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# Project Erebus Floating Offshore Wind Farm Draft Marine Mammal Mitigation Plan (UXO Clearance – Deflagration (low-order) and Pile Driving)

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| Authors: | Rachael Sinclair |
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| 3 | 22/11/2021 | Consideration of high-order UXO detonation | RRS | | | |

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# 1 Introduction

## 1.1 Project background

The proposed Project Erebus (the Project) is a demonstration scale Floating Offshore Wind (FLOW) development in the Celtic Sea region. The developer Blue Gem Wind (BGW) is a joint venture between Simply Blue Energy (SBE) and TotalEnergies, set up to create a new low carbon offshore energy sector in the region; that contributes to climate change targets, supply chain diversification and energy security.

The array area is located approximately 35 km southwest of the Pembrokeshire coastline, covering an area of 43.5 $km^2$ in water depths of between 65-85 m. The array area is located outside of the 12 nm limit, but all elements of the Project, array area, offshore export cable corridor and landfall, fall within Welsh territorial waters or the Welsh Zone.

The Project comprises six to ten Wind Turbine Generators (WTG) with a total generating capacity up to 100 MW. Each WTG is housed on a semi-submersible floating platform with a mooring system comprising a maximum of five catenary mooring lines, up to 870 m in length, and a range of foundation options including drag embedment anchors, driven piles, drilled piles and/or suction piles. Up to 10 dynamic array cables are proposed, with a lazy wave configuration from the semi-submersible floating platform to the seabed. The offshore export cable, up to 49 km in length, links the array area to landfall at West Angle Bay, Pembrokeshire.

## 1.2 Purpose of the draft Marine Mammal Mitigation Plan (MMMP)

The primary aim of this draft MMMP is to outline planned measures to reduce the risk of Permanent Threshold Shift (PTS) auditory injury to any marine mammal species from pile driving of mooring anchors or any UXO clearance to negligible levels. This draft MMMP draws on the guidance provided by the Joint Nature Conservation Committee (JNCC 2010b, a) and Statutory Nature Conservation Bodies (SNCB) recommendations with regards to Acoustic Deterrent Device (ADD) use (JNCC et al. 2016).

### 1.2.1 Implementation of the draft MMMP

This draft MMMP establishes the principles which will be implemented during construction. Following the granting of the Section 36 Consent and Marine Licence for the Project and once the final project design has been confirmed, a final MMMP will be prepared following the principles established in the draft MMMP.

# 2 Piling

## 2.1 Piling scenarios considered

The Project will consist of between six and ten semi-submersible floating platforms, which will be moored to the seabed. Various anchoring options are under consideration, including pile driven anchors. For impact pile driving the maximum design scenario is for the installation of 35 piled anchors with the following specifications:

- Diameter: 2.5 m;
- Length: 55 m;

- Penetration depth: 52 m;
- Hammer energy: 800 kJ;
- Piling duration: 114 min per pile (incl. soft-start and ramp-up);
- Total piling time for 35 anchors: 66.5 hours; and
- Total piling days = 18 days (assuming 2 piles installed per day)

Two piling scenarios have been modelled including worst-case and most-likely impact piling installation scenarios. Whereas the worst-case scenario utilises a layering of the most extreme parameters that could occur with the equipment expected to be used, the most-likely scenario takes a realistic selection of parameters likely to occur in practice. For full details on the underwater noise modelling conducted by Subacoustech Environmental Ltd, please see Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report.

**Table 1 Summary of the worst-case and most likely soft-start and ramp-up scenario for pile driving (obtained from Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report)**

| **Worst case scenario** | | | | | | |
|---|---|---|---|---|---|---|
| Hammer energy | 80 kJ | 160 kJ | 320 kJ | 480 kJ | 640 kJ | 800 kJ |
| Number of strikes | 300 | 150 | 150 | 150 | 150 | 1,920 |
| Duration | 30 mins | 5 mins | 5 mins | 5 mins | 5 mins | 64 mins |
| Strikes per minute | 10 str/min | 30 str/min | | | | |
| **Most likely scenario** | | | | | | |
| Hammer energy | 80 kJ | 120 kJ | 240 kJ | 360 kJ | 480 kJ | 600 kJ |
| Number of strikes | 300 | 150 | 150 | 150 | 150 | 1,440 |
| Duration | 30 mins | 5 mins | 5 mins | 5 mins | 5 mins | 48 mins |
| Strikes per minute | 10 str/min | 30 str/min | | | | |

For impact piling, the INSPIRE model (used by Subacoustech Environmental Ltd in the underwater noise modelling) assumes that the noise source (the hammer striking the pile) acts as a single point, as it will appear at a distance. The source level is estimated based on the pile diameter and the blow energy imparted on the pile by the hammer. This is then adjusted depending on the water depth at the modelling location to allow for the length of the pile in contact with the water, which can affect the amount of noise that is transmitted from the pile into its surroundings. The unweighted single strike $SPL_{peak}$ and $SEL_{ss}$ source levels estimated for impact piling are provided in Table 2 (for full details on the underwater noise modelling, please see Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report).

**Table 2 Summary of the unweighted $SPL_{peak}$ and $SEL_{ss}$ source levels for pile driving (obtained from Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report)**

| Source levels | Location | Worst-case 2.5 m / 800 kJ | Most Likely 2.5 m / 600 kJ |
|---|---|---|---|
| Unweighted SPLpeak (dB re 1 µPa @ 1 m) | WTG01 (NW) | 236.9 | 217.4 |
| | WTG10 (E) | 236.9 | 217.4 |
| Unweighted SELss (dB re 1 µPa$^2$s @ 1 m) | WTG01 (NW) | 235.3 | 216.0 |
| | WTG10 (E) | 235.3 | 216.0 |

## 2.2 Summary of potential impacts

### 2.2.1 Instantaneous PTS-onset

Table 3 presents the instantaneous PTS-onset impact area, impact range and number of each receptor within the PTS-onset impact area predicted to be impacted on each day of piling activities. The worst-case piling scenario is presented here for two modelling locations: WTG01 (NW) and WTG10 (E) (Figure 1).

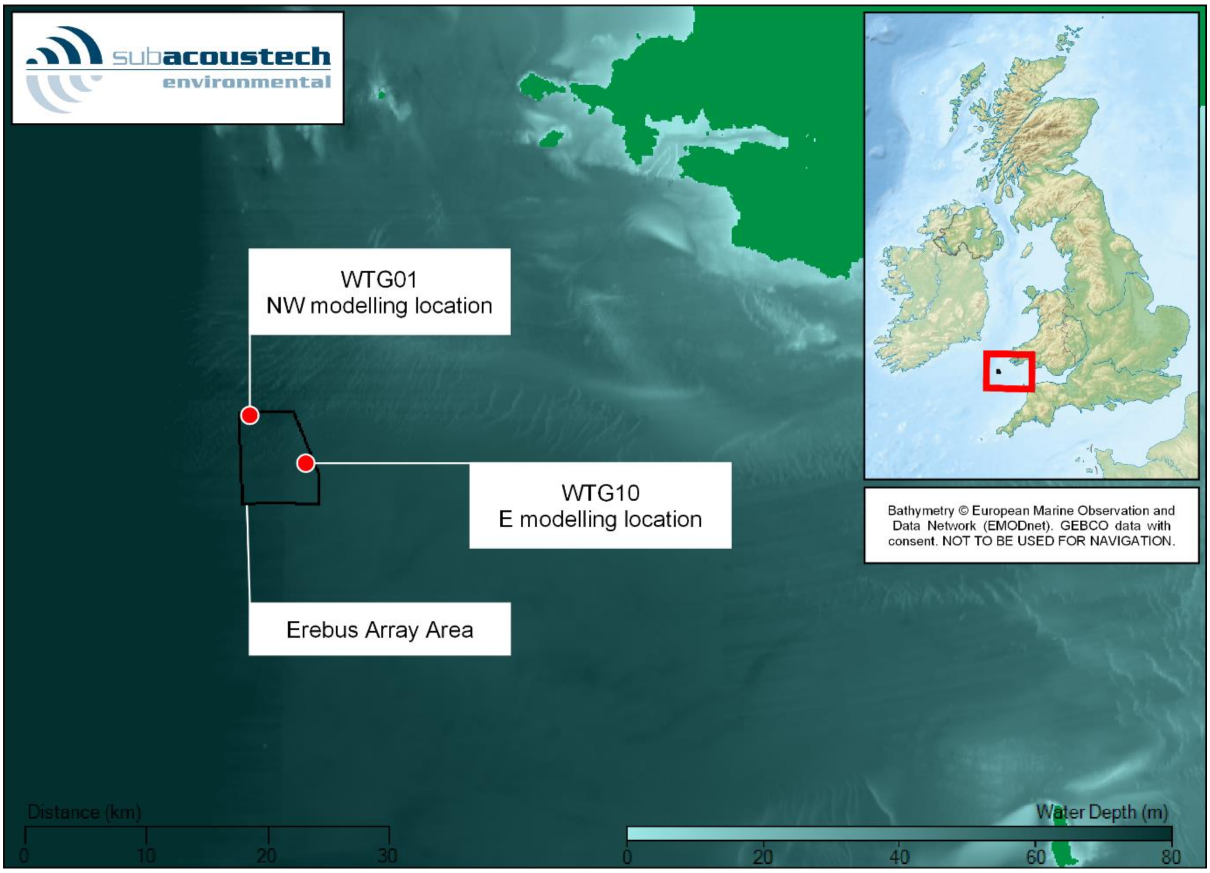


**Figure 1 The approximate impact piling locations used for modelling (obtained from Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report)**

The largest instantaneous PTS-onset impact range (unweighted $SPL_{peak}$) for impact piling is estimated at 280 m for harbour porpoise at both WTG locations. For all other marine mammal receptors, the maximum range was <50 m.

**Table 3 Instantaneous PTS-onset impact ranges and number of animals predicted to experience PTS-onset for pile driving**

| Threshold | Species | Metric | WTG01 (NW) | WTG10 (E) |
|---|---|---|---|---|
| **Instantaneous PTS: Unweighted $SPL_{peak}$** | | | | |
| 219 dB (LF) | Minke whale | Area ($km^2$) | < 0.01 | < 0.01 |
| | | Range (m) | < 50 | < 50 |
| | | # minke whales | <1 | <1 |
| 230 dB (HF) | Dolphins | Area ($km^2$) | < 0.01 | < 0.01 |
| | | Range (m) | < 50 | < 50 |
| | | # common dolphins | <1 | <1 |
| | | # bottlenose dolphins | <1 | <1 |
| 202 dB (VHF) | Porpoise | Area ($km^2$) | 0.25 | 0.25 |
| | | Range (m) | **280** | **280** |
| | | # harbour porpoise | <1 | <1 |
| 218 dB (PCW) | Seals | Area ($km^2$) | < 0.01 | < 0.01 |
| | | Range (m) | < 50 | < 50 |
| | | # grey seals | <1 | <1 |

### 2.2.2 Cumulative PTS-onset

The largest cumulative PTS-onset impact range (weighted $SEL_{cum}$) for impact piling is estimated at 2.7 km for minke whale at WTG10 (E). For all other marine mammal receptors, the maximum range was <100 m. In all modelled scenarios, <1 animal is expected to be within its respective PTS-onset impact range (Table 4).

The Applicant considers that the calculated $SEL_{cum}$ PTS-onset impact ranges are over-precautionary. Full details on the limitations of $SEL_{cum}$ modelling are provided in Appendix 1 - Limitations of SELcum predictions. In summary, the key limitations are:

- Growing empirical evidence that the equal energy hypothesis assumption behind the $SEL_{cum}$ threshold is not valid;
- Impulsive noise thresholds overestimate the risk of PTS-onset as impulsiveness reduces over distance;
- Fleeing swim speed modelled is precautionary; and
- $SEL_{ss}$ levels are lower at surface - model can overpredict exposure at the surface.

While the cumulative PTS-onset impact ranges are presented here for completeness (Table 4), it is important to note that this draft MMMP focuses on mitigating only the “instantaneous” PTS-onset impact ranges.

**Table 4 Cumulative PTS-onset impact ranges and number of animals predicted to experience PTS-onset for pile driving**

| Threshold | Species | Metric | WTG01 (NW) | WTG10 (E) |
|---|---|---|---|---|

| **Cumulative PTS: Weighted $SEL_{cum}$** | | | | |
|---|---|---|---|---|
| 183 dB (LF) | Minke whale | Area (km$^2$) | 8.2 | 12 |
| | | Range (km) | **2.2** | **2.7** |
| | | # minke whales | <1 | <1 |
| 185 dB (HF) | Dolphins | Area (km$^2$) | < 0.1 | < 0.1 |
| | | Range (m) | < 100 | < 100 |
| | | # common dolphins | <1 | <1 |
| | | # bottlenose dolphins | <1 | <1 |
| 155 dB (VHF) | Porpoise | Area (km$^2$) | < 0.1 | < 0.1 |
| | | Range (m) | < 100 | < 100 |
| | | # harbour porpoise | <1 | <1 |
| 185 dB (PCW) | Seals | Area (km$^2$) | < 0.1 | < 0.1 |
| | | Range (m) | < 100 | < 100 |
| | | # grey seals | <1 | <1 |

## 2.3 Mitigation methodology

In order to minimise the risk of any auditory injury to marine mammals from underwater noise during anchor pile driving, there are standard mitigation measures that the Project could implement for piling. These mitigation measures include the following measures:

- Marine mammal observation;
- Passive Acoustic Monitoring (PAM), and
- Piling soft-start procedure.

The following sections provide a high-level methodology for each of these elements. A final MMMP will be produced prior to the relevant works commencing for approval by NRW and JNCC.

Please note: the use of ADDs and at-source noise abatements methods (such as bubble curtains) were considered but given the very small instantaneous PTS-onset impact ranges that require mitigation (max 280 m), these were deemed to be unnecessary.

### 2.3.1 Mitigation zone

The mitigation zone (MZ) is defined as the maximum potential instantaneous PTS-onset impact ranges. The maximum instantaneous PTS-onset range for pile driven anchors is 280 m. **To be precautionary, a 500 m mitigation zone (MZ) will be monitored** for marine mammals around any piling location, as per the recommendations of the JNCC guidelines (JNCC 2010b).

### 2.3.2 Marine mammal observers (MMO)

**The pre-piling watch for marine mammals will be conducted for a minimum of 30 minutes prior to the commencement of the soft-start procedure.** The MMO will undertake visual monitoring for marine mammal within the MZ around the piling location from a suitable elevated platform. The MMO will record all periods of marine mammal observations, including start and end times. Details of environmental conditions (sea state, weather, visibility, etc.) and any sightings of marine mammals around the piling vessel will also be recorded as per JNCC marine mammal recording forms and guidelines.

In the event of an observation within the MZ during the MMO pre-piling watch, the soft-start will be delayed for 20 minutes after the last detection within the MZ to ensure any marine mammals have left the area.

It is expected that one dedicated and experienced MMO will be on watch, unless they do not have access to a location that provides a good all-round view of the mitigation zone (in which case multiple MMOs may be required).

#### 2.3.3 Passive Acoustic Monitoring (PAM)

A Passive Acoustic Monitoring System (PAMS) may be used to allow a trained PAMS operative to conduct acoustic monitoring. This may be utilised in conjunction with visual monitoring during daylight operations and/or as an alternative method of monitoring the mitigation zone during periods of reduced visibility (e.g. night, fog, high sea state i.e. above sea state 4 as per JNCC 2010b). If a PAMS is not available for monitoring, then piling will be unable to commence during such periods of restricted visibility that are not conducive to visual monitoring as there is a greater risk of failing to detect the presence of marine mammals.

#### 2.3.4 Soft-start procedure

Following the completion of the pre-piling search, a soft-start procedure will commence. This is where the piling hammer energy will gradually increase over a period of 30 minutes so that if any marine mammals are still present in the vicinity of the piling location, they are encouraged to leave by the initial low levels of underwater noise prior to the noise reaching levels which could cause PTS-onset.

The MMO will continue to note detections and observations on animal behaviour during the soft-start period.

If a marine mammal enters the MZ during the soft-start then the piling operation should either stop (if technically feasible), or the hammer energy should not be further increased until the marine mammal exits the MZ, and there is no further detection for 20 minutes.

Once the soft-start has been completed, there is no requirement to stop piling or reduce the hammer energy if a marine mammal is detected in the MZ.

#### 2.3.5 Breaks in piling

Breaks in the piling process could provide the potential for marine mammals to re-enter the mitigation zone. The guidance provided in JNCC (2010b) states that “*If there is a pause in the piling operations for a period of greater than 10 minutes, then the pre-piling search and soft-start procedure should be repeated before piling recommences*”.

#### 2.3.6 Communications

This communications protocol will include, but not be limited to:

- Procedure to notify the MMO and/or PAMS operative to begin the 30 minute pre-piling search prior to soft-start commencing;
- Procedure for the MMO and/or PAMS operative to notify the installation manager that soft-start can commence;

- Procedure for the MMO and/or PAMS operative to notify installation manager that a marine mammal has been detected in the MZ; and
- Procedure to notify MMO and/or PAMS operative that the piling operations have been successfully completed.

### 2.3.7 Reporting

A record of all piling operations, marine mammal observations and PAM detections will be maintained. Reports will include:

- Outline of the marine mammal monitoring methodology and procedures employed;
- Record of piling operations detailing date, soft-start duration, piling duration, hammer energy during soft-start and piling and any operational issues for each pile;
- Record of marine mammal observations and PAM detections including duration of the pre-piling watch, environmental conditions during the pre-piling search, description of any marine mammal sightings and any mitigating actions taken and a record of any incidental sightings made during the pre-piling search; and
- Details of any problems encountered during the piling process including instances of non-compliance with the agreed piling protocol.

Reports will be collated and provided to NRW and JNCC on a weekly basis. In addition, a final report will be provided which will be submitted to NRW and JNCC. The final report will include any data collected during piling operations, details of MMO watch periods and observations, a detailed description of any technical problems encountered and what, if any, actions were taken. The report will also discuss the protocols followed and put forward recommendations based on project experience that could benefit future construction projects.

# 3 UXO - deflagration

## 3.1 UXO scenario considered

The Project is seeking consent for one Unexploded Ordnance (UXO) detonation via deflagration (low-order). This is presented as the realistic worst-case scenario throughout the Environmental Statement and has formed the basis of the impact assessment undertaken in Chapter 12: Marine Mammal. Deflagration (low-order) is the Project's preferred method for UXO clearance and based on current industry knowledge and precedent set by other offshore developments, e.g. Greenlink Interconnector (Greenlink Interconnector Limited 2020), Sofia Offshore Wind Farm (Sofia Offshore Wind Farm UXO Clearance Marine License Application) (Sofia Offshore Wind Farm UXO Clearance Marine License Application, MLA/2020/00489; GoBe 2021), Seagreen Offshore Wind Farm (Marine Licence Application – Unexploded Ordnance Clearance – Seagreen Alpha and Bravo Wind Farm Site – 00009272)[1]; this method is considered the realistic worst-case scenario.

High order UXO detonation has also been modelled and reported in Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report; however, this has only been considered for completeness and is not deemed realistic (see Section 4).

[1]https://marine.gov.scot/data/marine-licence-application-unexploded-ordnance-clearance-seagreen-alpha-and-bravo-wind-farm

Current advice from the SNCBs is that Southall et al. (2019) should be used for assessing the PTS impacts from UXO detonation on marine mammals. However, the suitability of these criteria for UXO is under discussion, due to the lack of empirical evidence from UXO detonations using these metrics, in particular the range-dependent characteristics of the peak sounds, and whether current propagation models can accurately predict the range at which these thresholds are reached. For full details on the underwater noise modelling conducted by Subacoustech Environmental Ltd, please see Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report.

## 3.2 Summary of potential impacts

### 3.2.1 Instantaneous PTS-onset

The maximum instantaneous PTS-onset range for a 2 kg net explosive quantity (NEQ) donor charge is 1.9 km for harbour porpoise, and <1 km for all other marine mammals. The maximum cumulative PTS-onset range for a 2 kg NEQ donor charge is <1 km for all marine mammals.

**Table 5 Instantaneous PTS-onset impact ranges and number of animals predicted to experience PTS-onset for low order UXO detonation**

| Threshold | Species | Metric | 0.1 kg NEQ | 0.25 kg NEQ | 0.5 kg NEQ | 2 kg NEQ |
|---|---|---|---|---|---|---|
| **Instantaneous PTS: Unweighted $SPL_{peak}$** | | | | | | |
| 219 dB (LF) | Minke whale | Range km | 0.13 | 0.17 | 0.22 | 0.35 |
| | | # minke whales | <1 | <1 | <1 | <1 |
| 230 dB (HF) | Dolphins | Range km | 0.04 | 0.06 | 0.07 | 0.11 |
| | | # common dolphins | <1 | <1 | <1 | <1 |
| | | # bottlenose dolphins | <1 | <1 | <1 | <1 |
| 202 dB (VHF) | Porpoise | Range km | 0.73 | 0.99 | 1.2 | 1.9 |
| | | # harbour porpoise | <1 | 1 | 2 | 5 |
| 218 dB (PCW) | Seals | Range km | 0.14 | 0.19 | 0.24 | 0.39 |
| | | # grey seals | <1 | <1 | <1 | <1 |

### 3.2.2 Cumulative PTS-onset

The largest cumulative PTS-onset impact range (weighted $SEL_{cum}$) for a 2 kg NEQ donor charge is estimated at 0.63 km for minke whales. For all other marine mammal receptors, the maximum range was <0.2 km. In all modelled scenarios, <1 animal is expected to be within its respective PTS-onset impact range (Table 6).

As stated above and detailed in Appendix 1 - Limitations of SELcum predictions, the Project considers that the calculated $SEL_{cum}$ PTS-onset impact ranges are over-precautionary. While the cumulative PTS-onset impact ranges are presented here for completeness (Table 6), it is important to note that this draft MMMP focuses on mitigating only the "instantaneous" PTS-onset impact ranges.

**Table 6 Cumulative PTS-onset impact ranges and number of animals predicted to experience PTS-onset for low order UXO detonation**

| Threshold | Species | Metric | 0.1 kg NEQ | 0.25 kg NEQ | 0.5 kg NEQ | 2 kg NEQ |
|---|---|---|---|---|---|---|

| Cumulative PTS: Weighted $SEL_{cum}$ | | | | | | |
|---|---|---|---|---|---|---|
| 183 dB (LF) | Minke whale | Range km | 0.14 | 0.23 | 0.32 | 0.63 |
| | | # minke whales | <1 | <1 | <1 | <1 |
| 185 dB (HF) | Dolphins | Range km | <0.01 | <0.01 | <0.01 | <0.01 |
| | | # common dolphins | <1 | <1 | <1 | <1 |
| | | # bottlenose dolphins | <1 | <1 | <1 | <1 |
| 155 dB (VHF) | Porpoise | Range km | 0.05 | 0.08 | 0.11 | 0.2 |
| | | # harbour porpoise | <1 | <1 | <1 | <1 |
| 185 dB (PCW) | Seals | Range km | 0.03 | 0.04 | 0.06 | 0.11 |
| | | # grey seals | <1 | <1 | <1 | <1 |

## 3.3 Mitigation methodology

In order to minimise the potential risk of any auditory injury to marine mammals from underwater noise during UXO clearance, the following provides an outline of the mitigation that will be implemented (JNCC 2010a):

- Leave in situ and avoid the UXO;
- Remove or relocate the UXO;
- Pre-detonation deployment of ADDs;
- Pre-detonation MMO/PAM watch;
- Post-detonation MMO watch; and
- Underwater noise monitoring.

Please note: the use of bubble curtains was considered; however, given that the Project is intending to clear only one single UXO using the low-order deflagration method, it was not considered to be a viable mitigation option. The maximum instantaneous PTS-onset impact ranges predicted for the 2 kg donor charge is 1.9 km for porpoise, which is within the proven mitigable distances for the Lofitech ADD for harbour porpoise (see Appendix 2 – Lofitech ADD evidence base). In addition to this, it was considered that the use of a bubble curtain for one single low-order UXO clearance would likely cause more of a negative disturbance effect (due to increased vessel time, deployment and recovery of equipment), than it would provide in noise reduction benefits.

### 3.3.1 Mitigation zone

The MZ is defined as the maximum potential instantaneous PTS-onset impact ranges. **The maximum instantaneous PTS-onset range for the detonation of a 2 kg NEQ donor charge is 1.9 km**. The recommended MZ during UXO operations will, therefore, be larger than the recommended 1 km MZ recommended in the JNCC guidelines (JNCC 2010a).

### 3.3.2 Marine mammal observers (MMO)

**The MMO pre-detonation watch for marine mammals will be conducted for a minimum of 1 hour prior to the detonation.** The MMO will undertake visual monitoring for marine mammals within the MZ from a suitable elevated platform. The MMO will record all periods of marine mammal observations, including start and end times. Details of environmental conditions (sea state, weather, visibility, etc.) and any sightings of marine mammals will also be recorded as per JNCC marine mammal recording forms and guidelines.

Additionally, **a minimum of a 15 minute post-detonation search will occur after detonation activity**. The MMO will record any marine mammal sightings as well as any evidence of injury to marine life, including fish kills, or any unusual observations.

It is expected that one dedicated and experienced MMO will be on watch, unless they do not have access to a location that provides a good all-round view of the mitigation zone (in which case multiple MMOs may be required).

### 3.3.3 Passive Acoustic Monitoring (PAM)

PAMS may be used to allow a trained PAMS operative to conduct acoustic monitoring. This may be utilised in conjunction with visual monitoring during daylight operations and/or as an effective mitigation tool to allow detonation to occur during periods of reduced visibility and increased sea state; however, it is anticipated that UXO clearance activities will only occur in daylight and calm conditions. If a PAMS is not available for monitoring, then UXO detonation will be unable to commence during such periods of restricted visibility that are not conducive to visual monitoring as there is a greater risk of failing to detect the presence of marine mammals.

### 3.3.4 ADD

ADD mitigation will be applied prior to the low-order detonation to ensure that no animals are present within the MZ.

The ADD device most likely to be selected for use is the Lofitech AS seal scarer[2]. This ADD has been shown to have the most consistent effective deterrent ranges for harbour porpoise, seals and minke whales (Brandt et al. 2013b, Sparling et al. 2015, McGarry et al. 2017, Gordon et al. 2019) (see Appendix 2 – Lofitech ADD evidence base).

#### 3.3.4.1 Duration of deployment

Assuming a swimming speed of 1.5 m/s, it would take an animal 21.1 minutes to exit the 1.9 km radius MZ. To be precautionary, the **ADD will be used for 25 minutes prior to the low-order detonation**.

#### 3.3.4.2 ADD deployment procedure

It is expected that prior to deflagration (low-order) UXO detonation, one ADD will be deployed from the deck of the vessel closest to the detonation site, with the control unit and power supply on board the platform/vessel in suitable, safe positions on deck. The ADD will be verified for operation prior to activation. It is expected that a dedicated staff member will be responsible for ADD maintenance, operation, and recording/reporting. The exact deployment procedure will be agreed once the UXO contractor is in place and will follow safe, standard working practices using experienced staff to ensure the kit is used and deployed correctly within the confines of different vessel layouts.

[2] http://www.lofitech.no/en/seal-scarer.html

A dedicated ADD operator will be responsible for ADD maintenance, operation and reporting. The ADD duties involved would be to deploy the ADD from the platform or vessel, to verify the operation of the ADD before deployment, to operate the ADD prior to low-order detonation, ensure batteries are fully charged and that spare equipment is available in case of any problems, and record and report on all ADD activity. The ADD operator will typically be an individual that is experienced in the use of PAMS to allow them to effectively test and monitor the ADD functionality during operations.

The ADD will be activated for 25 minutes prior to the low-order detonation. In the unlikely event of an observation within the mitigation during the MMO watch, the ADD will continue to be activated and UXO clearance will be delayed until it is assessed by the MMO that the MZ has been clear of marine mammals for a minimum of 20 minutes.

#### 3.3.5 Communications

This communications protocol will include, but not be limited to:

- Procedure to notify the MMO and/or PAMS operative to commence visual observations for 1 hour prior to the detonation;
- Procedure to notify the ADD operator to set-up equipment, test and deploy ADDs to allow 25 min activation prior to the detonation;
- Procedure for the MMO and/or PAMS operative to notify installation manager that deployment of ADDs and activation for the required time has been successful and the pre-detonation search has been completed so that detonation can commence;
- Procedure for the MMO and/or PAMS operative to notify installation manager that a marine mammal has been detected in the mitigation zone and that the detonation will need to be delayed; and
- Procedure to notify MMO and/or PAMS operative that the detonation has been successfully completed and that the post-detonation watch should commence.

#### 3.3.6 Reporting

A record of the detonation activity, ADD deployment, marine mammal observations and PAM detections will be maintained. Reports will include:

- Outline of the marine mammal monitoring methodology and procedures employed;
- Record of detonation operations;
- Record of ADD deployment, including start and end times of all periods of ADD activation, any problems with ADD deployment;
- Record of marine mammal observations and PAM detections including duration of the pre-detonation watch, environmental conditions during the pre-detonation watch, description of any marine mammal sightings and any actions taken and a record of any incidental sightings made during out with the pre- and post-detonation watch;
- Details of any problems encountered during the piling process including instances of non-compliance with the agreed piling protocol; and
- Any recommendations for amendment of the protocol.

Reports will be collated and provided to NRW and JNCC on a weekly basis. In addition, a final report will be provided which will be submitted to NRW and JNCC. The final report will include any data collected during detonation operations, details of ADD deployment, details of MMO watch periods and observations, a detailed description of any technical problems encountered and what, if any, actions were taken. The report will also discuss the protocols followed and put forward recommendations based on project experience and the use of ADDs as mitigation during the construction period that could benefit future construction projects.

### 3.4 Noise measurements

There are limited data on underwater noise levels and potential impact ranges from UXO deflagration methods. Therefore, in order to provide evidence to fill this knowledge gap, underwater noise measurements will be conducted during the UXO deflagration event. The underwater noise measurements will follow the current guidance (Robinson et al. 2014, NPL 2020), and will be discussed and agreed with both NRW and JNCC.

# 4 UXO – high-order detonation

As stated above, the Project is seeking consent for one UXO detonation via deflagration. This is presented as the realistic worst-case scenario throughout the Environmental Statement and has formed the basis of the impact assessment undertaken in Chapter 12: Marine Mammal. This approach has been discussed with key stakeholders, including NRW, JNCC and The Wildlife Trusts, in EIA technical meetings and aligns with the approach adopted for the Greenlink Interconnector EIA (and HRA).

However, in line with the recommendations outlined within the recent position statement on UXO clearance (Department for Environment Food & Rural Affairs et al. 2021), the impact assessment also includes an assessment for a high-order detonation, though this is considered unlikely to occur in practice.

The site specific UXO Threat and Risk Assessment Report carried out for Erebus (6 Alpha Associates, 2020) concluded that the maximum realistic worst case charge weight that can be expected to be presented in the Erebus study area is 331 kg (ferrous mass).

### 4.1 Summary of potential impacts

The maximum instantaneous PTS-onset range for a 525 kg UXO is 13 km for harbour porpoise (Table 7). Given that the maximum expected UXO charge weight expected in the study area is only 331 kg, then the PTS-onset impact range for harbour porpoise would be between 9.8 km (for a 240 kg charge) and 13 km (for a 525 kg charge).

As stated in Volume 3, Technical Appendix 12.2: Underwater Noise and Vibration Technical Report, there are considerable assumptions behind this calculation: "*assumes no degradation of the UXO and no smoothing of the pulse over that distance, which is very precautionary… it is likely that the long-range smoothing of the pulse peak would reduce its potential harm and the maximum 'impulsive' range for all species is very precautionary*". Subacoustech therefore advises that "*it is likely that the long-range smoothing of the pulse peak would reduce its potential harm and the maximum 'impulsive' range for all species is very precautionary and unlikely in practice*". Given this, the PTS-onset impact range of up to 13 km for harbour porpoise is considered to be unrealistic.

**Table 7 Instantaneous PTS-onset impact ranges and number of animals predicted to experience PTS-onset for high-order UXO detonation**

| Threshold | Species | Metric | 25 kg | 55 kg | 120 kg | 240 kg | 525 kg |
|---|---|---|---|---|---|---|---|

| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Instantaneous PTS: Unweighted $SPL_{peak}$** | | | | | | | |
| 219 dB (LF) | Minke whale | Range km | 0.81 | 1.0 | 1.3 | 1.7 | 2.2 |
| | | # minke whales | <1 | <1 | <1 | <1 | <1 |
| 230 dB (HF) | Dolphins | Range km | 0.26 | 0.34 | 0.45 | 0.56 | 0.73 |
| | | # common dolphins | <1 | 1 | 1 | 2 | 3 |
| | | # bottlenose dolphins | <1 | <1 | <1 | <1 | <1 |
| 202 dB (VHF) | Porpoise | Range km | **4.6** | **6.0** | **7.7** | **9.8** | **13** |
| | | # harbour porpoise | 27 | 45 | 75 | 121 | 212 |
| 218 dB (PCW) | Seals | Range km | 0.90 | 1.1 | 1.5 | 1.9 | 2.5 |
| | | # grey seals | <1 | <1 | <1 | <1 | 1 |

**Table 8 Cumulative PTS-onset impact ranges and number of animals predicted to experience PTS-onset for high-order UXO detonation**

| Threshold | Species | Metric | 25 kg | 55 kg | 120 kg | 240 kg | 525 kg |
|---|---|---|---|---|---|---|---|
| **Instantaneous PTS: Unweighted $SPL_{peak}$** | | | | | | | |
| 183 dB (LF) | Minke whale | Range km | **2.1** | **3.2** | **4.6** | **6.5** | **9.5** |
| | | # minke whales | <1 | <1 | <1 | 2 | 3 |
| 185 dB (HF) | Dolphins | Range km | 0.01 | 0.02 | 0.03 | 0.04 | 0.05 |
| | | # common dolphins | <1 | <1 | <1 | <1 | <1 |
| | | # bottlenose dolphins | <1 | <1 | <1 | <1 | <1 |
| 155 dB (VHF) | Porpoise | Range km | 0.56 | 0.74 | 0.95 | 1.1 | 1.4 |
| | | # harbour porpoise | <1 | 1 | 1 | 2 | 2 |
| 185 dB (PCW) | Seals | Range km | 0.38 | 0.56 | 0.83 | 1.1 | 1.6 |
| | | # grey seals | <1 | <1 | <1 | <1 | <1 |

## 4.2 Mitigation methodology

In the highly unlikely event that high-order detonation is required, mitigation measures will be discussed and agreed with NRW and JNCC once UXO location and charge size is known.

Therefore, this draft MMMP provides only a *consideration* of the potential mitigation options that *could be* implemented to minimise the risk of PTS-onset from a high-order UXO detonation (JNCC 2010a):

- Leave in situ and avoid the UXO;
- Remove or relocate the UXO;
- Seasonal restrictions to high-order UXO detonation;
- Pre-detonation deployment of ADDs: for example, 56 min ADD use would allow marine mammals to exit a 5 km range;
- Pre-detonation MMO/PAM watch: at least 60 min (detonation delayed by 20 minutes after a marine mammal detection);
- Post-detonation MMO watch: at least 15 min;
- At source noise mitigation: a bubble curtain may be considered depending on environmental conditions – see Verfuss et al. (2019); and
- Underwater noise monitoring: following the current guidance (Robinson et al. 2014, NPL 2020).

# 5 Summary

Table 9 provides a summary of the key mitigation measures outlined in this draft MMMP, to mitigate the risk of PTS-onset to negligible levels.

**Table 9 Summary of the key mitigation measures in the draft MMMP**

| Impact | Mitigation measures |
|---|---|
| Pile driving | • Pre-piling MMO/PAM watch (at least 30 min)<br>• Piling soft-start procedure |
| UXO deflagration | • Leave in situ and avoid the UXO<br>• Remove or relocate the UXO<br>• Pre-detonation deployment of ADDs (25 min)<br>• Pre-detonation MMO/PAM watch (at least 60 min)<br>• Post-detonation MMO watch (at least 15 min)<br>• Underwater noise monitoring |
| UXO high-order | • Leave in situ and avoid the UXO<br>• Remove or relocate the UXO<br>• Seasonal restrictions<br>• Pre-detonation deployment of ADDs (56 min for a 5 km range)<br>• Pre-detonation MMO/PAM watch (at least 60 min)<br>• Post-detonation MMO watch (at least 15 min)<br>• At source noise mitigation |

| | |
|---|---|
| | • Underwater noise monitoring |

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# 7 Glossary of Terms, Acronyms and Abbreviations

| Term | Description |
|---|---|
| ADD | Acoustic Deterrent Device |
| DCO | Development Consent Order |
| JNCC | Joint Nature Conservation Committee |
| MMMP | Marine Mammal Mitigation Protocol |
| MMO | Marine Mammal Observer |
| MZ | Mitigation Zone |
| PAM(S) | Passive Acoustic Monitoring (System) |
| PTS | Permanent Threshold Shift |
| SEL | Sound Exposure Level |
| SNCB | Statutory Nature Conservation Body |
| SPL | Sound Pressure Level |
| TTS | Temporary Threshold Shift |
| UXO | Unexploded Ordnance |
| WTG | Wind Turbine Generator |

# 8 Appendix 1 - Limitations of $SEL_{cum}$ predictions

## 8.1 Introduction

Exposure to loud sounds can lead to a reduction in hearing sensitivity (a shift in hearing threshold), which is generally restricted to particular frequencies (e.g. Kastelein et al. 2017). This threshold shift results from physical injury to the auditory system and may be temporary (TTS) or permanent (PTS). The Erebus impact assessment for marine mammals presents PTS impact ranges for piling events, using the Southall et al. (2019) thresholds for all species. The thresholds are based on a dual criteria approach whereby both should be evaluated and that predicting the largest range of impact, should be considered for the impact assessment. The first metric is pressure based, taken as zero-to-peak sound pressure level ($SPL_{zp}$) or as peak-to-peak sound pressure level ($SPL_{pp}$). Any single exposure at or above this pressure-based metric is considered to have the potential to cause PTS, regardless of the exposure duration. The second metric is energy based and is a measure for the accumulated sound energy an animal is exposed to over an exposure period, referred to as sound exposure level (SEL) when considering single pulses, or cumulative sound exposure levels ($SEL_{cum}$) when considering exposure periods with multiple pulses.

The sound exposure level metric is based on the 'equal-energy assumption', having its origin in human research, and stating that sounds of equivalent energy will have generally similar effects on the auditory systems of exposed human subjects, even if they differ in SPL, duration, and /or temporal exposure pattern (Southall et al. 2007). While the sound pressure levels are analysed unweighted, NMFS (2018) and Southall et al. (2019) describe species specific frequency filters to be applied before the sound exposure level is calculated.

The SEL-thresholds for PTS take into account the received level and the duration of exposure, accounting for the accumulated exposure over the duration of an activity within a 24-hour period. NMFS (2018) recommends the application of $SEL_{cum}$ for the individual activity within 24 hours (e.g. one piling event with multiple strikes) rather than for multiple activities occurring within the same area or over the same time (e.g. concurrent piling).

The method used to calculate PTS impact ranges for 'instantaneous' PTS ($SPL_{pk}$), and PTS induced by cumulative sound exposure ($SEL_{cum}$, over 24 hours) are detailed in the Subsea Noise Technical Report.

## 8.2 Precaution in cumulative PTS ($SEL_{cum}$) calculations

There is much more uncertainty associated with the prediction of levels of cumulative exposure due to the difficulty in predicting the true levels of sound exposure over long periods of time, as a result of uncertainties about responsive movement, the position of animals in the water column, extent of recovery between pulses or in breaks in piling and the extent to which pulsed sound loses its impulsive characteristics over time. As a result of this uncertainty, model parameters are generally highly conservative and when considered across multiple parameters this precaution is compounded therefore the resulting predictions are very precautionary and very unlikely to be realised.

It is important to note that the $SEL_{cum}$ thresholds were determined with the assumption that a) the amount of sound energy an animal is exposed to within 24 hours will have the same effect on its auditory system, regardless of whether it is received all at once or in several smaller doses spread over a longer period (called the equal-energy hypothesis), and b) the sound keeps its impulsive character, regardless of the distance to the sound source. Both assumptions lead to a conservative determination of the impact ranges. Modelling the $SEL_{cum}$ impact ranges of PTS with a 'fleeing animal' model, as is typical in noise impact assessments, are subject to both of these uncertainties and the result is a highly precautionary prediction of impact ranges.

### 8.2.1 Equal energy hypothesis

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

### 8.2.2 Impulsive characteristics

Southall et al. (2019) acknowledges that, as a result of propagation effects, the signal of certain sound sources (e.g., pile driving) loses its impulsive characteristics and could potentially be characterised as a non-impulsive beyond a certain distance. The changes in noise characteristics with distance generally result in exposures becoming less physiologically damaging with increasing distance as sharp transient peaks become less prominent (Southall et al. 2019). In the draft version of the NMFS (2018) guidance that was released in 2015 for public consultation, four criteria were proposed to determine whether a signal is impulsive or non-impulsive in nature. These criteria were based on signal duration, rise time, crest factor and peak pressure divided by signal duration. Hastie et al. (2019) used these criteria to estimate the transition from impulsive to non-impulsive characteristics of pile driving noise during the installation of offshore wind turbine foundations at The Wash and in the Moray Firth based on sound recorded at increasing distances from the piling site. Southall et al. (2019) state that mammalian hearing is most readily damaged by transient sounds with rapid rise-time, high peak pressures, and sustained duration relative to rise-time. Therefore, of the four criteria used by Hastie et al. (2019), the rise-time and peak pressure may be the most appropriate indicators to determine the impulsive/non-impulsive transition. Based on the rise-time criterion (rise time <25 ms defines a signal as impulsive), Hastie et al. (2019) showed that the noise signal experienced a high degree of change in its impulsive characteristics within 3 - 9 km from the source. For pile driving at the Moray Firth (1.8 m diameter pin-piles in 42 m water depth), the probability of the piling noise being impulsive reduced from 70% at ~0.7 km down to 1% at ~3.1 km. For pile driving at The Wash (5.2 m diameter monopiles in water depths of 8-20 m), this probability reduced from 70% at ~1.4 km down to 1% at ~8.6 km. Therefore, predicted PTS-onset impact ranges based on the impulsive noise thresholds will overestimate the risk of PTS-onset in cases and at ranges where the likelihood increases that an animal is exposed to non-impulsive sound.

### 8.2.3 Swimming speed

To determine the number of animals experiencing energy-induced PTS, one has to calculate the accumulated energy over the course of the series of pile strikes. To do this, assumptions have to be made regarding swimming speed and direction of movement, which introduces a degree of uncertainty in the range within which animals are at risk of PTS-onset. All marine mammals were modelled to swim away at the onset of piling at a swimming speed of 1.5 m/s apart from minke whales which were modelled to flee at 3.25 m/s. There are data to suggest that these selected swim speeds are precautionary and that animals are likely to flee at much higher speeds, at least initially. Minke whales have been shown to flee from ADDs at a mean swimming speed of 4.2 m/s (McGarry et al. 2017). A recent study by Kastelein et al. (2018) showed that a captive harbour porpoise responded to playbacks of pile driving sounds by swimming at speeds significantly higher than baseline mean swimming speeds, with greatest speeds of up to 1.97 m/s which were sustained for the 30 minute test period. In another study, van Beest et al. (2018) showed that a harbour porpoise responded to an airgun noise exposure with a fleeing speed of 2 m/s. These recent studies have demonstrated porpoise and minke whale fleeing swim speeds that are greater than that used in the fleeing model here, which makes the modelled speeds used in this assessment precautionary.

### 8.2.4 Animal depth

Empirical data on $SEL_{ss}$ levels recorded during piling construction at the Lincs offshore wind farm have been compared to estimates obtained using the Aquarius pile driving model (Whyte et al. 2020). This has demonstrated that measured recordings of $SEL_{ss}$ levels made at 1 m depth were all lower than the model predicted single-strike sound exposure levels for the shallowest depth bin (2.5 m). In contrast, measurements made at 9 m depth were much closer to the model predicted single-strike sound exposure levels. This highlights the limitations of modelling exposure using depth averaged sound levels, as the acoustic model can overpredict exposure at the surface. This is important to note since animals may conduct shorter and shallower dives when fleeing (e.g. van Beest et al. 2018).

## 8.3 Conclusion

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

# 9 Appendix 2 – Lofitech ADD evidence base

The Lofitech AS seal scarer has been successfully used for marine mammal mitigation purposes at a number of offshore wind farm construction projects in Europe, including the C-Power Thornton Bank offshore wind farm in Belgium (Haelters et al. 2012), the Horns Rev II, Nysted and Dan Tysk offshore wind farms in Denmark (Carstensen et al. 2006, Brandt et al. 2009, Brandt et al. 2011, Brandt et al. 2013a, Brandt et al. 2013b) and on various German sites (Georg Nehls, pers comm). In UK waters the Lofitech device has recently been successfully used for marine mammal mitigation purposes for harbour porpoise, harbour and grey seal during piling construction activities at several Offshore Wind Farms.

## 9.1 Harbour porpoise

In the German North Sea, an array of CPODs was used to test the effectiveness of Lofitech devices for deterring harbour porpoise (Brandt et al. 2013b). The extent of deterrence was measured by recording porpoise vocalisations up to 7.5 km from the Lofitech deployment site. Ten trials were conducted, where each trial collected four hours of acoustic detections, in conjunction with an active ADD. During the 40 hours of collected data, there was a significant decline in porpoise detections. Within 750 m, detections of porpoise declined by 86% when the ADD was active. Furthermore, declines in porpoise detections were significant up to 7.5 km from the ADD source (Figure 2).

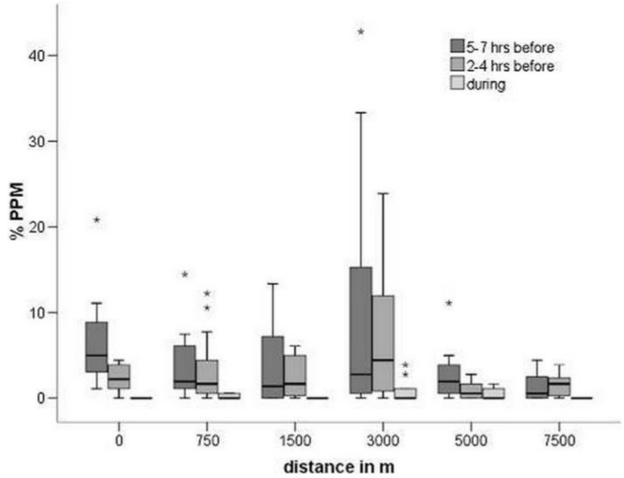


**Figure 2 Percentage of porpoise positive minutes recorded before and during Lofitech trials at various distances (Brandt et al. 2013b).**

In addition to acoustic monitoring, visual aerial surveys were conducted to identify changes in harbour porpoise presence during ADD activation. The average density fell to 0.3 porpoise/km$^2$ when the Lofitech device was activated, where baseline density estimates were 2.4 porpoise/km$^2$, over the 990 km$^2$ study area (Figure 3). To determine the duration of deterrence caused by ADDs, Brandt et al. (2013b) compared harbour porpoise detections before Lofitech activation, and after the device was switched off. Porpoise detection rates were significantly lower up to six hours after devices were switched off, and after 7-9 hours, no significant difference was detected.

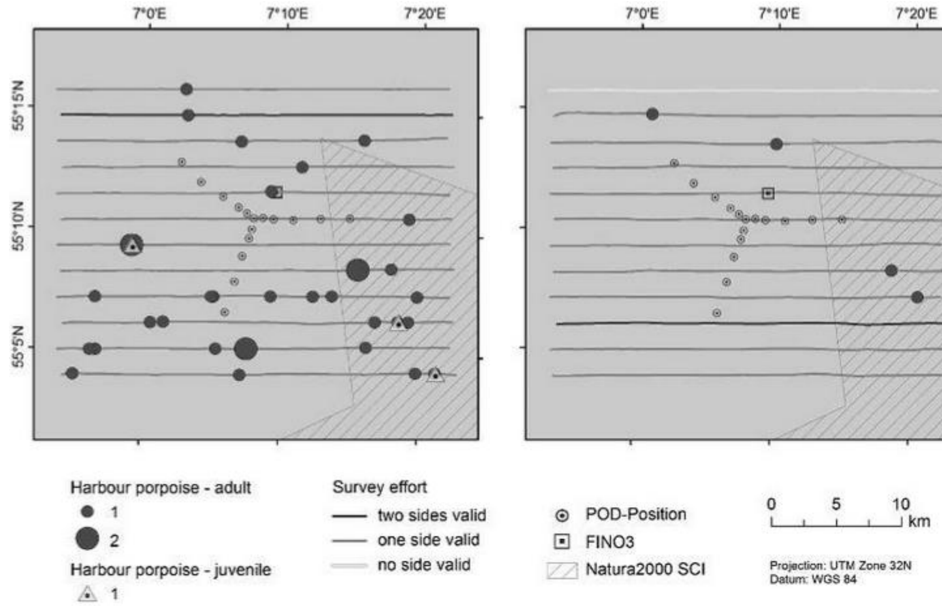


**Figure 3 Harbour porpoise aerial sightings before (left) and during (right) Lofitech activation (Brandt et al. 2013b).**

Brandt et al. (2013a) conducted visual surveys to determine the responses of harbour porpoises to Lofitech ADDs. In Danish waters, devices were active for four continuous hours, with seven trials in total, leading to 28 hours of collected data. Sighting rates of harbour porpoise significantly declined up to 1 km from the active Lofitech device, which was associated with a minimum sound level of 129 db re 1 µPa RMS. Upon activation of the ADD, the mean number of porpoises detected during a scan decreased from 0.86 to 0.01. While Lofitech trials in German waters observed avoidance up to 7.5 km from the device, in Danish waters avoidance was detected at a maximum of 2.4 km from the ADD. However, due to differences in water depth, the sound level at the offshore German site (119 dB re 1 µPa) and the more coastal Danish site were comparable. Porpoise avoidance behaviour occurred immediately upon device activation, with average swim speeds recorded at 1.6 m/s. Visual observations confirmed porpoises within a 1 km radius of the device, on average 51 minutes after the device was de-activated.

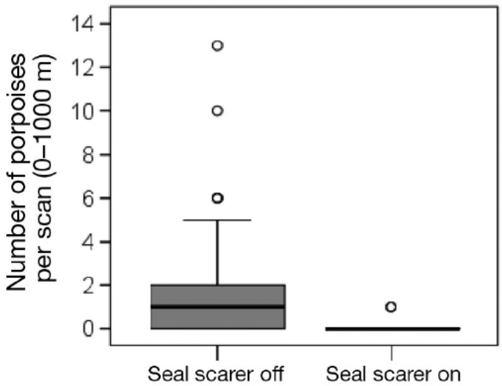


**Figure 4 Number of harbour porpoises seen during scans when the Lofitech device was active and inactive (Brandt et al. 2013a).**

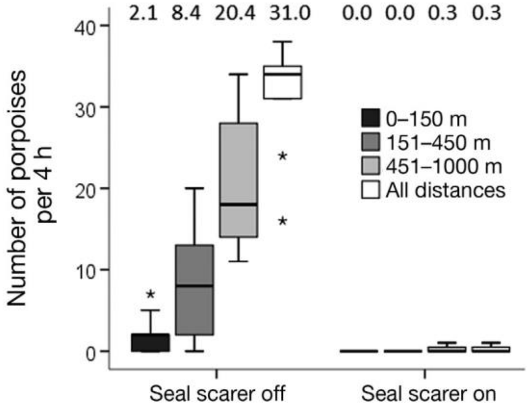


**Figure 5 Harbour porpoises sightings rates when the Lofitech device was active and inactive over a range of distances (Brandt et al. 2013a).**

## 9.2 Minke whales

During a study commissioned by ORJIP, the playback of Lofitech ADDs resulted in behavioural modifications of minke whales (McGarry et al. 2017, Boisseau et al. 2021). A significant increase in swim speed and direct movement away from the ADD source implied avoidance of the Lofitech device (Figure 6). It was therefore suggested that Lofitech seal scarers may be used as a deterrent of minke whales from mitigation zones in the future. One limitation of this study was the ability to follow the focal whale after it had been exposed to the ADD. The ADD was activated 1 km from the focal animal, and remained active for 15 minutes; all animals responded, which demonstrates an effective deterrence zone of at least 1 km. No measurements were made with ADDs activated at initial distances > 1 km from the focal animal, and the visual limit of observations limited how far animals could be observed responding to, so it is not known what the maximum effective deterrence range is. However, several animals continuing to swim further away to a distance of between c. 3 km and 4.5 km following exposure.

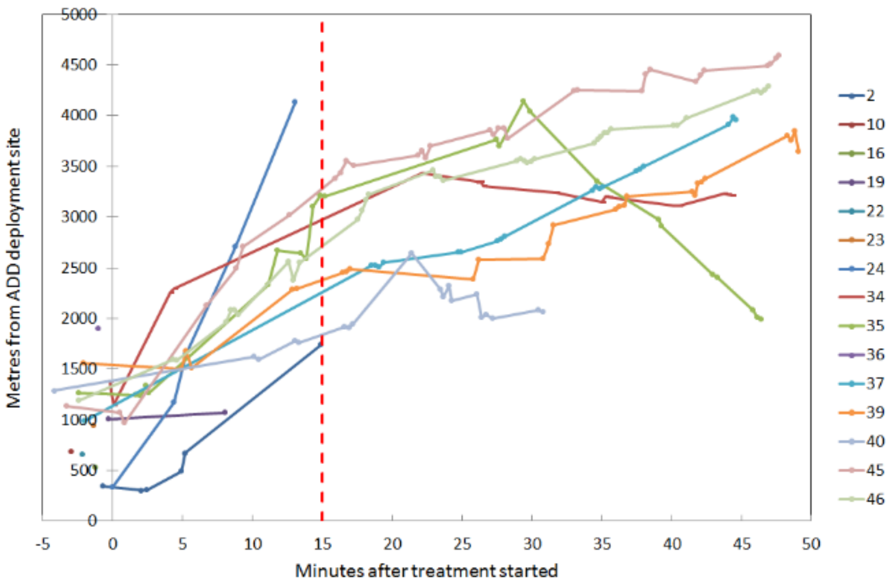


**Figure 6 Distance of focal whales from the ADD deployment site during treatment and post treatment phases of the experiment. The red dashed line indicates the end of the treatment phase.**

## 9.3 Seals

In 2015, Marine Scotland funded a project to assess the effectiveness of Lofitech devices as harbour seal deterrents (Gordon et al. 2015). In Kyle Rhea in 2013, 10 seals were tagged, and in the Moray Firth in 2014, 13 tags were deployed. In total, 73 controlled exposure experiments were conducted, and responses monitored using a novel telemetry tracking system. All animals within ~1 km of the source exhibited a behavioural response during CEEs (n=38) (Figure 9 and 10). A lack of response to the CEE was first observed 998 m from the device, with a predicted received sound level of 132 dB re 1 1 µPa RMS (Figure 9). Conversely, responses were detected up to 3.112 km from the ADD, where the predicted received level was 120 dB re 1 µPa RMS. However, distances further than 1 km device were characterised by lower response rates, for example, at 4.1 km from the source, only 20% of seals responded to the CEE (Figure 10). Overall, it was concluded that the use the Lofitech device would deter seals up to ~1 km from the source.

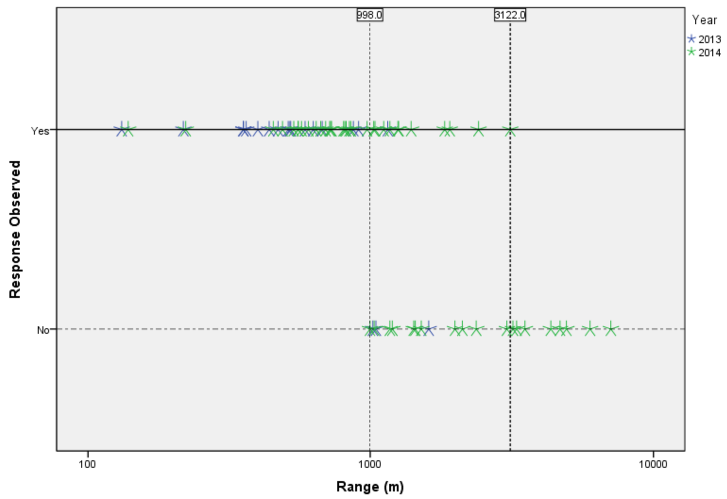


**Figure 7 Controlled exposure experiments with harbour seals and the Lofitech device which did and did not elicit responses plotted against range (reproduced from Gordon et al., 2015). The Range of the first closest non-responsive CEE and the most distant responsive CEEs are indicated by the dotted vertical lines.**

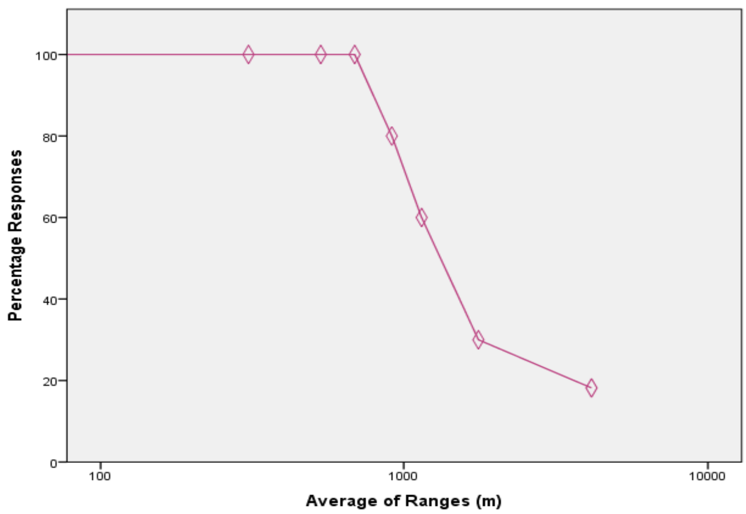


**Figure 8 Percentage of controlled exposure experiments with harbour seals and the Lofitech device eliciting a response ranked by range (reproduced from Gordon et al., 2015).**

## 9.4 Dolphin species

For dolphin species, there has been little/no research on deterrence using Lofitech device. However, the maximum instantaneous PTS-onset impact range for dolphin species from a low-order detonation using a 2 kg donor charge is only 0.11 km, which can easily be monitored by visual and PAM methods.