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Assessment of underwater noise during the installation of export power cables at the Beatrice Offshore Wind Farm

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1 Introduction

This report has been prepared by Subacoustech Environmental Ltd on behalf of Beatrice Offshore Wind Farm Limited (BOWL). It provides the results of modelling undertaken in order to determine the impact of underwater noise on marine species in the Moray Firth during the installation of the export power cables between the Beatrice Offshore Wind Farm and the Moray Coast at Portgordon. This location is illustrated in Figure 1-1 below. The cable length is approximately 65 km for the offshore section and either 2.43 km or 2.54 km for the inshore section, depending on which cable route option is used.

Each activity that has been identified to be used during the installation of the export power cables have been analysed and their impact assessed using Subacoustech Environmental's large database of underwater noise measurements and the proprietary SPEAR (Simple Propagation Estimator and Ranking) model.

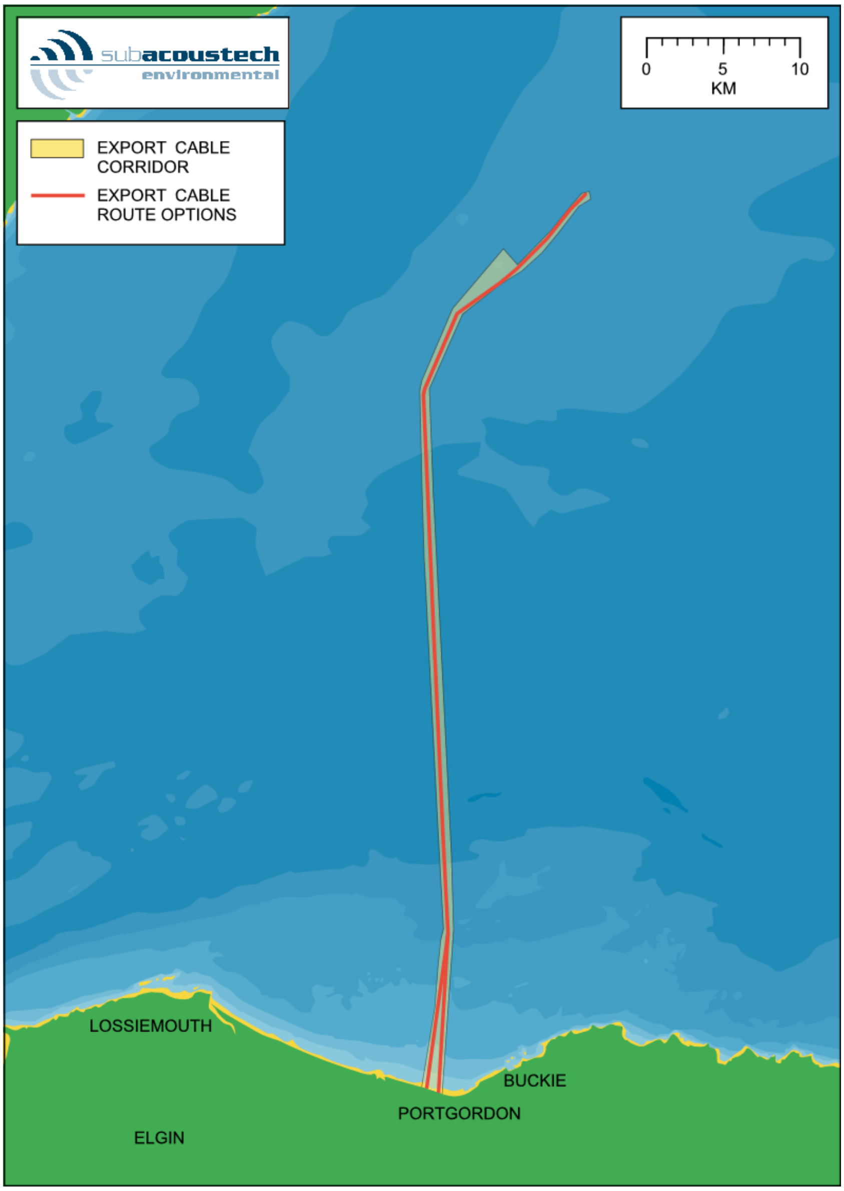

Figure 1-1 Approximate path of the export power cable from the Beatrice Offshore Wind Farm in the Moray Firth

2 Construction methods

The activities that have been identified for installing the export power cables have been sorted into three groups. These are cable laying, cable protection and vessel noise. A brief summary of these groups are given below:

2.1 Cable laying

There are two primary approaches to laying cable on the sea bed. These are simultaneous lay and bury, where the cable is laid in a trench as it is formed, usually using the same machinery, and post lay, where the cable is laid on the seabed and trenched subsequently.

2.1.1 Jetting / Trenching

Jetting, or jet trenching, is a process that involves a tool being dragged across the seabed, simultaneously laying and burying the cable as it travels along. This process is also being considered in a smaller scale at landfall and nearshore locations, using jet sleds or trolleys. However, there are environmental concerns about using this method in sensitive nearshore areas due to the displacement of sediment that will occur while using it.

2.1.2 Dredging

Backhoe dredging is being considered in shallower, nearshore locations. This involves the dredging bucket digging into the seabed, picking up material and depositing it into a barge to be moved. Also being considered in nearshore area is backfilling, where the dredged material would be used to refill the excavated area, covering the cable.

2.1.3 Horizontal directional drilling (HDD)

Directional drilling is the practice of drilling non-vertical wells, in this case horizontally. HDD has been proposed in nearshore locations to bring the export power cables from the sea and onto land. This process would eliminate bringing the cable onshore at the SSSI by drilling and bringing the cable underneath the sensitive area, minimizing any potential environmental effect.

2.2 Cable protection

Where the cable has not been sufficiently protected by the cable lay procedure, or obstructions are present, additional measures may be necessary to protect the cable. The two most commonly used cable protection methods are rock dumping and concrete mattressing.

2.2.1 Rock dumping

Rock dumping involves rocks and rubble being dropped from a large vessel through a tube down onto the seabed, creating a rock berm covering and protecting the cable.

2.2.2 Concrete mattressing

Concrete mattresses are constructed out of long concrete segments linked together to form a flexible layer of concrete that can be placed on the seabed to protect the cable.

2.3 Vessel noise

It is anticipated that the main component of underwater noise in the area during all these cable laying activities will come from the main cable laying, dredging and rock dumping vessels, as well as several smaller support vessels. The main cable lay vessel to be used for the export power cable is a 100 m long cable lay vessel with a DP2 dynamic positioning system.

3 Noise metrics

The purpose of this section is to introduce the concept behind the dB_{ht}(*Species*) and M-Weighted Sound Exposure Level (SEL) criteria that are used as a basis of the evaluation presented herein.

3.1 The dB_{ht}(*Species*)

The dB_{ht}(*Species*) metric (Nedwell *et al,* 2007[1]) has been developed as a means for quantifying the potential for a behavioural impact on a species in the underwater environment. As any given sound will be perceived differently by different species (since they have differing hearing abilities) the species name must be appended when specifying a level. For instance, the same construction event might have a level of 70 dB_{ht}(*Salmo salar*) for a salmon, and 110 dB_{ht}(*Tursiops truncatus)* for a bottlenose dolphin. Table 3-1 below summarises the assessment criteria when using the dB_{ht}(*Species*) process:

Level in dB_{ht}(*Species*)	Effect
90 and above	Strong avoidance reaction by virtually all individuals.
Above 110	Tolerance limit of sound; unbearably loud.
Above 130	Possibility of traumatic hearing damage from single event.

Table 3-1 – Assessment criteria proposed by Nedwell et al (2007) used in this study to assess the potential behavioural impact of underwater noise on marine species

In addition, a lower level of 75dB_{ht} has sometimes been used for analysis as a level of "significant avoidance". At this level, about 85% of individuals will react to the noise, although the effect will probably be limited by habituation.

The perceived noise levels of sources measured in dB_{ht}(*Species*) are usually much lower than the unweighted levels, both because the sound will contain frequency components that the species cannot detect and also because most species that live in the underwater environment have high thresholds of perception (*i.e.* are relatively insensitive) to sound when compared to terrestrial mammals. The reason for this reduction in sensitivity is related to the higher levels of noise that are typically present in the underwater environment. A species would not evolve to be able to hear below typical background noise levels over its frequency range of hearing. The typical levels of background underwater noise are considerably higher in rivers and oceans than on land and it can be shown that hearing thresholds for marine species typically match the background ocean noise levels at low sea state conditions.

Also included within this study is an assessment of the area of sea excluded with each activity; this gives an idea of the area expected to be excluded to an animal, based on a given dB_{ht}(*Species*) criteria over a period of time. This means direct comparisons can be made against the area of sea excluded during a short piling operation or a dredging operation lasting all day. These results have been given as kilometres squared excluded times hours (km^2-hours), for example, if 10 km^2-hours of sea are excluded this could mean that 1 km^2 of sea is excluded for 10 hours or that 10 km^2 of sea is excluded for 1 hour.

[1]Nedwell J R, Turnpenny A W H, Lovell J, Parvin S J, Workman R, Spinks J A L and Howell D. (2007). *A validation of the dB_{ht} as a measure of the behavioural and auditory effects of underwater noise.* Subacoustech Report Reference: 534R1231, Published by Department for Business, Enterprise and Regulatory Reform.

3.2 M-Weighted SELs

Based on the evidence of auditory damage from public domain studies, Southall *et al* (2007[2]) propose a set of auditory injury criteria based on peak pressure levels and M-weighted Sound Exposure Levels (dB re. 1 µPa^2/s (M)).

Sound Exposure Levels (SELs) sum the acoustic energy over a measurement period, and effectively takes account of both the SPL of the sound source and the duration the sound is present in the acoustic environment.

The M-weighting criteria proposed by Southall *et al* are generalised frequency weighting functions to filter underwater noise data to better represent the levels of underwater noise various marine species are likely to be able to hear. The authors group marine mammals into 5 groups, 4 of which are relevant to underwater noise (the fifth is for pinnipeds in air). For each group an approximate frequency range of hearing is proposed based on known audiogram data, where available, or inferred from other information such as auditory morphology.

The auditory injury criteria proposed by Southall *et al* are presented in Table 3-2 below, and the results of this study have also been presented in terms of this metric.

In addition to the metric proposed by Southall, a further criterion of 198 dB re 1 µPa^2/s (M_{pw}) has been suggested by Thompson and Hastie (in prep.) for Pinnipeds (in water). This is based on seal distribution data and its correlation to estimated noise levels.

	Sound type
Marine mammal group	**Single pulses**
Low Frequency Cetaceans	
Sound Pressure Level	230 dB re 1 µPa (peak)
Sound Exposure Level	198 dB re 1 µPa^2/s (M_{lf})
Mid Frequency Cetaceans	
Sound Pressure Level	230 dB re 1 µPa (peak)
Sound Exposure Level	198 dB re 1 µPa^2/s (M_{mf})
High Frequency Cetaceans	
Sound Pressure Level	230 dB re 1 µPa (peak)
Sound Exposure Level	198 dB re 1 µPa^2/s (M_{hf})
Pinnipeds (in water)	
Sound Pressure Level	218 dB re 1 µPa (peak)
Sound Exposure Level	186 dB re 1 µPa^2/s (M_{pw})
Sound Exposure Level	198 dB re 1 µPa^2/s (M_{pw}) Proposed by Thompson and Hastie (in prep.)

Table 3-2 – Proposed injury criteria for various marine mammal groups (Southall et al., 2007)

[2] Southall B L, Bowles A E, Ellison W T, Finneran J J, Gentry R L, Greene C R, Kastak D, Ketten D R, Miller J H, Nachtigall P E, Richardson W J, Thomas J A, Tyack P L. (2007). *Marine Mammal Noise Exposure Criteria.* Aquatic Mammals, Vol 33 (4).

4 The SPEAR model

4.1 Introduction

The Simple Propagation Estimator And Ranking (SPEAR) model is based on Subacoustech Environmental's substantial database of noise measurements from various sources. It can be used to provide a rank-ordering indication of the typical levels of underwater noise generated by wind farm related activities.

The SPEAR model uses a simple Source Level and Transmission Loss (SL-TL) model for calculating impact ranges and the area of sea excluded by the particular noise source. Results can easily be compared to determine the significance of the predicted impact as either the effect of multiple noise sources on one species, or as the effect of one type of noise source against multiple species with varying hearing abilities. The SPEAR model is intended for rank ordering a number of activities that cause underwater noise in order of significance, to that critical activities can be identified and selected or evaluated.

A typical result from running the SPEAR model is shown in Figures 4-1 and 4-2. Figure 4-1 shows a hypothetical situation comparing the range of which a noise impact would occur for a single species for several defined sources. Figure 4-2 compares the area of sea excluded from a single noise source that would occur for several different species.

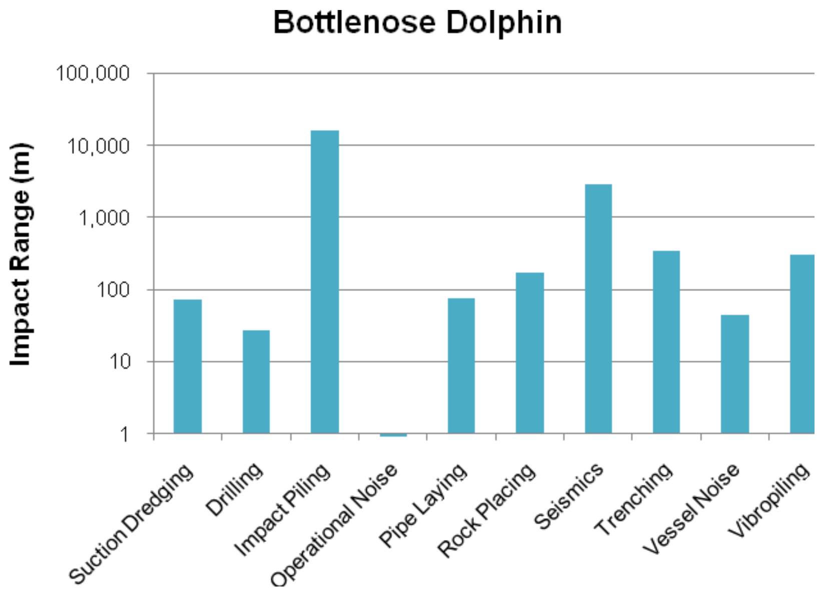

Figure 4-1 A typical summary of range of impact from the SPEAR model for a single species

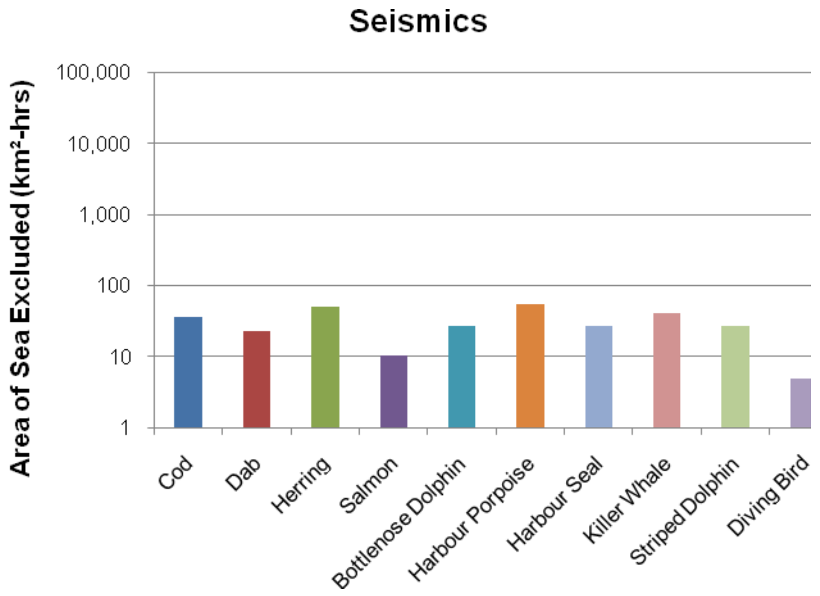

Figure 4-2 A typical summary of sea area excluded from the SPEAR model for a single noise source

4.2 Assumptions

Several assumptions have been made with regards to modelling the proposed construction methods for the export power cable.

After listening to and analysing previously measured data it has been found that the primary source of noise dominating the noise measurements during activities such as dredging, trenching and rock dumping is vessel propulsion noise. Therefore it has been assumed that the main contributing factor to the level of noise for each activity is the noise of the vessel needed to carry out each operation in particular.

There are no specific datasets in the Subacoustech noise measurement database of cable laying, however there are two projects where 11 comprehensive sets of measurements were taken of a pipe laying vessel 300 m in length, fitted with a DP2 class dynamic positioning system. The vessel used for these pipelaying operations is significantly larger than the vessel proposed for cable laying, which is 100 m in length, and is therefore likely to be a noisier process, which means that using the measurements of a pipelaying vessel will give a worst case set of results for the impacts of underwater noise from cable laying.

Three complete datasets of trenching measurements have been used as a basis for the assessment that the proposed trenching and jetting will have. These comprise of trenching vessels in excess of 100 m in length operating in water depths of between 30 and 80 m which is comparable to the water depths along the proposed cable route in the Moray Firth.

For the inshore dredging that is proposed, the SPEAR model has been used to estimate the noise from a typical backhoe dredging vessel. The SPEAR model contains information from measured data for four complete datasets of dredging vessels, including backhoe dredgers that are 50 m in length.

A worst case set of results for general vessel noise during transit and other operations during the cable laying has been assumed. Measurements of large vessels have been used as a basis of this assessment, incorporating noise from container ships, floating production storage and offloading (FPSO) vessels and other vessels in excess of 100 m using various propulsion methods including dynamic positioning.

There are four datasets for rock dumping in the Subacoustech noise measurement database. By listening to measurements of rock dumping it is possible to faintly hear rocks falling through a tube to the seabed however; the noise is dominated by the sound of DP thrusters. In the absence of further measurements, rock dumping has been considered to be a louder process than installing concrete mattressing over the cable, therefore the rock dumping measurements from the SPEAR model have also been used as the worst case when considering the proposed options for cable protection.

It is predicted that 1.5 km of cable is to be installed per day in three trenches as a worst case. All the modelling that has been carried out using the SPEAR model has assumed the operations taking place constantly over a 24 hour period.

Measurements of a generic HDD operation have been taken by Subacoustech Environmental in shallow riverine conditions while drilling was being undertaken directly below the riverbed. Measurements with HDD operations occurring 39 m below the river bed gave maximum unweighted Sound Pressure Levels of 129.5 dB re. 1µPa on the riverbed, which equates to measured dB_{ht} levels of between 25 and 41 dB_{ht}(*Phoca vitulina*) for harbour seal and between 26 and 47 dB_{ht}(*Phocoena phocoena*) for harbour porpoise. There are few limitations in using these riverine values, for example, the shallow water conditions result in a more rapid attenuation of sound. However, these measurements were taken directly above the underground drilling and with no shipping noise present. Due to the very low levels of noise measured during these operations, HDD operations have not been considered any further in this assessment.

5 Modelling Results

The results have been summarised into 5 groups of activities; cable laying, trenching, dredging, cable protection and vessel noise, and are summarised in Tables 5-1 to 5-10 below.

5.1 dB_{ht}(Species)

Tables 5-1 to 5-5 give summaries, calculated using the SPEAR model, of impact ranges for the nine key marine species using the dB_{ht}(*Species*) metric (Nedwell *et al,* 2007). From these results it can be seen that trenching operations are expected to have the greatest impact on the various marine species, with 90 dB_{ht} impact ranges estimated out to a maximum of 140 m for the harbour porpoise, which equates to an area of sea excluded of 11 km^2-hours. It should also be noted that the estimated impact ranges are greater for species of marine mammal than they are for fish. This is most likely to be because of a substantial high frequency component of the trenching noise; marine mammals can perceive higher frequencies of noise than fish, and the noise sources involved in cable laying are primarily in the higher frequencies that they can hear.

In order to give these results perspective, SPEAR modelling was also carried out for a typical impact piling operation to install a 3 m diameter pile and typical seismic investigations. The results for harbour porpoise show that installing a 3 m diameter pile by impact piling is estimated to cause a 90 dB_{ht} impact range of 12 km, which for 1 hour of piling equates to 452 km^2-hours of sea excluded. For the seismic operations 90 dB_{ht} impact ranges of 1.6 km are estimated, which for 3 hours of activity equates to 24 km^2-hours of sea excluded.

Also considered was the general vessel noise within a typical 50 km x 50 km square offshore area (a total area of 2500 km^2). This was done using the Automatic Identification System (AIS) vessel tracking data; every vessel that entered the 50 x 50 km square of sea was noted by its size and how long it was present in the area. This method showed that over a 24 hour period an estimated exclusion area of 9 km^2-hours resulted for the harbour porpoise, which is only 2 km^2-hours smaller than the area of sea excluded predicted during cable laying operations. Consequently, it may be commented that the impact of the cable laying is of a lesser magnitude than the impact of existing vessel noise.

Figure 5-1 illustrates the extent of impact predicted impact ranges using the dB_{ht}(*Species*) metric for harbour porpoise during trenching operations.

Cable Laying	**90 dB_{ht}(*Species*)**		**75 dB_{ht}(*Species*)**	
	Impact Range (m)	**Area of sea effected (km^2-hours)**	**Impact Range (m)**	**Area of sea effected (km^2-hours)**
Cod	1	< 1	20	< 1
Dab	< 1	< 1	1	< 1
Herring	8	< 1	66	< 1
Salmon	< 1	< 1	1	< 1
Bottlenose Dolphin	9	< 1	75	< 1
Harbour Porpoise	29	< 1	220	4
Harbour Seal	2	< 1	29	< 1
Killer Whale	20	< 1	170	2
Striped Dolphin	9	< 1	75	< 1

Table 5-1 Summary of the dB_{ht}(Species) impact ranges predicted for cable laying operations

Trenching	**90 dB_{ht}(*Species*)**		**75 dB_{ht}(*Species*)**	
	Impact Range (m)	**Area of sea effected (km^2-hours)**	**Impact Range (m)**	**Area of sea effected (km^2-hours)**
Cod	1	< 1	16	< 1
Dab	< 1	< 1	< 1	< 1
Herring	< 1	< 1	27	< 1
Salmon	< 1	< 1	2	< 1
Bottlenose Dolphin	81	< 1	350	9
Harbour Porpoise	140	1	640	31
Harbour Seal	12	< 1	87	1
Killer Whale	120	1	570	24
Striped Dolphin	52	< 1	200	3

Table 5-2 Summary of the dB_{ht}(Species) impact ranges predicted for trenching operations

Backhoe Dredging	**90 dB_{ht}(*Species*)**		**75 dB_{ht}(*Species*)**	
	Impact Range (m)	**Area of sea effected (km^2-hours)**	**Impact Range (m)**	**Area of sea effected (km^2-hours)**
Cod	< 1	< 1	3	< 1
Dab	< 1	< 1	1	< 1
Herring	1	< 1	4	< 1
Salmon	< 1	< 1	< 1	< 1
Bottlenose Dolphin	< 1	< 1	1	< 1
Harbour Porpoise	1	< 1	9	< 1
Harbour Seal	< 1	< 1	< 1	< 1
Killer Whale	< 1	< 1	4	< 1
Striped Dolphin	< 1	< 1	3	< 1

Table 5-3 Summary of the dB_{ht}(Species) impact ranges predicted for backhoe dredging operations

Cable Protection	**90 dB_{ht}(*Species*)**		**75 dB_{ht}(*Species*)**	
	Impact Range (m)	**Area of sea effected (km^2-hours)**	**Impact Range (m)**	**Area of sea effected (km^2-hours)**
Cod	2	< 1	25	< 1
Dab	< 1	< 1	4	< 1
Herring	6	< 1	62	< 1
Salmon	< 1	< 1	4	< 1
Bottlenose Dolphin	31	< 1	170	2
Harbour Porpoise	99	1	550	23
Harbour Seal	17	< 1	99	1
Killer Whale	56	< 1	310	7
Striped Dolphin	31	< 1	170	2

Table 5-4 Summary of the dB_{ht}(Species) impact ranges predicted for cable protection operations

Vessel Noise	90 dB$_{ht}$(*Species*)		75 dB$_{ht}$(*Species*)	
	Impact Range (m)	Area of sea effected (km^2-hours)	Impact Range (m)	Area of sea effected (km^2-hours)
Cod	2	< 1	36	< 1
Dab	< 1	< 1	2	< 1
Herring	2	< 1	29	< 1
Salmon	< 1	< 1	1	< 1
Bottlenose Dolphin	29	< 1	260	5
Harbour Porpoise	41	1	350	9
Harbour Seal	1	< 1	43	< 1
Killer Whale	25	< 1	370	10
Striped Dolphin	17	< 1	170	2

Table 5-5 Summary of the dB$_{ht}$(Species) impact ranges predicted for vessel noise during the export cable installation

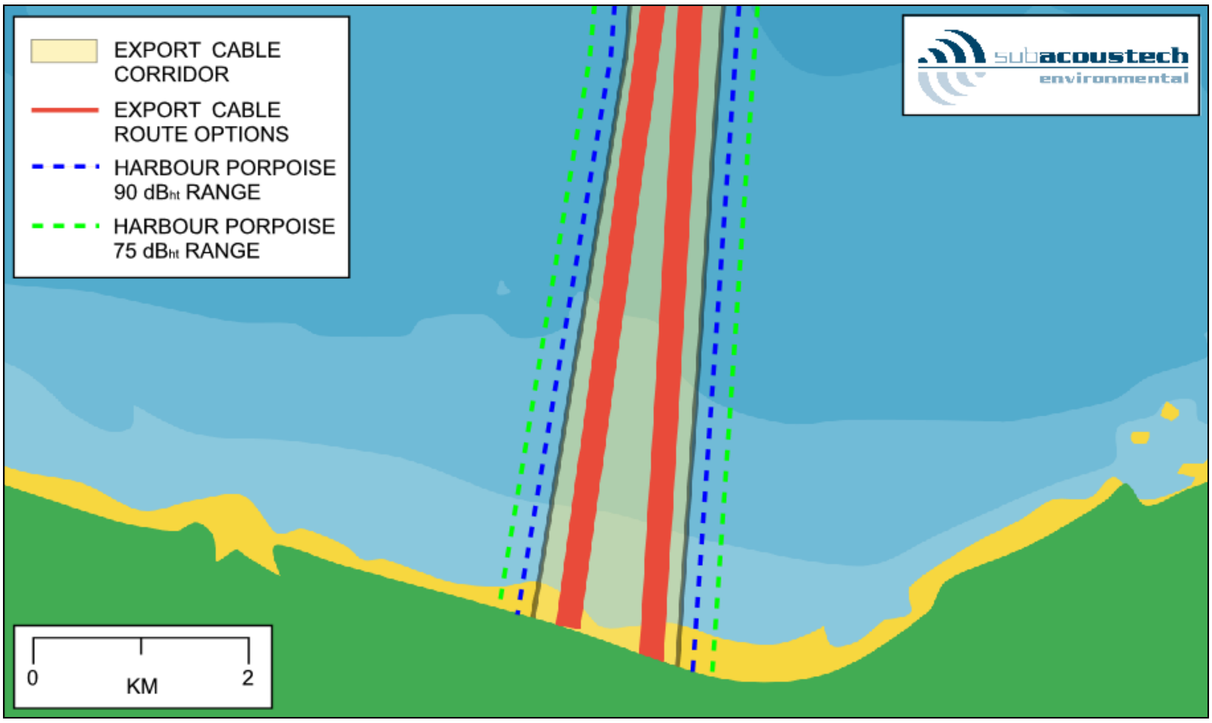

Figure 5-1 Contour plot showing the 90 and 75 dB$_{ht}$ impact ranges for harbour porpoise during trenching operations

5.2 M-Weighted SELs

Tables 5-6 to 5-10 summarise the results of the SPEAR modelling in terms of M-Weighted SELs for assessing the impact of underwater noise on marine mammals. Assuming an animal fleeing from the noise source at a rate of 1.5 $m.s^{-1}$, which is considered to be a typical cruising speed for a marine mammal, it is unlikely that a marine mammal will receive a level of noise at which auditory injury is expected to occur based on the criteria proposed by Southall *et al* (2007) for any of the activities proposed for the export cable construction. Using a stationary animal model, where it is assumed that the receptor stays in the same location relative to the vessel for the 24 hour period the largest ranges out to which auditory injury is expected to occur are predicted for the pinnipeds (in water) hearing group, with standoff ranges of 510 m estimated during cable laying, 660 m during cable protection and 770 m from movements of large vessels. It should be noted that not only are these thought to be highly precautionary levels, also it is highly unlikely that an animal will stay in the same position near a noise source for a 24 hour period.

These results have been compared to estimated impact ranges using the SPEAR model for typical activities that are not occurring, impact piling, seismic operations and general vessel noise, For impact piling a 3 m diameter pile over an hour with one pile strike per second, a pinniped fleeing at 1.5 $m.s^{-1}$ may suffer auditory injury if it is within 2.3 km of the operation at the onset of piling. This range increases to 4.1 km when using the stationary animal model. For seismic operations the level out to which auditory injury is expected is below 1 m using the fleeing animal model and up to 970 m using the stationary animal model. Using typical vessel noise for a 50 x 50 km area of the North Sea over a 24 hour period, a much smaller range of 90 m has been predicted for stationary pinnipeds out to which auditory injury is expected using the stationary animal model.

It may be summarised that assuming the animal will flee the noise; there is no likelihood of auditory injury. Assuming a stationary animal during a 24 hour period, where a receptor would have to stay at a constant distance from the different noise sources ranges at which auditory injury is expected to occur of up to a maximum of 770 m are predicted for vessel noise. However, it should be noted that this approach is considered to be extremely unlikely as it relies on a marine mammal staying at the same distance from a moving noise source, e.g. a cable laying vessel or a backhoe dredger.

Figure 5-2 illustrates the ranges out to which auditory injury is expected to occur for the pinnipeds (in water) hearing group assuming a stationary animal using the Southall *et al* 186 dB re.1µPa/s^2(M_{pw}) criteria for all five activities. The 198 dB re.1µPa/s^2(M_{pw}) ranges have not been shown on this figure as they are too small to be displayed clearly at this scale.

Cable Laying	Fleeing animal (1.5 ms^{-1}) Auditory injury range (m)	Stationary animal Auditory injury range (m)
Low Frequency Cetaceans (198 dB re.1µPa/s^2(M_{lf}))	< 1	89
Mid Frequency Cetaceans (198 dB re.1µPa/s^2(M_{mf}))	< 1	65
High Frequency Cetaceans (198 dB re.1µPa/s^2(M_{hf}))	< 1	55
Pinnipeds (in water) (186 dB re.1µPa/s^2(M_{pw}))	< 1	510
Pinnipeds (in water) (198 dB re.1µPa/s^2(M_{pw}))	< 1	91

Table 5-6 Summary of the M-Weighted SEL ranges out to which auditory injury is expected for cable laying operations

Trenching	**Fleeing animal (1.5 ms^{-1}) Auditory injury range (m)**	**Stationary animal Auditory injury range (m)**
Low Frequency Cetaceans (198 dB re.1μPa/s^2(M_{lf}))	< 1	76
Mid Frequency Cetaceans (198 dB re.1μPa/s^2(M_{mf}))	< 1	65
High Frequency Cetaceans (198 dB re.1μPa/s^2(M_{hf}))	< 1	55
Pinnipeds (in water) (186 dB re.1μPa/s^2(M_{pw}))	< 1	360
Pinnipeds (in water) (198 dB re.1μPa/s^2(M_{pw}))	< 1	57

Table 5-7 Summary of the M-Weighted SEL ranges out to which auditory injury is expected for trenching operations

Backhoe Dredging	**Fleeing animal (1.5 ms^{-1}) Auditory injury range (m)**	**Stationary animal Auditory injury range (m)**
Low Frequency Cetaceans (198 dB re.1μPa/s^2(M_{lf}))	< 1	9
Mid Frequency Cetaceans (198 dB re.1μPa/s^2(M_{mf}))	< 1	8
High Frequency Cetaceans (198 dB re.1μPa/s^2(M_{hf}))	< 1	7
Pinnipeds (in water) (186 dB re.1μPa/s^2(M_{pw}))	< 1	35
Pinnipeds (in water) (198 dB re.1μPa/s^2(M_{pw}))	< 1	9

Table 5-8 Summary of the M-Weighted SEL ranges out to which auditory injury is expected for backhoe dredging operations

Cable Protection	**Fleeing animal (1.5 ms^{-1}) standoff range (m)**	**Stationary animal standoff range (m)**
Low Frequency Cetaceans (198 dB re.1μPa/s^2(M_{lf}))	< 1	150
Mid Frequency Cetaceans (198 dB re.1μPa/s^2(M_{mf}))	< 1	120
High Frequency Cetaceans (198 dB re.1μPa/s^2(M_{hf}))	< 1	110
Pinnipeds (in water) (186 dB re.1μPa/s^2(M_{pw}))	< 1	660
Pinnipeds (in water) (198 dB re.1μPa/s^2(M_{pw}))	< 1	120

Table 5-9 Summary of the M-Weighted SEL ranges out to which auditory injury is expected for cable protection operations

Vessel Noise	Fleeing animal (1.5 ms^{-1}) standoff range (m)	Stationary animal standoff range (m)
Low Frequency Cetaceans (198 dB re.1µPa/s^2(M_{lf}))	< 1	120
Mid Frequency Cetaceans (198 dB re.1µPa/s^2(M_{mf}))	< 1	84
High Frequency Cetaceans (198 dB re.1µPa/s^2(M_{hf}))	< 1	69
Pinnipeds (in water) (186 dB re.1µPa/s^2(M_{pw}))	< 1	770
Pinnipeds (in water) (198 dB re.1µPa/s^2(M_{pw}))	< 1	86

Table 5-10 Summary of the M-Weighted SEL ranges out to which auditory injury is expected for vessel noise during the export cable installation

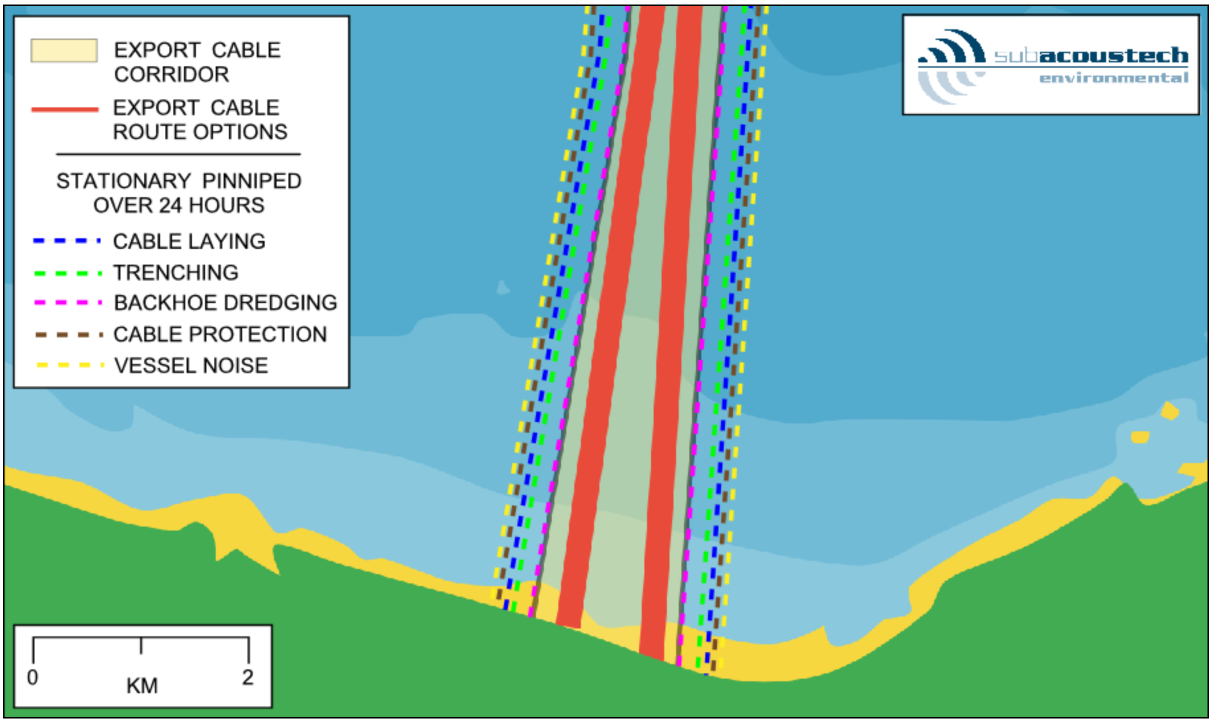

Figure 5-2 Contour plot showing the ranges out to which auditory injury is expected for the pinnipeds hearing group using the 186 dB re.1µPa/s^2(M_{pw}) criteria for a stationary animal model for the five activities

6 Summary and Conclusions

An assessment has been undertaken to determine the estimated underwater noise generated during the installation of export power cables at the Beatrice Offshore Wind Farm, using the SPEAR underwater noise model.

1. The results from the modelling have been summarised into 3 groups of activities; cable laying, cable protection and vessel noise.
2. Analysis using the dB_{ht}(*Species*) metric shows that trenching operations are expected to have the greatest impact on the various marine species, with 90 dB_{ht} impact ranges estimated out to a maximum of 140 m for the harbour porpoise, which equates to an area of sea excluded of 1 km^2-hours.
3. The estimated impact ranges are greater for species of marine mammal than they are for fish, due to both the frequency content of the cable laying noise and that marine mammals are more sensitive to underwater noise than fish.
4. Comparing these impact ranges to other sources of underwater noise show that the predicted impact ranges for the cable laying operations are much smaller than those predicted for other typical activities not occurring, such as impact piling or seismic operations.
5. Analysis of the modelling data using the M-Weighted SEL metric for assessing marine mammals shows that, for an animal fleeing from the noise source at a rate of 1.5 $m.s^{-1}$, it is unlikely that a marine mammal will receive a level of noise at which auditory injury is expected to occur using the criteria proposed by Southall *et al* (2007).
6. Assuming a stationary animal, during a 24 hour period of cable laying activity, the largest ranges out to which auditory injury is expected to occur are predicted for pinnipeds, with predicted ranges at which auditory injury is expected to occur of 510 m during cable laying, 660 m during cable protection and 770 m from movements of large vessels, however these ranges are reduced when using the additional 198 dB re.1µPa/s^2(M_{pw}) criteria for pinnipeds.
7. Comparing these results against other noise sources show that the ranges where auditory injury is predicted to occur during operations for cable laying are much less than those for impact piling and seismic operations.

Report Documentation Page

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E318R0101	10/08/2011	First draft for internal review
E318R0102	11/08/2011	Amendments following internal review
E318R0103	15/08/2011	Further amendments following director review
E318R0104	18/10/2011	Amendments regarding the calculation of the area of sea effected
E318R0105	06/01/2012	Amendments and inclusion of the 198dB SEL criterion for Pinnipeds (in water) following client review
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