temporary threshold shift (TTS), recoverable injury and behavioural changes in hearing by the respective functional groups; Relative risk (high, moderate, low) is given for animals at three distances from the source defined in relative terms as near (N), intermediate (I), and far (F).

Functional hearing group	Species examples	Low- and mid-frequency impulsive noise						Non-impulsive			
		Mortality & mortal injury	Recoverable injury	TTS	Masking	Behaviour	Mortality & mortal injury	Recoverable injury	TTS	Masking	Behaviour
Marine turtle	Leatherback turtle	210 dB SEL or 207 dB peak SPL	(N) High (I) Low (F)Low	(N) High (I) Low (F)Low	(N) Low (I) Low (F) Low	(N) High (I) Moderate (F)Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) High (I) Moderate (F) Low
Group 1 fish	Basking shark	219 dB SEL or 213 dB peak SPL	216 dB SEL or 213 dB peak SPL	186 dB SEL	(N) Low (I) Low (F)Low	(N) High (I) Moderate (F)Low	(N) Low (I) Low (F) Low	(N) Low (I) Low (F) Low	(N) Moderate (I) Low (F) Low	(N) High (I) High (F) Moderate	(N) Moderate (I) Moderate (F) Low

4.2.3 Behavioural responses to underwater noise

Behavioural responses to underwater noise are challenging to assess for a number of reasons (Gomez *et al.,* 2016; Southall *et al.,* 2021). Changes in behaviour can be driven by the condition of individuals, the age-class of individuals, the context (e.g., transiting an area vs. present at an important foraging ground). As such, deriving a threshold for disturbance has proven far more challenging than for TTS and PTS onset (Gomez *et al.,* 2016; Southall *et al.,* 2021). There is a growing body of literature on experimental and observational studies which has expanded our understanding of behavioural responses to discrete underwater noise events, such as vessel presence (e.g., Nowacek *et al.,* 2001; Hastie *et al.,* 2003; Lusseau, 2003; Benhemma-Le Gall *et al.,* 2022; Pirotta *et al.,* 2012; Culloch *et al.,* 2016), across situations and contexts, for individuals and groups. However, these studies only serve to highlight that attempts to derive thresholds for single noise exposure parameters and behavioural responses across broad taxonomic and sound categories is unlikely to be appropriate and can lead to significant errors in predicting impacts (Southall *et al.,* 2021).

There are more studies on the impacts of underwater noise on harbour porpoise (e.g., Brandt *et al.,* 2011; Carstensen *et al.*, 2006; Dyndo *et al.,* 2015; Lucke *et al.,* 2009; Schaffeld *et al.*, 2019) than on other marine mammal species, in part because they are the most acoustically sensitive, and because they are the most ubiquitous species of marine mammal in UK and Irish waters. In a recent study, Benhemma-Le Gall *et al.* (2022) investigated the broad-scale responses of harbour porpoises to construction works at an offshore windfarm site and found that porpoise displacement (assessed using passive acoustic monitoring) was observed up to 12 km from pile-driving activities and up to 4 km from construction vessels. A study in Danish waters investigated the high intensity pulses from an air gun on a small sample size (n = 5) of harbour porpoises that were captured and tagged with high resolution location and dive loggers (van Beest *et al.,* 2018). They used a single 10 inch^3 underwater air gun producing high intensity noise pulses (2-3 second intervals) for one minute, at ranges of 420 to 690 m, with noise level estimates of 135-147 dB re 1µPa^{2}s (SEL). They reported noise-induced movements (directly away from the sound source and/or shorter and shallower dives than usual) for three of the five individuals, with the effects lasting less than eight hours. There was no quantifiable behavioural response for the other two individuals. These examples, and particularly the latter study by van Beest *et al.* (2018), illustrate the challenges in the experimental design of *in situ* studies, obtaining these data, analysing them (e.g., accounting for extrinsic and confounding parameters, spatial and temporal autocorrelation) and making inferences on behaviour based on the context of the situation.

Assessments of the impacts of underwater noise in free-living fishes is challenging; however, a few robust experiments conducted on captive/caged fishes do exist (Popper *et al.,* 2014). The primary responses recorded relate to behaviour and startle reactions and shift in distribution in the water column, and reactions related to swim bladder physiology, such as orientation and buoyancy (Hassel *et al.,* 2004). However, it has been suggested that individuals may habituate to a sound source and return to pre-exposure behaviours either late in an exposure period or after exposure ceases (Pearson *et al.,* 1992). Studies on the behaviour of sea turtles has also been tested, with Weir (2007) reporting fewer sea turtles near active airguns as opposed to silent airguns. However, the cause could not be identified; for example, the turtles may have reacted to the ship and/or towed equipment rather than the airgun (Weir 2007).

5 Approach to risk assessment

The general approach and terminology used in this document is consistent with the Guidelines for ecological impact assessment in the UK and Ireland: terrestrial, freshwater and coastal (CIEEM, 2016) and the protection of marine European protected species from injury and disturbance guidance for Scottish Inshore waters (Scottish Government, 2020), in terms of describing the effects and determining significance.

The approach is complemented by the receptor specific guidance JNCC guidelines for minimising the risk of injury to marine mammals from geophysical surveys (JNCC, 2017) which has been used to inform this risk assessment. This guidance will also be applied to other species, specifically leatherback turtles and basking sharks that are included within this risk assessment. This guidance recommends that coastal and marine activities undergo a risk assessment for anthropogenic sound-related impacts on relevant protected marine mammal species to address any area-specific sensitivities, both in timing and spatial extent, and to inform the consenting process. The guidance states that an evidence-based risk assessment for each marine mammal species that occurs in and around the Proposed Development needs to consider the nature of the impact, its likely and/or potential effects on individuals and/or populations and on their likely habitats, and could usefully address the following questions where appropriate:

- Do individuals or populations of marine mammal species (or leatherback turtles or basking sharks) occur within the proposed area?
- Is the plan or project likely to result in death, injury, or disturbance of individuals?
- Is it possible to estimate the number of individuals of each species that are likely to be affected?
- Will individuals be disturbed at a sensitive location or sensitive time during their life cycle?
- Are the impacts likely to focus on a particular section of the species' population, e.g., adults vs. juveniles, males vs. females?
- Will the plan or project cause displacement from key functional areas, e.g., for breeding, foraging, resting or migration?
- How quickly is the affected population likely to recover once the plan or project has ceased?

Where appropriate, consideration will be given to the sensitivity of marine mammals, leatherback turtle and basking sharks to the impact pathways assessed. The sensitivity of EPS and protected species to potential risk will be determined subjectively based on species' ecology and behaviour. Judgement will take account of information available on species responses to various stimuli (e.g., underwater noise and change in water quality) where such information exists, and whether their ecology makes them vulnerable to potential impacts (e.g., species that have high sensitivity to underwater noise). The receptor will be assigned a value from one of four levels – high, medium, low, or negligible where:

- High – a species with no tolerance of sources of disturbance, such as noise, prey disturbance and vessel movements;
- Medium – a species with limited tolerance of sources of disturbance;

- Low – a species with some tolerance, and the assessed effect is unlikely to be long-term; and
- Negligible – a species that is generally tolerant of sources of disturbance.

The magnitude of impacts will also be considered, which refers to the scale of an impact and will be determined on a quantitative basis, such as number or percentage of individuals impacted whilst considering a management/population unit, where possible. Impact magnitude will be assigned a value from one of four levels – high, medium, low, or negligible, when it is not possible to be determined quantitatively, where:

- High – effects that will irreversibly alter the population in the short-to-long-term and potentially alter the long-term viability of the population;
- Medium – effects resulting in irreversibly alter the population in the short-to-long-term, but not the long-term viability of the population;
- Low – effects with temporary and reversible change in the size or distribution of the population; and
- Negligible – effects with very slight change in the size or distribution of the population that is rapidly reversible following cessation of the proposed surveys.

The likelihood of impact will be determined by considering the sensitivity of a receptor along with the magnitude of the impact to which the receptor is exposed, and appropriate mitigation will be proposed to manage the risk identified.

6 Baseline

In order to assess the impacts on marine mammals, leatherback turtles and basking sharks due to underwater noise arising from the proposed survey operations, it is necessary to address the following aspects:

- The hearing sensitivities of the species most likely to be present within or close to the survey areas (as described in Section 4).
- The frequency and amplitude of the sounds that will be produced by the proposed survey operations (as outlined in Section 3, detail in Section 7.1).
- The risk of acoustic injury to marine mammals, leatherback turtles and basking sharks (as described in Section 4.2).
- The risk of disturbance to marine mammal, leatherback turtle and shark species.

The risk of acoustic injury or disturbance is considered for all the species identified in Section 4.2, which specifically discusses the likelihood of underwater noise to impair an individual's ability to survive, breed, reproduce or raise young, or the likelihood that an individual may be displaced from an area for a longer period than would occur during normal behaviour.

During the proposed activities the main impact pathways of concern to the EPS and protected species relate to underwater noise. Therefore, in defining the zone of influence (ZoI), consideration was given to the propagation of noise, from activities such as geophysical surveys, and the potential impact on the EPS and protected species. For geophysical surveys in the North Sea, studies have shown that harbour porpoise were deterred from the area, up to 12 km from the source (measured by a reduction in acoustic activity) during seismic airgun surveys (Sarnocińska *et al.,* 2020). More is known on the impacts of geophysical surveys and other noisy activities not relevant to these activities, such as pile driving and UXO clearance. Tougaard *et al.* (2009) and Dähne *et al.* (2013) identified that harbour porpoises (the most acoustically sensitive species of marine mammals in Irish and UK waters) were excluded temporarily from an area of 26 km from the noise source of monopile driving. Conversely, there are few studies (Erbe and McPherson, 2017; Huang *et al.,* 2023) investigating potential impact ranges of underwater noise resulting from geotechnical activities such as drilling. Available information on the noise levels from geotechnical survey equipment, both broadly and specific to the proposed activities, shows that they will not exceed geophysical surveys in amplitude and footprint.

Therefore, considering that:

- the activities likely to have the greatest impact are geophysical surveys;
- uncertainties regarding important site-specific variations that will influence noise propagation (e.g., water depth, sediment type) and variations in project design; and
- most recent available information on potential impact zones for such activities suggest a radius of up to 12 km from source,

a precautionary approach will be adopted, and the assessment will present a 12 km buffer and a very precautionary 26 km buffer (Figure 2 refers). Relevant to the spatial scale of the density data where relevant, this will be presented for Aspen Survey Area.

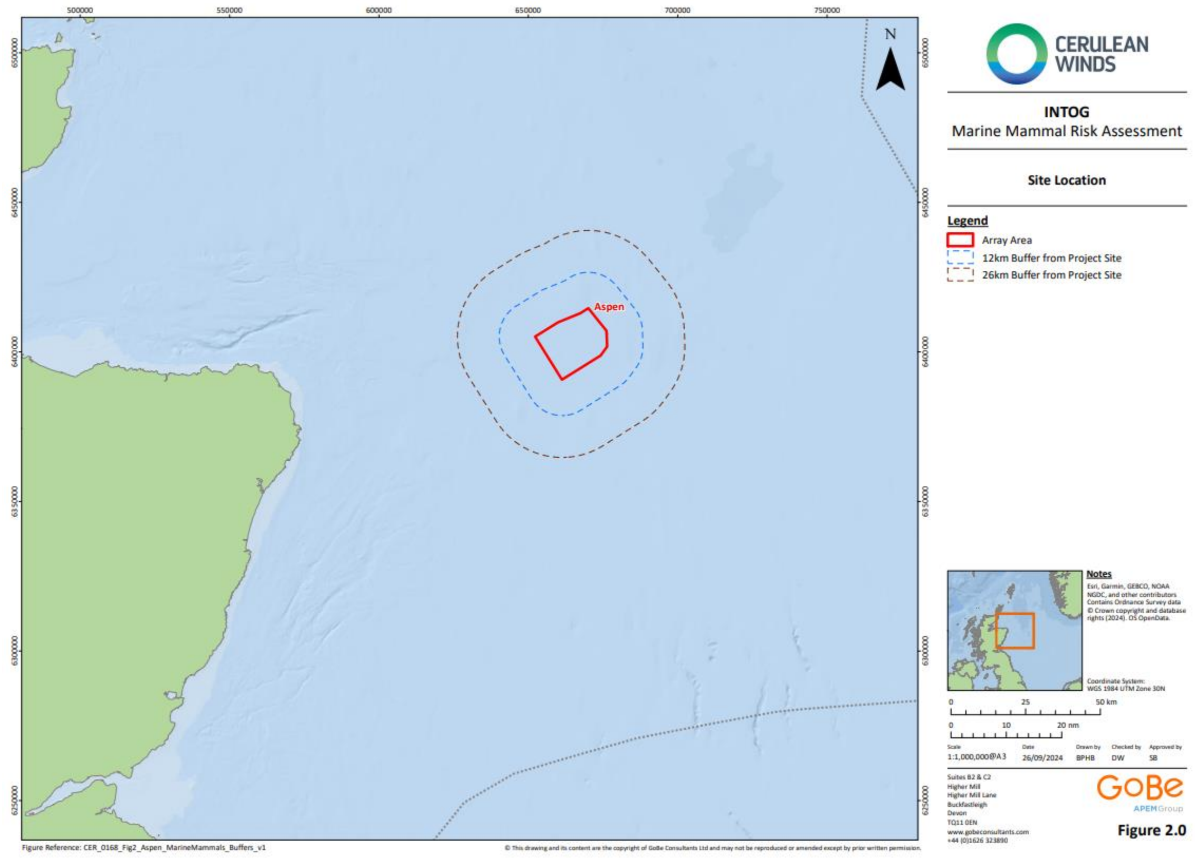

Figure 2 Assessment areas for Aspen Survey Area and a 12 km and 26-km buffer

It is important to note that the actual immediate ZoI during each survey activity associated with the proposed activities will be localised and often short in duration, and therefore will not affect the entire Proposed Development and out to 26 km, with respect to using the precautionary buffer zone. The ZoI used here is to ensure that the baseline study considered the area in which an impact may occur at any point in time during the proposed activities, and in doing so, taking a precautionary approach to extending that boundary beyond the range in which an impact would occur. As such, there is confidence in the assessment with respect to detailing relevant designated sites in the area and the EPS and protected species present.

Management units (MUs) for cetaceans were adopted when considering population-level impacts from proposed activities (IAMMWG, 2022). In considering broad-scale information on cetacean occurrence, distribution, and abundance, the Aspen Survey Area lies within survey block NS-D of SCANS IV, which was conducted in the summer of 2022 (Giles *et al.,* 2023). This correspond respectively to survey block R of SCANS-III, which was conducted in the summer of 2016 (Hammond *et al.,* 2017). In the case where cetacean abundance and density estimates are available from both SCANS-III and SCANS-IV, the higher estimate across the relevant survey block is used in the assessment, as this is the most precautionary approach. For seals, modelled at-sea density and abundance estimates were obtained and calculated from telemetry tracking and count data (seals counted at haul out sites) (Carter *et al.*, 2020; 2022). The modelled relative densities (Carter *et al*., 2022) were then converted to absolute density estimate (actual numbers of animals relative to the population) of grey and harbour seals for each ZoI by scaling from percentage of at-sea population to number of individuals, using two scalars outlined in Carter *et al.* (2020). For leatherback turtles and basking sharks, reported sightings from NBN Trust (2023) during the last 12 months have been used to inform species occurrence and distribution, as well as sightings data collated in relevant literature (leatherback turtle: Botterell *et al.,* 2020; basking shark: Shark Trust, 2024).

6.1 Cetaceans

6.1.1 Harbour porpoise

The harbour porpoise is the most widespread and frequently recorded species in the North Sea (Evans *et al.,* 2003). They are listed as a species of Least Concern on the International Union for Conservation of Nature (IUCN) Red List (Sharpe and Berggren*,* 2023). Abundance and density estimates are presented in Table 6.1 using data collected during the SCANS IV surveys (Giles *et al.,* 2023) and SCANS-III surveys (Hammond *et al.,* 2021). Harbour porpoises are opportunistic foragers with a varied diet and are known to forage at high energy, near-shore sites, where their distribution is linked to year-round proximity to small shoaling fish species, such as sandeel (*Ammodytidae*) (Santos & Pierce, 2003).

6.1.2 White-beaked dolphin

White-beaked dolphins are present in Scottish offshore waters year-round, with peaks in sightings over the summer months (Hague *et al.,* 2020). The species has an estimated density of 0.0799 animals/km² and an abundance estimate of 5,149 within block NS-D (Gilles *et al.,* 2023). This is considerably lower than the SCANS-III surveys, which provided a density estimate of 0.243 animals/km² and an abundance estimate of 15,694 within the corresponding survey block R (Hammond *et al*., 2021). The Site lies within the Celtic and Greater North Seas MU, which has an estimated abundance of 34,025 white-beaked dolphins within the UK portion of the MU (IAMMWG, 2023). The current UK conservation status for white-beaked dolphin is unknown due to insufficient data available for the species (JNCC, 2019).

6.1.3 Bottlenose dolphin

Bottlenose dolphins are listed as a species of Least Concern on the IUCN Red List (Wells *et al.,* 2019). There are two ecotypes of bottlenose dolphin in UK and Irish waters, a coastal and offshore ecotype (Cheney *et al.,* 2012). With respect to the coastal ecotype, comparison of images within bottlenose dolphin photo-identification catalogues confirms movement of individuals through prospective corridors linking designated Special Areas of Conservation (SACs) in the Moray Firth (Scotland), Cardigan Bay (Wales) and Shannon Estuary (Ireland) (Robinson *et al.,* 2012). Bottlenose dolphins off the east coast of Scotland are regularly observed with calves and juveniles, indicating a breeding population (Arso Civil *et al.,* 2021). The ODC Corridor of the Proposed Development running from landfall at Stonehaven to Aspen Survey Area would intersect an area of the coastline known to be used by the Moray Firth SAC population of bottlenose dolphins, which has an estimated abundance of 224 (CV=0.8; 95% CI=214-234) individuals (IAMMWG, 2023) within the Coastal East Scotland MU. Bottlenose dolphins travelling to or from the Moray Firth SAC may therefore be present and/or near the ODC Corridor. Connectivity of the Moray Firth SAC population with areas to the east and southeast have not been considered here, nor has any potential impacts on the CES MU in which this population is associated with. The total area of the proposed survey that overlaps with the CES MU is negligible, and the activities in those areas would be short-term and localised. Where the assessment concludes that activities require mitigation, the mitigation proposed relative to the CIS MU for bottlenose dolphins would be applicable to the CES MU for bottlenose dolphins.

Relative to the wider and offshore region, the SCANS-III surveys (Hammond *et al.*, 2021) estimated bottlenose dolphin density at 0.0298 animals/km^2 with an abundance estimate of 1,924 individuals within survey block R, where the Aspen Survey Area and ODC Corridor are situated. There are no density or abundance estimate available for bottlenose dolphin in the SCANS-IV survey blocks NS-D, due to little or no sightings (Giles *et al.,* 2023).

Prey species of bottlenose dolphin include, but are not limited to, hake (*Merluccius merluccius*), whiting (*Merlangius merlangus*), haddock (*Melanogrammus aeglefinus*), conger eel (*Conger conger*), gadoids, flatfish, and cephalopods (Hernandez-Milian *et al.,* 2012; 2015).

6.1.4 Minke whale

Minke whales are the most abundant baleen whale species within Scottish waters and occur throughout the northeast of Scotland (Robinson *et al.,* 2009). The minke whale is currently listed as a species of Least Concern on the IUCN Red List (Cooke *et al.,* 2018) and is a feature of conservation interest for the Southern Trench Marine Protected Area (MPA). Abundance and density estimates are presented in Table 6.1 using data collected during the SCANS IV surveys (Giles *et al.,* 2023) and SCANS III surveys (Hammond *et al*., 2017). There is currently no evidence of minke whales calving in Scottish waters.

Table 6.1 The relevant Management Units (MUs) and abundance and density estimates for each cetacean species considered in this assessment for all the seasons in which there were sightings in SCANS IV NS-G and NS-D (Giles et al, 2023), and SCANS III block R and block Q (Hammond et al., 2017).

Species	MU abundance (IAMMWG, 2023)	Survey blocks	Density (individuals/km^2)	Abundance
Harbour porpoise	North Sea MU: 346,601 animals (CV=0.09; 95% CI=289,498-419,967)	SCANS-IV NS-D	0.5985 (CV=0.367)	38,577 (95% CI=18,017-76,361)
		SCANS-III block R	0.599 (CV=0.287)	38,646 (95% CI=20,584-66,524)
Bottlenose dolphin	Greater North Sea MU: 2,022 animals (CV=0.75; 95% CI=548-7,453)	SCANS-III block R	0.0298 (CV=0.861)	1,924 (95% CI=0-5,048)
White-beaked dolphin	Celtic and Greater North Seas MU: 43,951 animals (CV=0.22; 95% CI=28,439-67,924)	SCANS-IV NS-D	0.0799 (CV=0.481)	5,149 (95% CI=961-10,586)
		SCANS-III block R	0.243 (CV=0.484)	15,694 (95% CI=3,022-33,340)
Minke whale	Celtic and Greater North Seas MU: 20,118 animals (CV=0.18; 95% CI= 14,061 – 28,786)	SCANS-IV NS-D	0.0419 (CV=0.594)	2,702 (95% CI=547-7,357)
		SCANS-III block R	0.0387 (CV=0.614)	2,498 (95% CI=604-6,791)

6.2 Pinnipeds

Two species of pinniped, the grey seal (*Halichoerus grypus*) and harbour seal (*Phoca vitulina*), inhabit Scottish waters year-round. Both are listed as species of Least Concern on the IUCN Red List (Bowen, 2016; Lowry, 2016). The diet of grey and harbour seals is broadly similar, with both species having a highly variable diet. Sandeels make up a large percentage of prey for both grey and harbour seals, with other prey species including salmonids, squid, dragonets, and flatfish species (Hernandez-Milian *et al.,* 2012).

6.2.1 Harbour seal

Harbour seals are present year-round on the east coast of Scotland where there is an estimated population of 364 (95 % CI=298-485) within the east Scotland Seal Management Unit (SMU) as of the 2016-2021 census period (SCOS, 2023). Foraging ranges of up to 273 km from a haul-out have been reported for harbour seals, based on analysis of telemetry data (Carter *et al.*, 2022). However, typically, harbour seals normally forage within 50 km of their haul-out site and show high site fidelity (Carter et *al.,* 2022). Harbour seals haul-out during the breeding season in June and July, and the moulting season in August (Carter *et al*., 2022; SCOS, 2023). The latest August counts of harbour seals at haul-outs within the east Scotland SMU were 262 in 2021, indicating a 24 % decline compared to the 2016 figure (SCOS, 2023). This is largely due to the low seal count of 41 individuals for the Firth of Tay and Eden Estuary SAC, which represents a drastic decline of 94 % from the mean counts recorded between 1990 and 2002, despite a recent levelling off of the decline at a depleted level (SCOS, 2023).

6.2.2 Grey seal

Grey seals are present year-round on the east coast of Scotland and are the more abundant seal species in the region. Foraging ranges of up to 448 km from a haul-out have been reported for grey seals, based on the analysis of telemetry data (Carter *et al.*, 2022). However, typical foraging distances tend to be shorter, for example, McConnell *et al.* (1999) reported that 88 % of trips undertaken were local and repeated and were within 65 km of the haul-out site. Grey seals haul-out during the breeding season from September to December, and during the moulting period from December to April (Carter et al., 2022; SCOS, 2023). The latest August counts of grey seals at haul-outs within the east Scotland SMU was 2,712 in 2021, which is lower than the 2016-2019 annually averaged count 3,683 (SCOS, 2023).

6.3 Leatherback turtles

Leatherback turtles have been recorded around UK waters, though become considerably scarcer in northern latitudes (Weir, 2001). They are listed as a vulnerable species on the IUCN Red List (Wallace *et al.,* 2013). In Scotland, approximately 38 sightings of leatherback turtles were reported between 2010 and 2022 (Penrose and Westfield, 2023), with approximately 10 of these made near the North Sea Renewable Grid (NSRG) or around Moray Firth (NBN Trust, 2023). Live turtles were largely sighted off the west of Scotland, Wales, and southwest England in 2021. Despite few sightings of this species in this region of the North Sea, as a precautionary measure, leatherback turtles are included in this assessment.

6.4 Basking sharks

Basking shark are the second largest species of elasmobranch globally and occur regularly in aggregations around Scotland during the summer months, mostly on the west coast (Austin *et al.,* 2019). This highly mobile species is distributed globally and considered endangered by the IUCN throughout its range (Rigby *et al.,* 2021). A total of 9 basking shark sightings (14 individuals) were reported around the UK in 2023, none of which were from eastern Scotland with the closest sighting reported in Orkney (Shark Trust, 2024). Despite relatively few sightings of this species in this region of the North Sea, as a precautionary measure, basking sharks are included in this assessment.

6.5 Summary of baseline

Considering the sightings, distribution, and density of the EPS and protected species within the survey area and nearby, the species taken through to the risk assessment are harbour porpoise, bottlenose dolphin, minke whale, white-beaked dolphin, leatherback turtle, basking shark, grey seal and harbour seal.

7 Risk Assessment

This risk assessment will assess the risk to the EPS and protected species outlined in Section 6 during the proposed activities, with the intention of addressing two key questions:

- Is the activity likely to result in death, injury, or disturbance of individuals?
- Is mitigation required?

7.1 Introduction

During the proposed activities there is potential for EPS (i.e., cetaceans) and other protected species (i.e., pinnipeds, leatherback turtles, and basking sharks) to be affected.

The potential impact pathways are:

- Underwater noise,
  - Geophysical surveys: hearing injuries and behavioural responses
  - Geotechnical and benthic surveys: hearing injuries and behavioural responses
- Vessel collision,
- Changes in water quality,
- Pollution events.

7.2 Underwater noise

7.2.1 Geophysical survey assessment

Specific geophysical survey equipment to be used during the proposed activities include boomers and sparkers (for SBP and UHRS systems), MBES, USBL and SSS. Empirical operating frequencies and sound pressure levels of previous measurements available in the public domain (Genesis Oil and Gas, 2011) have been considered for impact assessment here, and the respective reference values are listed in Table 7.1.

Table 7.1 Summary of typical geophysical survey equipment to be used during the proposed activities and their known or typical operating frequencies and sound pressure levels (Genesis Oil and Gas, 2011).

Equipment type	Operating frequencies	Sound Pressure Level	References
Boomers (30-100m depth) (for SBP and UHRS)	500 Hz – 300 kHz	204 – 227 dB re 1µPa @ 1 m	Innomar, 2023
Sparkers (for SBP and UHRS)	100 Hz – 300 kHz	180 dB re 1 µPa @ 1 m	Nedwell, 1994 Dantas dos Santos *et al.*, 2021
USBL (Sonardyne 8370-1111)	18 kHz – 50 kHz	184 – 193 dB re 1 µPa @ 1 m	Sonardyne, manufacturer specification
SSS	114 kHz – 455 kHz	220-226 dB re 1 µPa @ 1 m	Kongsberg, 2009
MBES	50 kHz– 200 kHz	225-245 dB re 1 µPa @ 1 m	Kongsberg, 2005

7.2.1.1 Hearing injuries

Five types of equipment operate within the auditory ranges of the functional hearing groups of the EPS and protected species included in this assessment, and are capable of producing a peak SPL which exceeds the onset thresholds for instantaneous TTS and PTS, and/or other impacts, where relevant (Table 7.2 below).

Table 7.2 The risk of instantaneous TTS, PTS, mortal or recoverable injury, auditory masking and behavioural disturbance from impulsive noise sources for each of the functional hearing groups where Y (orange) indicates onset is possible (using an extremely precautionary approach) and N (green) indicates that it is not. Where * indicates the risk is high, and ^ indicates the risk is low.

Equipment	LF (minke whale)		HF (bottlenose & white-beaked dolphin)		VHF (harbour porpoise)		PCW (harbour & grey seal)		Leatherback turtle					Basking shark				
	TTS	PTS	TTS	PTS	TTS	PTS	TTS	PTS	Mortality or mortal injury	Recoverable injury	TTS	Masking	Behaviour	Mortality or mortal injury	Recoverable injury	TTS	Masking	Behaviour
Boomer (for SBP and UHRS)	Y	Y	Y	N	Y	Y	Y	Y	Y*	Y*	Y*	Y^	Y*	N	N	N	N	N
Sparker (for SBP and UHRS)	N	N	N	N	N	N	N	N	N	Y*	Y*	Y^	Y*	N	N	N	Y^	Y*
USBL	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N	N
SSS	N	N	Y	N	Y	Y	N	N	N	N	N	N	N	N	N	N	N	N
MBES	N	N	Y	Y	Y	Y	Y	Y	N	N	N	N	N	N	N	N	N	N

This risk matrix is based on the animal being close to the sound source (within 1 m), which is highly unlikely and, therefore, extremely precautionary.

Broadly speaking, the geophysical equipment with the greatest potential impacts are the boomer and the MBES (Table 7.2). This is particularly true for marine mammals, and for some equipment, such as the sparker, there is no risk to marine mammals; the only auditory risk for this equipment is TTS and recoverable injury in leatherback turtles. Although some of the equipment types may produce noise in the hearing range of EPS and protected species, directionality must also be considered, as well as the potential for sound propagation into the wider marine environment. For example, sound propagation through the water column on the horizontal plane from the SSS is minimal; therefore, noise levels in this direction would decrease more rapidly with distance from the source (Trabant, 2013). As such, once the sound pulse has been emitted, the intensity is greatly reduced within a few metres due to scattering and absorption (Medwin 1970; Deane & Stokes 2010; Farcas *et al.,* 2016). It should be noted that the geophysical surveys are expected to last for a short period of approximately six months, and that high frequency noise at shallow waters (<200 m) is likely to attenuate more quickly. Even in the context of an extremely precautionary approach, there is no risk of instantaneous TTS or PTS for any EPS and protected species from the USBL, for example. In this case, given how the sound from the USBL propagates, and harbour porpoises typically avoid vessels (Benhemma-Le Gall *et al.,* 2022), this outcome is highly unlikely.

With respect to injury from underwater noise during geophysical surveys, the **sensitivity** of this potential impact is assessed as **medium** for marine mammals, leatherback turtles and basking sharks, the specifics of which will depend on the equipment used, and the species of interest, as noted above.

The **magnitude** of this potential impact is assessed as **low** for marine mammals. This is based on the extremely precautionary assessment of behavioural impacts, which show that less than 1 % of a MU/SMU would be affected. Whilst, in the absence of population estimates for leatherback turtles and basking sharks, given that these species are recorded in higher numbers in other regions of the UK and Ireland, the **magnitude** for these species is also assessed as **negligible** in respect to injury from underwater noise during geophysical surveys.

The **likelihood** of injury to marine mammals from underwater noise during geophysical surveys is assessed as **extremely low** given the precautionary nature of the assessment. Similarly, the **likelihood** of the impact is assessed as **extremely low** for leatherback turtles and basking sharks, given the precautionary nature of the assessment and that these species are recorded in higher numbers in other regions of the UK and Ireland.

To calculate the SEL and therefore assess the risk of cumulative TTS, PTS or other auditory injuries would require additional information on the specific source levels of geophysical survey equipment, the distance of the animal from the source, and the duration of the exposure, and to apply the weighting for the relevant functional hearing group. Whilst there is a theoretical potential for instantaneous and/or cumulative TTS and PTS, these impact zones are expected to be very localised and temporary, and the likelihood of such impacts is greatly reduced due to the likely displacement of animals from the area within which the onset of TTS, PTS and other hearing injuries would occur (see section 7.2.1.2 for further information on behavioural responses).

7.2.1.2 Behavioural responses

For marine mammal species, the relevant management unit (MU) or seal management unit (SMU) population estimates, and higher density estimates from the relevant regions in SCANS surveys or at-sea modelled estimates by Carter *et al.* (2022) have been used alongside the impact area of the activity to estimate number of animals potentially affected.

With respect to SCANS, Aspen Survey Area lies within blocks R (SCANS-III) and NS-D (SCANS-IV), as a precautionary measure, the highest number of individuals is impacted across the SCANS surveys and the array areas are carried through the assessment. Where data do not exist for a given array area (i.e. no or too few sightings of the species during SCANS surveys) the adjacent SCANS block is used to generate an estimated number of animals impacted. By adopting this extremely precautionary approach of a 26 km ZoI, this equates to a maximum of: 553 harbour porpoises, 130 white-beaked dolphins, 16 bottlenose dolphins, 23 minke whales, fewer than one harbour seal, and 19 grey seals potentially disturbed. Respectively, this reflects 0.16 %, 0.29 %, 0.78 %, 0.11 %, <0.001 % and 0.69 % of the relevant MU/SMU population.

It should be noted that behavioural responses by marine mammals within and near to the Proposed Development would be limited to short-term avoidance over the approximate six month period of geophysical surveys.

Error! Reference source not found.Table 7.3 The number of individual marine mammals estimated to have the potential to be disturbed by the geophysical survey equipment carried through to assessment (see Table 6.1), using an extremely precautionary approach.

Species	Range of potential impact (km)	Zone of influence (ZoI) per each array area (km^2)	Max. density of animals per km^2	Number of animals in ZoI of Aspen Array Area	Number of animals in the MU	% of reference population which has the potential to be affected in Aspen Array ZoI
Harbour porpoise	12	113.1	0.599 (SCANS-III Block R)	67.75	346,601	0.020 %
	26	530.9	0.599 (SCANS-III Block R)	318.01		0.092 %
White-beaked dolphin	12	113.1	0.243 (SCANS-III Block R)	27.48	43,951	0.063 %
	26	530.9	0.243 (SCANS-III Block R)	129.01		0.29 %
Bottlenose dolphin	12	113.1	0.0298 (SCANS-III Block R)	3.37	2,022 (GNS MU)	0.17 %
	26	530.9	0.0298 (SCANS-III Block R)	15.82		0.78 %
Minke whale	12	113.1	0.0419 (SCANS-IV NS-D)	4.74	20,118	0.024 %

	26	530.9	0.0419 (SCANS-IV NS-D)	22.24		0.11%
Harbour seal	12	113.1	<0.0001 (Carter *et al.*, 2022)	<0.001	364 (East Scotland SMU)	<0.0001%
	26	530.9	<0.0001 (Carter *et al.*, 2022)	<0.001		<0.0001%
Grey seal	12	113.1	0.0318 (Carter *et al.*, 2022)	3.60	2,712 (East Scotland SMU)	0.13%
	26	530.9	0.035 (Carter *et al.*, 2022)	18.58		0.69%

With respect to disturbance from underwater noise during geophysical surveys, the **sensitivity** of this potential impact is assessed as **medium** for marine mammals, leatherback turtles and basking sharks, the specifics of which will depend on the equipment used, and the species of interest, as noted above.

The **magnitude** of this potential impact is assessed as **low** for marine mammals. This is based on the extremely precautionary assessment of behavioural impacts, which show that less than 1 % of a MU/SMU would be affected. Whilst, in the absence of population estimates for leatherback turtles and basking sharks, given that these species are recorded in higher numbers in other regions of the UK and Ireland, the **magnitude** for these species is assessed as **negligible** in respect to injury from underwater noise during geophysical surveys.

The **likelihood** of disturbance to marine mammals from underwater noise during geophysical surveys is assessed as **medium** considering both the number of animals potentially disturbed and the precautionary nature of the assessment. Whilst the **likelihood** of the impact is assessed as **low** for leatherback turtles and basking sharks, given the precautionary nature of the assessment and that these species are recorded in higher numbers in other regions of the UK and Ireland.

7.2.1.3 Conclusion

Based on the sensitivity, magnitude, and likelihood of the impact of injury from underwater noise during geophysical surveys this risk is assessed as **Not Significant** to all EPS and protected species.

Based on the sensitivity, magnitude, and likelihood of an impact on behavioural responses due to underwater noise from geophysical activities this risk is assessed as **Significant** to marine mammals and **Not Significant** to leatherback turtles and basking sharks.

The use of boomers (for SBP and UHRS), SSS and MBES may cause behavioural disturbance to marine mammals when adopting a very precautionary approach. Compliance with Regulation 45 (1) of the Offshore Regulations, mitigation following JNCC (2017) guidance is recommended (refer to Section 9).

7.2.2 Geotechnical survey assessment and benthic sampling

Geotechnical equipment types and associated activities incorporated are borehole by cable percussion drilling, rotary drilling, CPT, as well as benthic grab sampling. There are very few estimates of operating frequencies and SPLs of these equipment and activities published in the public domain.

Drilling usually produces moderate levels of continuous omnidirectional sound at low frequencies (several tens of Hz to several thousand Hz and up to around 10 kHz), with source sound pressure levels reported to lie within the 145-190 dB re: 1 µPa range (DAHG, 2014). Noise from such operations would be audible to all the EPS and protected species functional hearing groups, and largely within the estimated peak sensitivity range of minke whales in terms of sound frequency. It is however outside of the estimated range of peak sensitivity in harbour porpoises, and just overlaps with the lower frequency components of peak sensitivity in dolphins and seals, meaning at lower SPLs (or received levels, relative to the distance the animal is from the source) the noise is unlikely to be detected.

USBL will be used for the calibration of positioning equipment to be used in the geotechnical surveys. Calibration exercises are only expected to take place as part of the initial planned geotechnical survey. The Sonardyne 8370-1111 USBL has a primary operating frequency of 18 kHz – 50 kHz and a maximum SL of 193 dB re 1 µPa @ 1 m. The USBL operates within the frequency ranges of all marine mammal functional hearing groups but outside of the frequency ranges of basking sharks and leatherback turtles. It is within the estimated peak sensitivity ranges of porpoises, dolphins, and seals, whilst just overlapping with the lower frequency components of peak sensitivity in minke whales. Therefore, in the case of minke whales, at lower SPLs (or received levels, relative to the distance the animal is from the source) the noise is unlikely to be detected. However, the SPL is below the instantaneous TTS and PTS onset threshold for all marine mammal functional hearing group. Therefore, as a worst-case scenario, any impact is likely to relate to behavioural disturbance, which would be short-term and localised.

7.2.2.1 Hearing injuries

Instantaneous PTS (and TTS) is not possible for these non-impulsive sound sources. To assess the risk of cumulative TTS or PTS would require additional information on the specific source levels of the equipment, the distance of the animal from the source, the duration of the exposure (which is expected to be short), and to apply the weighting for the relevant functional hearing group to calculate the SEL.

For harbour porpoise, dolphin species and seals species considered here, the hearing sensitivity of low-frequency sound is relatively poor. There could however be a sound frequency overlap between drilling noise and peak auditory sensitivity of the minke whale. While for basking sharks and leatherback turtles the only auditory risk is TTS in leatherback turtles and basking sharks, if an individual is at close to the sound sources (Table 4.3).

With respect to injury from underwater noise during geotechnical and benthic surveys, the **sensitivity** of this potential impact is assessed as **negligible** for all EPS and protected species except for minke whale, whose **sensitivity** has precautionarily been assessed as **low.**

The **magnitude** of this potential impact is assessed as **low** for marine mammals. This is based on the extremely precautionary assessment of behavioural impacts for geophysical survey, which show that less than 1 % of a MU/SMU would be affected. Whilst, in the absence of population estimates for leatherback turtles and basking sharks, given that these species are recorded in higher numbers in other regions of the UK and Ireland, the **magnitude** for these species is assessed as **negligible** in respect to injury from underwater noise during geotechnical and benthic surveys.

The **likelihood** of injury to marine mammals (excluding minke whales) from underwater noise during geotechnical and benthic surveys is assessed as **extremely low**, and **low** for minke whales given the precautionary nature of the assessment. Similarly, the **likelihood** of the impact is assessed as **extremely low** for leatherback turtles and basking sharks, given the precautionary nature of the assessment and that these species are recorded in higher numbers in other regions of the UK and Ireland.

7.2.2.2 Behavioural responses

As described in Section 7.2.1.2, behavioural responses to underwater noise can vary greatly between and among the EPS and protected species. Currently, there are no specific deterrence ranges noted or predicted for geotechnical surveys, and none are outlined in any guidance documents. The lack of such guidance on deterrence ranges for geotechnical equipment is attributable to the fact that these deterrence ranges, based on the operating frequencies and SPL, will be negligible at worst, and not comparable to any geophysical survey equipment in either amplitude or footprint.

For harbour porpoise, dolphin species and seals species considered here, the hearing sensitivity of low-frequency sound from geotechnical and benthic survey is relatively poor. Low-frequency noise from these surveys is more audible to minke whales, which may result in a behavioural response; however, this is expected to be short-term and reversible, given the nature of the activities (i.e. short duration and small footprint). While for basking sharks and leatherback turtles masking and behavioural disturbance due to underwater noise from geotechnical and benthic survey is assessed to be moderate to high if an individual is at near (tens of metres) to intermediate (hundreds of metres) distances from the sound source (Table 4.3).

With respect to disturbance from underwater noise during geotechnical and benthic surveys, the **sensitivity** of this potential impact is assessed as **negligible** for all marine mammal species, and **medium** for basking sharks and leatherback turtles, based on a very precautionary approach.

The **magnitude** of this potential impact is assessed as **negligible** for all EPS and protected species. This is based on the extremely precautionary assessment of behavioural impacts, and as these activities are not comparable to any geophysical survey equipment in amplitude or footprint, as they are localised and short in duration, so any disturbance and/or displacement is anticipated to be minimal and short-term.

The **likelihood** of disturbance to marine mammals from underwater noise during geophysical surveys is assessed as **extremely low** considering the precautionary nature of the assessment. Similarly, the **likelihood** of the impact is assessed as **extremely low** for leatherback turtles and basking sharks, given the precautionary nature of the assessment and that these species are recorded in higher numbers in other regions of the UK and Ireland.

7.2.2.3 Conclusion

Based on the sensitivity, magnitude, and likelihood of the impact of injury from underwater noise during geotechnical surveys and benthic sampling this risk is assessed as **Not Significant** to all EPS and protected species.

Based on the sensitivity, magnitude, and likelihood of an impact on behavioural responses due to underwater noise from geotechnical surveys and benthic sampling this risk is assessed as **Not Significant** to all EPS and protected species.

Therefore, the proposed geotechnical and benthic activities do not require specific mitigation.

7.3 Vessel collision

Shipping activity within this region is frequent, particularly in coastal waters around the landfall site (EMODnet, 2021). Cargos, service vessels, fishing vessels, and other ships were all recorded around the coastal region and near the Aspen Survey Area during this period. As these areas are busy with respect to vessel traffic, it is likely that EPS and protected species in this region are habituated to the presence of vessels.

Collisions between marine mammals and vessels are widely reported, with one of the key parameters influencing this being vessel speed (NOAA, 2008). Slow speeds and predictable movement are known to be key factors in minimising collision risk between vessels and marine mammals (Nowacek *et al.,* 2001; Lusseau, 2003; Lusseau *et al.,* 2006). It is assumed that the same would be true for other marine megafauna, including leatherback turtles and basking sharks. Once on site for geophysical surveys, the vessel is anticipated to travel slowly, and in consistent and predictable patterns, following predetermined survey lines. When considering slow speeds and the predictable movement, animals can react to the vessel. This has been demonstrated with similarly slow vessels as used in dredging (Todd *et al.,* 2015). For geotechnical and benthic surveys the vessel will spend periods of time stationary and travel at slow speeds between sampling locations. It is not expected that the level of vessel activity during surveys would cause a significant increase in the risk of mortality from collisions.

With respect to vessel collision, the **sensitivity** of this potential impact is assessed as **high** for all EPS and protected species, considering the serious consequences of a strike, as a collision event has the potential to kill the animal.

The **magnitude** of this potential impact is assessed as **negligible** for all EPS and protected species. This is based on the extremely precautionary assessment of behavioural impacts and considering the temporary nature of increased in vessel activity, slow speeds of survey vessels and predictable vessel movement.

The **likelihood** of vessel collision risk to all EPS and protected species is therefore assessed as **extremely low** given the precautionary nature of the assessment, and that basking sharks and leatherback turtles are recorded in higher numbers in other regions of the UK and Ireland.

Based on the sensitivity, magnitude, and likelihood of the impacts relating to vessel collision this risk is assessed as **Not Significant** to all EPS and protected species.

7.4 Change in water quality

Sedimentation and increased turbidity are unlikely to have a direct effect on the EPS or protected species but may have an indirect effect through impacts on prey (Todd *et al.,* 2015). Harbour porpoises, the most abundant cetacean species within the area, use echolocation to navigate and locate prey and thus would not be affected by increased turbidity. Even when increased turbidity has been shown to substantially reduce visual acuity in seals, which do not use sonar for prey detection, there is no evidence of reduced foraging efficiency (Todd *et al.,* 2015). For example, seals can detect water movements and hydrodynamic trails with their mystacial vibrissae; while odontocetes primarily use echolocation to navigate and find food in darkness (Hanke *et al*., 2010; Hanke and Dehnhardt, 2013; Hanke *et al.*, 2013).

Leatherback turtles and basking shark are highly mobile species and would be able to move away from intermittent, localised sediment plumes and associated sediment deposition (e.g., Wilson *et al.*, 2020). In addition, these species show no dependence on the seabed for reproduction, with basking shark bearing live young (Wilson *et al*., 2020) and leatherback turtles nesting on tropical grounds (Rowley, 2005). Therefore, they are considered to have a high tolerance to such impacts and can avoid localised sediment plumes and deposition.

With respect to change in water quality, the **sensitivity** of this potential impact is assessed as **negligible** for all EPS and protected species, considering marine mammals rely primarily on hearing, and that all EPS and protected species can recover quickly from short-term displacement given the temporary nature of the potential impact, with quick dissipation of sediment plumes.

The **magnitude** of this potential impact is assessed as **negligible** for all EPS and protected species, considering the short-term duration of proposed surveys and their relatively small footprints, coupled with the likelihood that sediment material is likely to fall out of suspension relatively quickly.

The **likelihood** of any risks associated with water quality change to all EPS and protected species is therefore assessed as **extremely low** given the precautionary nature of the assessment.

Based on the sensitivity, magnitude, and likelihood of the impacts relating to changes in water quality this risk is assessed as **Not Significant** to all EPS and protected species.

7.5 Pollution events

The potential sources of pollution during proposed surveys include vessel movements, use of drilling muds and storage of chemicals including lubricants and coolant on sampling vessels. The release of contaminants from the small proportion of fine sediments is likely to be rapidly dispersed with the tide and/or currents and therefore increased bioavailability resulting in adverse eco-toxicological effects are not expected. All vessels will follow the International Convention for the Prevention of Pollution from Ships (MARPOL) and the Marine Pollution Contingency Plan (MPCP), which contain the necessary steps to initiate an external response for any oil-related discharges, or in the case of a maritime accident/collision that results in an oil spill. Published guidelines and best working practices will be adhered to, to ensure that the likelihood of accidental spills is extremely low. In the unlikely event of a spill, the volumes of potential contaminants released would likely be negligible and would be rapidly gathered and disposed appropriately. In addition, released hydrocarbons would be subject to rapid dilution, weathering and dispersion and would be unlikely to persist in the marine environment. Therefore, it is considered unlikely that there would be any pathway for an impact on EPS or protected species, including consideration of indirect effect through changes to prey.

Release of contaminants into the water column may lead to direct impacts on cetaceans and basking sharks through ingestion, inhalation or absorption through the skin, and potentially longer-term indirect impacts from bioaccumulation in the food chain. However, these species are highly mobile, and are expected to be capable of detecting surface slicks in open water to avoid any minor events. Seals and leatherback turtles are likely to be more vulnerable to the effects of surface pollution than cetaceans because of their reliance on terrestrial sites. Seal pups entering the water would be particularly vulnerable as oil residues can reduce the thermal properties of neonate animals, increasing their susceptibility to hypothermia (Jenssen, 1996). While for leatherback turtles, they reliance on land is for nesting, which occurs in tropical regions; therefore, in this respect, they are not susceptible to accidental pollution nearby terrestrial sites in this region (Rowley, 2005). Both seals and leatherback turtles are also highly mobile, and are expected to be capable of detecting surface slicks in open water.

With respect to pollution events, the **sensitivity** of all EPS and protected species is assessed as **negligible**.

The magnitude of pollution events is assessed as **negligible** for all EPS and protected species, given the short-term and localised nature of any such pollution event, in the unlikely event that one should occur.

The **likelihood** of risk from pollution events to all EPS and protected species is therefore assessed as **extremely low** given the precautionary nature of the assessment.

Based on the sensitivity, magnitude, and likelihood of the impacts relating to pollution events this risk is assessed as **Not Significant** to all EPS and protected species.

7.6 Summary of risk assessment

EPS and protected species have been recorded within the North Sea all year round with harbour porpoise, white-beaked dolphin, bottlenose dolphin, minke whale, grey seal, harbour seal, basking shark and leatherback turtle being the most commonly recorded species. The risk assessment has followed a precautionary approach when assessing impacts of geophysical, geotechnical and benthic surveys on these most commonly recorded species and has concluded that, the use of boomers (for SBP and UHRS), SSS and MBES may cause behavioural disturbance to bottlenose dolphin, minke whale, white-beaked dolphin, harbour porpoise. As for USBL, no risk of auditory injury or disturbance has been identified, however as precautionary approach it will be included in the EPS application.

In the case of all assessments for leatherback turtles and basking sharks, all risks were concluded to be **Not Significant** and therefore no EPS or protected species licence is required for these species.

8 Consideration of alternatives

8.1 Do-nothing scenario

Site investigation surveys are required to inform the design and consenting (including the EIA processes) of the Proposed Development. There is a potential that infrastructure would be inappropriately sited and potentially over designed without any ground investigation works, giving rise to increased adverse impacts on EPS and other protected species during construction, operation and maintenance, and decommissioning phases of the Project.

8.2 Alternative survey locations

The suggested survey locations for geophysical, geotechnical, and benthic surveys provide optimal coverage of the sediment and seabed in order to inform the design of the Proposed Development. The information gathered will be used to inform the layout of floating wind turbines and moorings, design of all associated offshore components, cable alignment and cable burial risk assessment for the ODC, in addition to the EIA processes.

Alternative survey locations adjacent or near to the Proposed Development would not provide the specific geophysical details needed for the development and would potentially lead to installation and project longevity risks, which would potentially result in greater impacts on EPS and protected species. Therefore, alternative survey locations are not a feasible option.

9 Mitigation measures

9.1 Geophysical surveys

Following a precautionary approach to this assessment it has been concluded that there is a significant risk of underwater noise from geophysical activities impacting on the behaviour of marine mammals (i.e. porpoise, dolphins, whales and seals). As Cerulean Winds is committed to a proportionate approach to managing any risks identified, mitigation will be applied following the JNCC (2017) guidance. Activities requiring mitigation are all seismic surveys, including, but not limited to, sparkers, boomers and SSS.

To adhere to the JNCC guidance, it is recommended that the mitigation measures include use of Marine Mammal Observers (MMOs) and/or Passive Acoustic Monitoring (PAM), depending on the situation and the equipment used. Mitigation measures should be followed during the use of boomers (for SBP and UHRS), SSS, and MBES. If used in isolation (i.e. not alongside other geophysical equipment), mitigation of USBL is not required given the directional nature of the equipment (with respect to sound propagation), which means behavioural disturbance is unlikely and, as demonstrated by the precautionary assessment, there is no risk of instantaneous TTS or PTS to any EPS or protected species. A PAM operator would be required if proposed activities are to continue when visual observation is not possible, due to nightfall or poor weather conditions, for example.

The MMO/PAM operators are responsible for advising the client representative, survey and bridge crew on compliance with the Project's EPS licence regarding marine mammal mitigation procedures. Following JNCC guidelines (2017), this would typically include conducting at least a 30-minute pre-watch (in waters <200 m) of the mitigation zone (typically 500 m surrounding the sound source, any variation to this would be stipulated in the marine licence) to ensure no marine mammal is within this zone before soft-start. The MMO/PAM operator must maintain good communication with survey to inform them it is safe to begin operations. If a marine mammal (or other protected marine megafauna such as leatherback turtles and basking sharks) is sighted within the mitigation zone, the MMO/PAM operator are required to advise a delay in operations until at least 20 minutes of the last observation within the specified zone. Where possible, it is recommended that mitigated survey equipment commence a soft-start, where pressure is ramped up over the specified time in the marine licence (typically 20 minutes for water depths <200 m) until the equipment reaches full power. The guidance also recommends best practice during line changes or if there is any delay in sound source greater than ten minutes. Once mitigation is applied the impact on all EPS and protected species as a result of PTS, TTS, and/or disturbance as a result of geophysical surveys will be **Not Significant.**

9.2 Geotechnical and benthic surveys

The JNCC (2017) guidance does outline mitigation measures which are applicable to some geotechnical surveys, such as drilling operations, but these are subject to a risk assessment on a case-by-case basis. In this case, for the activities proposed, the risk assessment concluded that all aspects of the geotechnical and benthic surveys were **Not Significant,** including for the use of USBL during geotechnical and benthic surveys. Therefore, it is concluded that no specific mitigation is required for the proposed geotechnical and benthic survey activities.

9.3 Other impacts

All other risks to EPS and protected species assessed in this report have been assessed as **Not Significant.** It is therefore concluded that no additional mitigation is required in relation to vessel management plans, changes in water quality or pollution events.

10 Conclusion

The assessment has followed a precautionary approach when assessing impacts of geophysical, geotechnical and benthic surveys. In terms of EPS licensing, the assessments have concluded that the use of boomers (for SBP and UHRS), SSS and MBES may cause behavioural disturbance to bottlenose dolphin, minke whale, white-beaked dolphin, harbour porpoise. However, with mitigation measures in place, it is concluded that there would be no adverse residual impact to these EPS species, or their Favourable Conservation Status for any of the proposed activities. As for USBL, no risk of auditory injury or disturbance has been identified, however as precautionary approach it will be included in the EPS application.

In the case of all assessments for leatherback turtles and basking sharks, all risks were concluded to be Not Significant and therefore no EPS or protected species licence is required for these species.

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