Note / Memo

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Industry & Buildings

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Subject: Moray East UXO marine mammal assessment update

List of Acronyms

ADD	Acoustic Deterrent Device
ADD-Op	Acoustic Deterrent Device Operator
ECoW	Ecological Clerk of Works
EOD	Explosive Ordnance Disposal
EPS	European Protected Species
HE	High Explosive
HF	High Frequency
LF	Low Frequency
MF	Mid Frequency
ML	Marine Licence
MMMP	Marine Mammal Mitigation Plan
MMO	Marine Mammal Observer
MTD	Marine Technology Directorate
NEQ	Net Explosive Quantity
NOAA	National Oceanic and Atmospheric Administration
OfTI	Offshore Transmission Infrastructure
OWF	Offshore Wind Farm
PAM	Passive Acoustic Monitoring
PAM-Op	Passive Acoustic Monitoring Operator
PTS	Permanent Threshold Shift
PW	Phocid Pinnipeds in Water
SPL	Sound Pressure Level
SEL	Sound Exposure Level
TTS	Temporary Threshold Shift
UXO	Unexploded Ordnance

1 Introduction

Moray East has undertaken surveys for identification of unexploded ordnance (UXO) prior to commencement of construction of the Moray East Offshore Wind Farm and associated Offshore Transmission Infrastructure (OfTI) (referred to as “the Development").

This technical note provides an update of the ‘worst case scenarios’ that were previously assessed and submitted with the European Protected Species (EPS) licence application for

Explosive Ordnance Disposal (EOD) operations, following updated information being made available from the Moray East UXO inspection campaign.

2 UXO Survey Results Summary

Table 1 outlines the UXO devices that have been identified in the Moray East site and OfTI Corridor. Below is a summary of the main findings:

- Fifteen confirmed UXO have been identified in the Moray East site (Figure 1) and three in the OfTI Corridor (Figure 2).
- No UXO were located within 3 km of the coast (Figure 2).
- The largest UXO is up to 365 kg and will require a donor charge of 25 kg.
- The two UXO located together (MC118) will be detonated together (2 x 60 kg plus 8 kg donor charge). Note the Marine Mammal Mitigation Plan (MMMP; Appendix 2) advises that where charges are to be detonated together, then appropriate fusing should be used wherever practicable to allow for a functional delay (of a few milliseconds only) to reduce the cumulative impact of multiple charges. However, this is not possible for MC118 as the 8kg donor charge would trigger both UXOs as they are located directly next to each other.

Table 1: UXO devices identified in the Moray East site (Wind Farm) and OfTI Corridor

Target ID	UXO status	Location	NEQ required to detonate	Donor charge (kg)	Recommended Safety Clearance Zone for all other seafarers
ER_MC256	Confirmed UXO	Export Cable Route	163 kg to 220 kg of HE	8	300 m
ER_MC321	Confirmed UXO	Export Cable Route	176 kg to 365 kg of HE	25	300 m
ER_MC405	Confirmed UXO	Export Cable Route	22 kg to 60 kg of HE	8	50 m
MC013	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	8	50 m
MC094	EOD Debris	Wind Farm	Detonation unlikely to be required.	N/A	5 m
MC095	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	10	50 m
MC098	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	10	50 m
MC101	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	10	50 m
MC118	Confirmed UXO x 2	Wind Farm	22 kg to 60 kg of HE	8	50 m
MC274	Confirmed UXO	Wind Farm	~3 kg	5	5 m
MC290	Confirmed UXO	Wind Farm	<0.5 kg	5	5 m
MC291	Confirmed UXO	Wind Farm	~3 kg	5	25 m
MC462	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	10	50 m
MC469	Confirmed UXO	Wind Farm	<5 kg HE	5	25 m
MC480	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	10	50 m
MC613	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	10	50 m
MC624	Confirmed UXO	Wind Farm	22 kg to 60 kg of HE	8	50 m
MC665	Confirmed UXO	Wind Farm	<5 kg HE	5	25 m

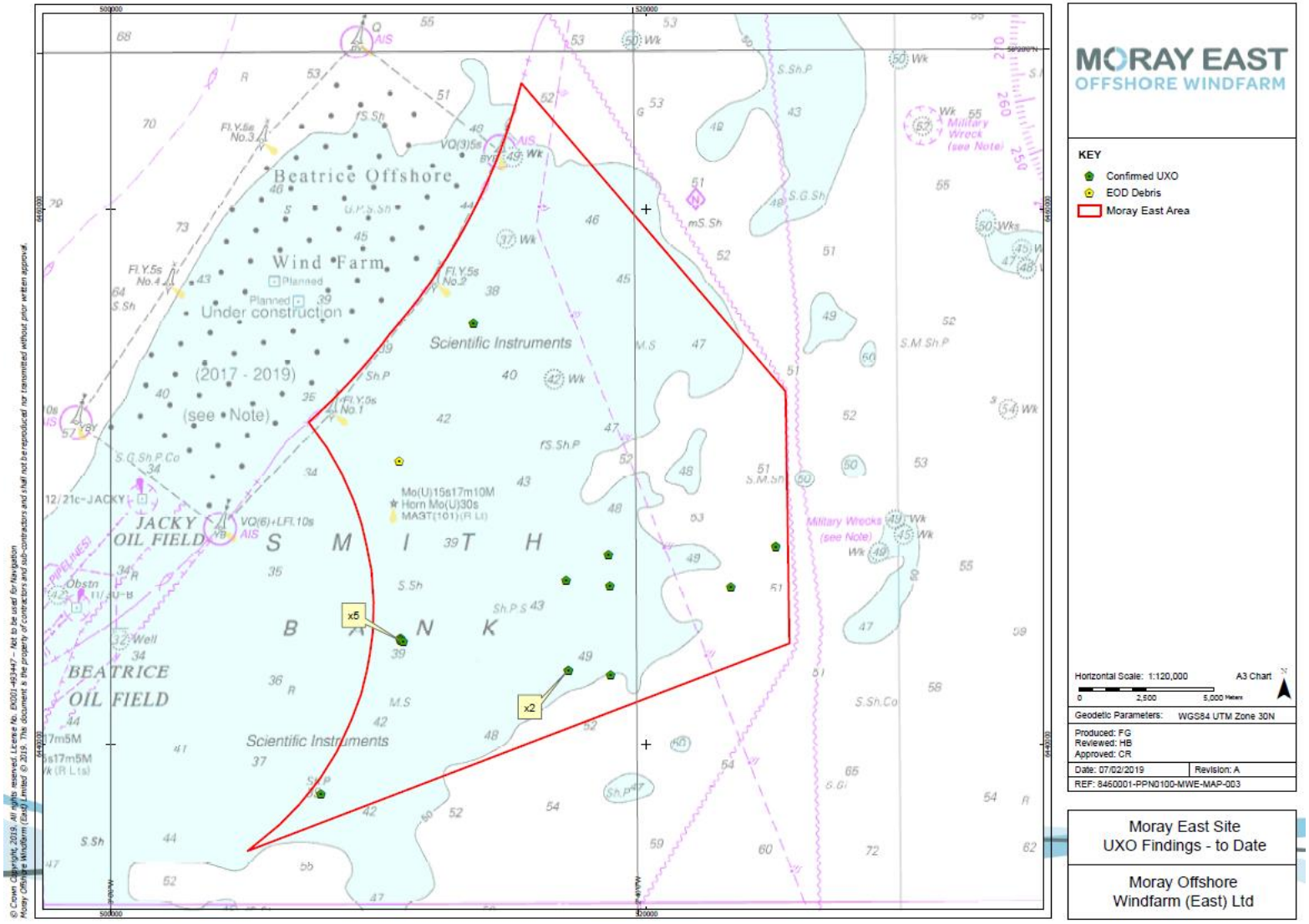

Figure 1: UXO locations in Moray East wind farm site

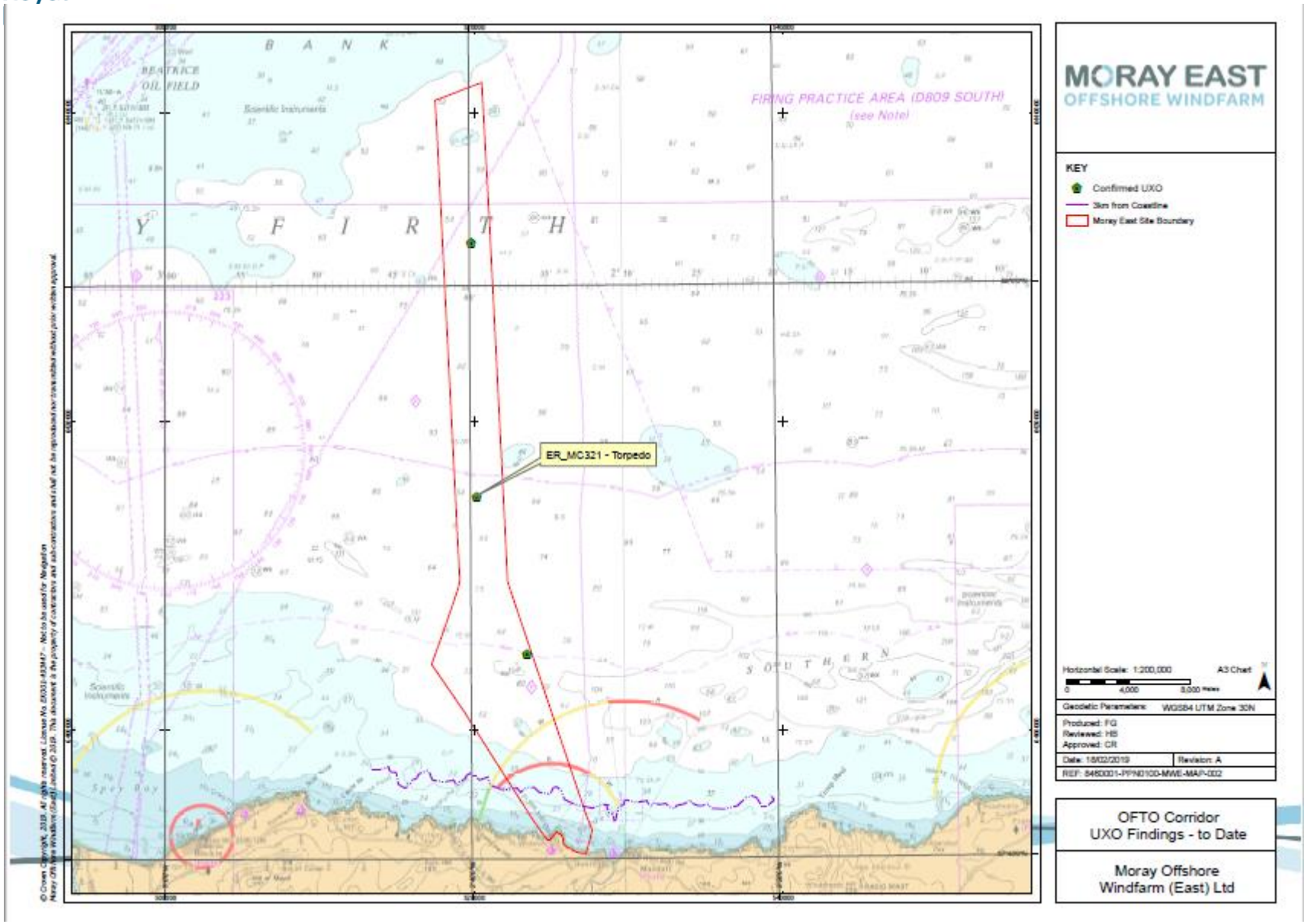

Figure 2: UXO locations in Moray East OfTI corridor

2.1 Comparison with previous assessment

2.1.1 Number of UXO

In the previous assessment, the worst-case scenario for the total numbers of UXO that may require detonation within the Development area was ten: four within the Moray East Wind Farm site and six within the OfTI Corridor.

The results of the UXO survey indicate that the number of UXO in the Wind Farm area is higher than previously predicted, with 15 confirmed UXO in the Moray East Wind Farm site and lower than previously predicted (three confirmed UXO) in the OfTI Corridor. Therefore, the total number of UXO (18) is higher than the previous worst-case estimate of ten UXO.

2.1.2 Size of UXO and charge required

In the previous assessment, the most likely UXO were expected to be German EMA Buoyant mines, with a maximum UXO Net Explosive Quantity (NEQ) of 160 kg, or allied 500 lb or 1,000 lb HE bomb, with a maximum NEQ of 126 kg and 260 kg respectively. It was predicted that these UXO would require a minimum of 5 kg to 10 kg HE per UXO for a controlled explosion using bulk charges. The assessment was based on the most realistic worst-case for 260 kg NEQ, requiring a charge of 10 kg. However, the effect of using a larger charge size (up to 700 kg) was also assessed, and information on the additional mitigation requirements that would be needed was provided.

The result of the UXO survey (**Table 1**), indicates that the largest UXO is up to 365 kg and will require a donor charge of 25 kg. However, five of the UXO devices are less than 5 kg and would require a 5 kg donor charge. The majority, 11 of the 18 UXO devices are 22 kg to 60 kg, requiring 8 kg to 10 kg donor charge; and one UXO is 163 kg to 220 kg, requiring a donor charge of 8 kg.

3 UXO Underwater Noise Modelling

The risk associated with clearance of UXO associated with the Development has been investigated by Subacoustech Environmental Ltd, in respect of the underwater noise produced (**Appendix 1**).

Underwater noise modelling was conducted for range of equivalent charge weights for the UXO identified within the Moray East site and OfTI Corridor, from less than 1 kg to 365 kg (**Table 2**) of HE. The associated donor charge size required for the UXO to detonate was also considered for each UXO charge weight identified.

The noise modelling based on these charge weights cannot take into account a range of variables (e.g. UXO design, composition, age, position, orientation, whether the UXO is covered by sediment) and thus only provide an indication of the noise output from each detonation. A worst-case estimation has therefore been used for calculations, assuming the UXO to be detonated is not buried, degraded or subject to any other significant attenuation from its ‘as new’ condition. The modelling also assumes a worst-case freely suspended charge, and that the blast from the main and donor charges are combined.

Table 2: Range of charge weights, NEQ and TNT equivalent, of UXO devices modelled for the Moray East site

NEQ	Donor charge	Total	TNT Eq.
<1 kg HE	5 kg	6 kg	8 kg
3 kg HE	5 kg	8 kg	10 kg
22 kg HE	10 kg	32 kg	39 kg
60 kg HE	10 kg	70 kg	84 kg
163 kg HE	25 kg	188 kg	226 kg
220 kg HE	25 kg	245 kg	294 kg
365 kg HE	25 kg	390 kg	468 kg

Estimation of the source noise level for each combined charge weight was carried out in accordance with the methodology of Soloway and Dahl (2014), which follows Arons (1954) and MTD (1996). A summary of the unweighted UXO source levels calculated using this method for modelling are given in **Table 3**.

Table 3: Summary of the unweighted SPL_{peak} and SEL source levels used for UXO modelling

Charge weight TNTeq	5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
SPL_{peak} dB re 1 µPa	279.6	281.9	286.3	288.8	292.1	292.9	294.4
SEL dB re 1 μPa^2s	223.5	225.4	229.1	231.3	234.0	234.7	236.0

It should be noted that SPL_{peak} noise levels over larger distances are difficult to predict accurately (von Benda-Beckmann *et al*., 2015). Therefore, at larger ranges, greater confidence is expected with the calculations using the Sound Exposure Levels (SEL) metric rather than SPL_{peak}.

In addition, with increased distance from the source, impulsive noise, such as UXO detonation, becomes more of a non-impulsive noise, therefore it is currently difficult to determine the distance at which an impulsive noise becomes more like a non-impulsive noise. NMFS (2018) suggests 3 km as an estimate of a distance at which transition away from this impulse to a more non-pulse type of noise could occur, although the sound will not go through a 'step change' and this distance will change depending on the type of sound and situation. This consideration is still under review. Explosive noise is highly impulsive and an upper conservative estimate of 5 km is suggested for the transition. It is therefore suggested that, for any injury ranges calculated using the impulsive criteria in excess of 5 km, the non-pulse criteria should be considered more appropriate.

- Subacoustech, therefore suggest that 5 km is likely to be the limit of risk of PTS onset.

The modelling was conducted using both the impulsive and non-impulsive criteria for Permanent Threshold Shift (PTS) weighted SEL to give an indication of the difference between maximum potential impact ranges.

A further limitation that must be considered is that variation in noise levels at different positions in the water column are not taken into account. Where animals are swimming near the surface, the

acoustics can cause the noise level, and hence the exposure, to be lower (MTD, 1996). The risk to animals near the surface may therefore be lower than indicated by the impact ranges and so the results in this assessment can be considered conservative in respect of the impact at different depths.

The modelling was conducted using thresholds and weightings based on the National Oceanic and Atmospheric Administration (NOAA) (National Marine Fisheries Services (NMFS), 2018) criteria (see **Appendix 1**). The thresholds indicate the onset of PTS and Temporary Threshold Shift (TTS), the point at which there is an increase in risk of permanent hearing damage (PTS) or temporary hearing impacts (TTS) in an underwater receptor (although not all individuals within the maximum PTS or TTS range will have permanent or temporary hearing damage, this is assumed as a worst-case scenario). These indicators do not take into account the spreading of underwater sound over long distances, and thus there is a greater likelihood of accuracy where the ranges are small.

3.1 PTS impact ranges

Table 4 presents the predicted PTS impact ranges for UXO detonation, for the range of UXO devices and charge weights identified within the Moray East site and OfTI Corridor. All charge weights are TNTeq for the combined UXO and donor charge, Table 2 demonstrates how the TNTeq figures were derived.

It is important to note differences in the SPL_{peak} and SEL criteria and changes from impulsive to non-impulsive sound, as outlined above. Also, the duration the noise is present must be taken into account. For detonation of UXO each explosion is only a single noise event, compared to the multiple pulse nature of impact piling, so there is no continued exposure nor the need to calculate cumulative effects.

The following provides a summary of the results presented within Table 4 below:

- The maximum predicted PTS impact range for harbour porpoise is 12.2 km based on impulsive unweighted SPL_{peak} criteria; however, based on the weighted SEL impulsive and non-impulsive criteria the maximum predicted PTS impact range is 1.4 km and 0.13 km, respectively.

- The maximum predicted PTS impact range for dolphin species is 0.7 km based on impulsive unweighted SPL_{peak} criteria; however, based on the weighted SEL impulsive and non-impulsive criteria the maximum predicted PTS impact range is less than 50 m.

- The maximum predicted PTS impact range for minke whale is 9 km based on the weighted SEL impulsive criteria, 2.1 km based on impulsive unweighted SPL_{peak} criteria and 0.54 km for the weighted SEL non-impulsive criteria.

- The maximum predicted PTS impact range for grey and harbour seal is 2.4 km based on impulsive unweighted SPL_{peak} criteria and 1.6 km and 0.1 km, respectively, for the weighted SEL impulsive and non-impulsive criteria.

- It can be seen that the predicted ranges of impact for PTS to harbour porpoise and minke whale using impulse-type criteria are in excess of 5 km. However, using the non-pulse

criteria, the impact ranges for all species for PTS criteria are less than 1 km. Therefore, Subacoustech suggest that **5 km is likely to be the limit of risk of PTS onset**.

Table 4: Potential impact of permanent auditory injury (PTS) on marine mammals during UXO clearance without mitigation

Species	Potential impact and threshold	TNT equivalent for the combined UXO and donor charge (kg)						
		5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
Harbour porpoise (high frequency cetacean)	PTS SPL_{peak} Unweighted 202 dB re 1 µPa Impulsive criteria	2.7 km	3.4 km	5.3 km	6.9 km	9.6 km	10.5 km	12.2 km
	PTS SEL Weighted 155 dB re 1 μPa^2s Impulsive criteria	0.3 km	0.4 km	0.66 km	0.85 km	1.1 km	1.2 km	1.4 km
	PTS SEL Weighted 173 dB re 1 μPa^2s Non-impulsive criteria	<0.05 km	<0.05 km	<0.05 km	0.06 km	0.09 km	0.1 km	0.13 km
Dolphin species (mid frequency cetaceans)	PTS SPL_{peak} Unweighted 230 dB re 1 µPa Impulsive criteria	0.15 km	0.19 km	0.3 km	0.4 km	0.55 km	0.6 km	0.7 km
	PTS SEL Weighted 185 dB re 1 μPa^2s Impulsive criteria	<0.05 km	<0.05 km	<0.05 km	<0.05 km	<0.05 km	<0.05 km	<0.05 km
	PTS SEL Weighted 198 dB re 1 μPa^2s Non-impulsive criteria	<0.05 km	<0.05 km	<0.05 km	<0.05 km	<0.05 km	<0.05 km	<0.05 km
Minke whale (low frequency cetacean)	PTS SPL_{peak} Unweighted 219 dB re 1 µPa Impulsive criteria	0.47 km	0.6 km	0.95 km	1.2 km	1.7 km	1.8 km	2.1 km

Species	Potential impact and threshold	TNT equivalent for the combined UXO and donor charge (kg)						
		5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
	PTS SEL Weighted 183 dB re 1 μPa^2s Impulsive criteria	0.99 km	1.4 km	2.7 km	3.9 km	6.3 km	7.2 km	9.0 km
	PTS SEL Weighted 199 dB re 1 μPa^2s Non-impulsive criteria	0.06 km	0.09 km	0.16 km	0.23 km	0.38 km	0.43 km	0.54 km
Grey and harbour seal (Phocid pinnipeds in water)	PTS SPL_{peak} Unweighted 218 dB re 1 µPa Impulsive criteria	0.53 km	0.66 km	1.0 km	1.3 km	1.8 km	2.0 km	2.4 km
	PTS SEL Weighted 185 dB re 1 μPa^2s Impulsive criteria	0.17 km	0.24 km	0.48 km	0.69 km	1.1 km	1.2 km	1.6 km
	PTS SEL Weighted 201 dB re 1 μPa^2s Non-impulsive criteria	<0.05 km	<0.05 km	<0.05 km	<0.05 km	0.07 km	0.08 km	0.1 km

3.2 TTS impact ranges

Table 5 presents the predicted TTS impact ranges for UXO detonation, for the range of UXO devices and charge weights identified within the Moray East site and OfTI Corridor. All charge weights are TNTeq for the combined UXO and donor charge.

Subacoustech note the predicted TTS ranges, especially for minke whale, are expected to be over-estimated, particularly when using the impulsive criteria over large distances.

For TTS, the most appropriate criteria to use is the weighted SEL, which takes into account the species hearing. However, for minke whale, grey and harbour seal the impulsive unweighted SPL_{peak} criteria may provide the more realistic TTS range.

The following provides a summary of the results presented within Table 5 below:

- The maximum predicted TTS impact range for harbour porpoise based on the weighted SEL impulsive and non-impulsive criteria is 3.9 km and 1.6 km, respectively.

- The maximum predicted TTS impact range for dolphin species based on the weighted SEL impulsive and non-impulsive criteria is 0.51 km and 0.15 km, respectively.

- The maximum predicted TTS impact range for minke whale based on the weighted SEL impulsive and non-impulsive criteria is 99.3 km and 17.8 km, respectively. As outlined above, these ranges are expected to be greatly over-estimated. The predicted maximum TTS range for minke whale based on the impulsive unweighted SPL_{peak} criteria is 4 km.

- The maximum predicted TTS impact range for grey and harbour seal based on the weighted SEL impulsive and non-impulsive criteria is 18.8 km and 3.2 km, respectively. The predicted maximum TTS range for grey and harbour seal based on the impulsive unweighted SPL_{peak} criteria is 4.4 km.

Table 5: Potential impact of temporary auditory injury (TTS) on marine mammals during UXO clearance without mitigation

Species	Potential impact and threshold	TNT equivalent for the combined UXO and donor charge (kg)						
		5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
Harbour porpoise (high frequency cetacean)	TTS SPL_{peak} Unweighted 196 dB re 1 µPa Impulsive criteria	4.9 km	6.2 km	9.8 km	12.7 km	17.6 km	19.3 km	22.5 km
	TTS SEL Weighted 140 dB re 1 μPa^2s Impulsive criteria	1.7 km	2.0 km	2.6 km	3.0 km	3.5 km	3.6 km	3.9 km
	TTS SEL Weighted 153 dB re 1 μPa^2s Non-impulsive criteria	0.4 km	0.53 km	0.84 km	1 km	1.4 km	1.4 km	1.6 km
Dolphin species (mid frequency cetaceans)	TTS SPL_{peak} Unweighted 224 dB re 1 µPa Impulsive criteria	0.28 km	0.36 km	0.57 km	0.73 km	0.1 km	0.11 km	0.13 km
	TTS SEL Weighted 170 dB re 1 μPa^2s Impulsive criteria	0.08 km	0.1 km	0.18 km	0.26 km	0.38 km	0.43 km	0.51 km
	TTS SEL Weighted 178 dB re 1 μPa^2s Non-impulsive criteria	<0.05 km	<0.05 km	<0.05 km	0.08 km	0.11 km	0.12 km	0.15 km
Minke whale (low frequency cetacean)	TTS SPL_{peak} Unweighted 213 dB re 1 µPa Impulsive criteria	0.88 km	1.1 km	1.7 km	2.2 km	3.1 km	3.4 km	4.0 km

Species	Potential impact and threshold	TNT equivalent for the combined UXO and donor charge (kg)						
		5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
	TTS SEL Weighted 168 dB re 1 μPa^2s Impulsive criteria	13.6 km	18.9 km	35.2 km	49.3 km	74.5 km	82.8 km	99.3 km
	TTS SEL Weighted 179 dB re 1 μPa^2s Non-impulsive criteria	2 km	2.8 km	5.4 km	7.9 km	12.6 km	14.3 km	17.8 km
Grey and harbour seal (Phocid pinnipeds in water)	TTS SPL_{peak} Unweighted 212 dB re 1 µPa Impulsive criteria	0.97 km	1.2 km	1.9 km	2.5 km	3.4 km	3.7 km	4.4 km
	TTS SEL Weighted 170 dB re 1 μPa^2s Impulsive criteria	2.4 km	3.3 km	6.4 km	9.0 km	13.9 km	15.5 km	18.8 km
	PTS SEL Weighted 181 dB re 1 μPa^2s Non-impulsive criteria	0.35 km	0.5 km	0.97 km	1.4 km	2.2 km	2.5 km	3.2 km

4 Updated Assessment for Marine Mammals

4.1 Density estimates and reference populations

Table 6 outlines the species included in the assessment, the relevant density estimates and reference populations that each species will be assessed against. These are the same values used in the previous assessments.

Grey and harbour seal are not EPS, but have also been included in this assessment.

Table 6: Summary of marine mammal species density estimates and reference populations

Species	Density estimate	Reference population
Harbour porpoise	1.7/km^2 (*Moray Firth offshore development area*; Paxton *et al*., 2016)	345,373 (North Sea MU; Hammond *et al*., 2017)
Bottlenose dolphin	0.3/km^2 (*Moray Firth offshore development area*; Paxton *et al*., 2016)	195 (Coastal East Scotland MU; Hammond *et al*., 2017)
Minke whale	0.03/km^2 (*Moray Firth offshore development area*; Paxton *et al*., 2016)	23,528 (Celtic and Greater North Sea MU; Hammond *et al*., 2017)
White-beaked dolphin	0.021/km^2 (Survey Block S; Hammond *et al*., 2017)	15,895 (Celtic and Greater North Sea MU; Hammond *et al*., 2017)
Common dolphin	0.025/km^2 (*Moray Firth offshore development area*; Paxton *et al*., 2016)	56,556 (Celtic and Greater North Sea MU; Hammond *et al*., 2017)
Grey seal	0.23/km^2 (Moray East site and OfTI Corridor; Russell *et al*., 2017)	1,252 (Moray Firth MU; SCOS, 2017)
Harbour seal	0.014/km^2 (Moray East site and OfTI Corridor; Russell *et al*., 2017)	940 (Moray Firth MU; SCOS, 2017)

4.2 Assessment for the risk of Permanent Auditory Injury (PTS)

The updated assessment (**Table 7**) based on the underwater noise modelling indicates that based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq) and 12.2 km range up to 795 harbour porpoise (0.2 % of the reference population) could potentially be at risk of PTS. However, based on the recommended maximum 5 km range for PTS up to 134 harbour porpoise (0.04 % of the reference population) could potentially be at risk. The magnitude of effect is assessed as medium for both scenarios.

Up to 0.5 bottlenose dolphin (0.3 % of reference population) could potentially be at risk of PTS based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq). However, for the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), up to 0.2 bottlenose dolphin (0.1 % of reference population) could potentially be at risk. The magnitude of effect is assessed as medium for both scenarios (**Table 7**).

For minke whale the assessment indicates that, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), 0.5 minke whale (0.002 % of reference population) could potentially be at risk of PTS. Based on the weighted SEL impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq) and 9 km range up to 8 minke whale (0.03 % of reference population) could be at risk. However, based on the recommended maximum 5 km range for PTS up to 2.4 minke whale (0.01 % of reference population) could be at risk, with the magnitude of effect assessed as low (**Table 7**). For the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), 3.9 km range based on weighted SEL impulsive criteria up to 1.4 minke whale (0.006 % of reference population) could potentially be at risk, with the magnitude of effect assessed as low (**Table 7**).

Up to 0.03 white-beaked dolphin (0.0003 % of reference population) could potentially be at risk of PTS based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486kg TNTeq). However, for the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), up to 0.01 white-beaked dolphin (0.00006 % of reference population) could potentially be at risk, with the magnitude of effect assessed as negligible for both scenarios (**Table 7**).

Up to 0.04 common dolphin (0.00007 % of reference population) could potentially be at risk of PTS based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq). However, for the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), up to 0.013 common dolphin (0.00002 % of reference population) could potentially be at risk. With the magnitude of effect assessed as negligible for both scenarios (**Table 7**).

For grey seal the assessment indicates that, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), 4.2 grey seal (0.3 % of reference population) could potentially be at risk of PTS. Based on the weighted SEL impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq) up to 1.8 grey seal (0.14 % of reference population) could be at risk. For the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), based on the unweighted SPL_{peak} impulsive criteria, up to 1.2 grey seal (0.1 % of reference population) could potentially be at risk. With the magnitude of effect assessed as medium for the three scenarios (**Table 7**).

For harbour seal the assessment indicates that, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), 0.25 harbour seal (0.03 % of reference population) could potentially be at risk of PTS, with the magnitude of effect assessed as medium. Based on the weighted SEL impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq) up to 0.1 harbour seal (0.01 % of reference population) could be at risk, with the magnitude of effect assessed as low. For the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), based on the unweighted SPL_{peak} impulsive criteria, up to 0.07 harbour seal (0.0075 % of reference population) could potentially be at risk, with the magnitude of effect assessed as low (**Table 7**).

Table 7: Assessment of marine mammal species at potential risk of permanent auditory injury (PTS)

Species	Potential Impact Criteria	Maximum Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
Harbour porpoise	Unweighted SPL_{peak} Impulsive	467.6km^2	795 (0.2%)	**Medium**

Species	Potential Impact Criteria	Maximum Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
		(based on 12.2km range for 365kg UXO + charge (486kg TNTeq))		(more than 0.01% of the reference population anticipated to be exposed to permanent effect)
		149.6km^2 (based on 6.9km range for 60kg UXO + charge (84kg TNTeq))	254 (0.074%)	**Medium**
	Weighted SEL Impulsive	6.2km^2 (based on 1.4km range for 365kg UXO + charge (486kg TNTeq))	11 (0.003%)	Low (0.01% or less of the reference population anticipated to be exposed to permanent effect)
	5km PTS range	**78.5km^2**	**134 (0.04%)**	**Medium**
Bottlenose dolphin	Unweighted SPL$_{peak}$ Impulsive	1.5km^2 (based on 0.7km range for 365kg UXO + charge (486kg TNTeq))	0.5 (0.3%)	**Medium**
		0.5km^2 (based on 0.4km range for 60kg UXO + charge (84kg TNTeq))	0.2 (0.1%)	**Medium**
	Weighted SEL Impulsive	0.008km^2 (based on 0.05km range for 365kg UXO + charge (486kg TNTeq))	0.0024 (0.001%)	Low
Minke whale	Unweighted SPL$_{peak}$ Impulsive	15.2km^2 (based on 2.1km range for 365kg UXO + charge (486kg TNTeq))	0.5 (0.002%)	Low
		4.5km^2 (based on 1.2km range for 60kg UXO + charge (84kg TNTeq))	0.14 (0.0006%)	Negligible (0.001% or less of the reference population anticipated to be exposed to permanent effect)

Species	Potential Impact Criteria	Maximum Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
	Weighted SEL Impulsive	254.5km^2 (based on 9km range for 365kg UXO + charge (486kg TNTeq))	8 (0.03%)	**Medium**
		47.8km^2 (based on 3.9km range for 60kg UXO + charge (84kg TNTeq))	1.4 (0.006%)	Low
	5km PTS range	78.5km^2	2.4 (0.01%)	Low
White-beaked dolphin	Unweighted SPL_{peak} Impulsive	1.5km^2 (based on 0.7km range for 365kg UXO + charge (486kg TNTeq))	0.03 (0.0002%)	Negligible
		0.5km^2 (based on 0.4km range for 60kg UXO + charge (84kg TNTeq))	0.01 (0.00006%)	Negligible
	Weighted SEL Impulsive	0.008km^2 (based on 0.05km range for 365kg UXO + charge (486kg TNTeq))	0.0002 (0.000001%)	Negligible
Common dolphin	Unweighted SPL_{peak} Impulsive	1.5km^2 (based on 0.7km range for 365kg UXO + charge (486kg TNTeq))	0.04 (0.00007%)	Negligible
		0.5km^2 (based on 0.4km range for 60kg UXO + charge (84kg TNTeq))	0.013 (0.00002%)	Negligible
	Weighted SEL Impulsive	0.008km^2 (based on 0.05km range for 365kg UXO + charge (486kg TNTeq))	0.0002 (0.0000004%)	Negligible
Grey seal	Unweighted SPL_{peak} Impulsive	18.1km^2 (based on 2.4km range for 365kg	4.2 (0.3%)	**Medium**

Species	Potential Impact Criteria	Maximum Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
		UXO + charge (486kg TNTeq))		
		5.3km^2 (based on 1.3km range for 60kg UXO + charge (84kg TNTeq))	1.2 (0.1%)	**Medium**
	Weighted SEL Impulsive	8km^2 (based on 1.6km range for 365kg UXO + charge (486kg TNTeq))	1.8 (0.14%)	**Medium**
Harbour seal	Unweighted SPL_{peak} Impulsive	18.1km^2 (based on 2.4km range for 365kg UXO + charge (486kg TNTeq))	0.25 (0.03%)	**Medium**
		5.3km^2 (based on 1.3km range for 60kg UXO + charge (84kg TNTeq))	0.07 (0.0075%)	Low
	Weighted SEL Impulsive	8km^2 (based on 1.6km range for 365kg UXO + charge (486kg TNTeq))	0.1 (0.01%)	Low

*Maximum area based on area of circle with maximum impact range for radius

4.2.1 Comparison with previous assessment of PTS

Table 8 summarises the previous assessment and **Table 9** summarises the updated assessment for the potential risk of PTS in marine mammals.

The magnitude of effect in the updated assessment remains the same as the previous assessment for all species.

For harbour porpoise, based on the recommended maximum 5 km range for PTS up to 134 harbour porpoise (0.04 % of the reference population) could potentially be at risk, which is less than the 385.9 (0.1 % of the reference population) in the previous assessment.

For both the previous and updated assessments, *based on the high sensitivity of harbour porpoise and the medium magnitude of effect,* ***harbour porpoise are assessed as being at risk of a major impact due to PTS from UXO detonation without mitigation, which is considered to be significant.***

For bottlenose dolphin, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), up to 0.5 bottlenose dolphin (0.3 % of reference population) could potentially be at risk of PTS, which is slightly higher than the previous assessment of 0.3 bottlenose dolphin. However, for the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), up to 0.2 bottlenose dolphin (0.1 % of reference population) could potentially be at risk, which is lower than the previous assessment.

For both the previous and updated assessments, *based on the high sensitivity of bottlenose dolphin and the medium magnitude of effect,* ***bottlenose dolphin are assessed as being at risk of a major impact due to PTS from UXO detonation without mitigation, which is considered to be significant.***

For minke whale, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), up to 0.5 individuals (0.002 % of reference population) could potentially be at risk, which is only slightly higher than the 0.3 (0.001 % of the reference population) in the previous assessment.

For both the previous and updated assessments, *based on the high sensitivity of minke whale and the low magnitude of effect,* ***minke whale are assessed as being at risk of a moderate impact due to PTS from UXO detonation without mitigation, which is considered to be significant.***

For white-beaked dolphin, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), up to 0.03 individuals (0.0002 % of reference population) could potentially be at risk, which is only slightly higher than the 0.02 (0.0001 % of the reference population) in the previous assessment.

For common dolphin, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), up to 0.04 individuals (0.00007 % of reference population) could potentially be at risk, which is only slightly higher than the 0.003 (0.00005 % of the reference population) in the previous assessment.

For both the previous and updated assessments, *based on the high sensitivity of white-beaked and common dolphin and the negligible magnitude of effect,* ***white-beaked and common dolphin are assessed as being at risk of a minor impact due to PTS from UXO detonation without mitigation, which is considered to be non-significant.***

For grey seal, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), up to 4.2 individuals (0.3 % of reference population) could potentially be at risk, which is higher than the 2.6 (0.2 % of the reference population) in the previous assessment. However, for the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), up to 1.2 grey seal (0.1 % of reference population) could potentially be at risk, which is lower than the previous assessment.

For harbour seal, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), up to 0.25 individuals (0.03 % of reference population) could potentially be at risk, which is higher than the 0.16 (0.02 % of the reference population) in the previous assessment. However, for the majority of the UXO at the site (60 kg UXO and charge (84 kg TNTeq)), up to 0.07 harbour seal (0.0075 % of reference population) could potentially be at risk, which is lower than the previous assessment.

For both the previous and updated assessments, *based on the high sensitivity of grey and harbour seal and the medium magnitude of effect,* ***grey and harbour seal are assessed as being at risk of a major impact due to PTS from UXO detonation without mitigation, which is considered to be significant.***

Table 8: Previous assessment of marine mammal species at potential risk of permanent auditory injury (PTS)

Species	Potential Impact Criteria	Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
Harbour porpoise	202 SPL_{peak} (dB re 1µPa)	226.98km^2	385.9 (0.1%)	**Medium**
Minke whale	219 SPL_{peak} (dB re 1µPa)	9.08km^2	0.3 (0.001%)	Low
Bottlenose dolphin	230 SPL_{peak} (dB re 1µPa)	1.02km^2	0.3 (0.2%)	**Medium**
White-beaked dolphin			0.02 (0.0001%)	Negligible
Common dolphin			0.03 (0.00005%)	Negligible
Grey seal	218 SPL_{peak} (dB re 1µPa)	11.34km^2	2.6 (0.2%)	**Medium**
Harbour seal			0.16 (0.02%)	**Medium**

** Note that this is based on the area of a circle*

Table 9: Updated assessment of marine mammal species at potential risk of permanent auditory injury (PTS)

Species	Potential Impact Criteria	Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
Harbour porpoise	5km maximum PTS range	78.5km^2	134 (0.04%)	**Medium**
Minke whale	Unweighted SPL_{peak} Impulsive	15.2km^2	0.5 (0.002%)	Low
Bottlenose dolphin	Unweighted SPL_{peak} Impulsive	1.5km^2	0.5 (0.3%)	**Medium**
White-beaked dolphin			0.03 (0.0002%)	Negligible
Common dolphin			0.04 (0.00007%)	Negligible
Grey seal	Unweighted SPL_{peak} Impulsive	18.1km^2	4.2 (0.3%)	**Medium**
Harbour seal			0.25 (0.03%)	**Medium**

** Note that this is based on the area of a circle*

4.3 Assessment for the risk of Temporary Auditory Injury (TTS)

As outlined in **Section 3.2**, for TTS the most appropriate criteria to use is the weighted SEL, which takes into account the species hearing. However, for minke whale, grey and harbour seal the impulsive unweighted SPL_{peak} criteria may provide the more realistic TTS range.

Also outlined in **Section 3.2**, Subacoustech note the predicted TTS ranges, especially for minke whale and seals, are expected to be over-estimated, particularly when using the impulsive criteria over large distances.

It should also be noted that the fleeing response based on the TTS impact range would be for a short, temporary duration. For detonation of UXO each explosion is only a single noise event, compared to the multiple pulse nature of impact piling, so there is no continued exposure.

The updated assessment (**Table 10**) based on the underwater noise modelling indicates that for the 365 kg UXO and charge (486 kg TNTeq) and 3.9 km impact range, up to 81.3 harbour porpoise (0.02 % of the reference population) could potentially be at risk of TTS / fleeing response. However, for the majority of the UXO in the Development area (60 kg UXO and charge (84 kg TNTeq)), up to 48 harbour porpoise (0.01 % of reference population) could potentially be at risk. The magnitude of effect is assessed as negligible for both scenarios (**Table 10**).

For bottlenose dolphin, based on the 365 kg UXO and charge (486 kg TNTeq) and 0.51 km impact range, up to 0.25 bottlenose dolphin (0.1 % of the reference population) could potentially be at risk of TTS / fleeing response. However, for the majority of the UXO in the Development area (60 kg UXO and charge (84 kg TNTeq)), up to 0.06 bottlenose dolphin (0.03 % of reference population) could potentially be at risk. The magnitude of effect is assessed as negligible for both scenarios (**Table 10**).

For minke whale the assessment indicates that, based on the weighted SEL impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq) up to 4 % of reference population could be at risk, with the magnitude of effect assessed as low. However, based on the more realistic unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), 1.5 minke whale (0.006 % of reference population) could potentially be at risk of TTS / fleeing response, with the magnitude of effect assessed as negligible (**Table 10**).

For white-beaked dolphin, based on the 365 kg UXO and charge (486 kg TNTeq) and 0.51 km impact range, up to 0.02 dolphin (0.0001 % of the reference population) could potentially be at risk of TTS / fleeing response. However, for the majority of the UXO in the Development area (60 kg UXO and charge (84 kg TNTeq)), up to 0.004 dolphin (0.00003 % of reference population) could potentially be at risk. The magnitude of effect is assessed as negligible for both scenarios (**Table 10**).

For common dolphin, based on the 365 kg UXO and charge (486 kg TNTeq) and 0.51 km impact range, up to 0.02 dolphin (0.00004 % of the reference population) could potentially be at risk of TTS / fleeing response. However, for the majority of the UXO in the Development area (60 kg UXO and charge (84 kg TNTeq)), up to 0.005 dolphin (0.000009 % of reference population) could potentially be at risk. The magnitude of effect is assessed as negligible for both scenarios (**Table 10**).

For grey seal the assessment indicates that, based on the weighted SEL impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq) up to 20 % of reference population could be at risk, with the magnitude of effect assessed as high. However, based on the more realistic unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), 14 grey seal (1 % of reference population) could potentially be at risk of TTS / fleeing response, with the magnitude of effect assessed as negligible (**Table 10**).

For harbour seal the assessment indicates that, based on the weighted SEL impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq) up to 1.7 % of reference population could be at risk, with the magnitude of effect assessed as low. However, based on the more realistic unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq), 0.9 harbour seal (0.1 % of reference population) could potentially be at risk of TTS / fleeing response, with the magnitude of effect assessed as negligible (**Table 10**).

Table 10: Assessment of marine mammal species at potential risk of temporary auditory injury (TTS)

Species	Potential Impact Criteria	Maximum Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
Harbour porpoise	Weighted SEL Impulsive	47.8km^2 (based on 3.9km range for 365kg UXO + charge (486kg TNTeq))	81.3 (0.02%)	Negligible (1% or less of the reference population anticipated to be exposed to temporary effect)
		28.3km^2 (based on 3km range for 60kg UXO + charge (84kg TNTeq))	48 (0.01%)	Negligible
Bottlenose dolphin	Weighted SEL Impulsive	0.82km^2 (based on 0.51km range for 365kg UXO + charge (486kg TNTeq))	0.25 (0.1%)	Negligible
		0.21km^2 (based on 0.26km range for 60kg UXO + charge (84kg TNTeq))	0.06 (0.03%)	Negligible
Minke whale	Weighted SEL Impulsive	30,978km^2 (based on 99.3km range for 365kg UXO + charge (486kg TNTeq))	929 (4%)	Low (between 1% and 5% of the reference population anticipated to be exposed to temporary effect)
		7,636km^2 (based on 49.3km range for 60kg UXO + charge (84kg TNTeq))	229 (0.97%)	Negligible
	Unweighted SPL_{peak} Impulsive	50.3km^2 (based on 4km range for 365kg UXO + charge (486kg TNTeq))	1.5 (0.006%)	Negligible

Species	Potential Impact Criteria	Maximum Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
		15.2km^2 (based on 2.2km range for 60kg UXO + charge (84kg TNTeq))	0.5 (0.002%)	Negligible
White-beaked dolphin	Weighted SEL Impulsive	0.82km^2 (based on 0.51km range for 365kg UXO + charge (486kg TNTeq))	0.02 (0.0001%)	Negligible
		0.21km^2 (based on 0.26km range for 60kg UXO + charge (84kg TNTeq))	0.004 (0.00003%)	Negligible
Common dolphin	Weighted SEL Impulsive	0.82km^2 (based on 0.51km range for 365kg UXO + charge (486kg TNTeq))	0.02 (0.00004%)	Negligible
		0.21km^2 (based on 0.26km range for 60kg UXO + charge (84kg TNTeq))	0.005 (0.000009%)	Negligible
Grey seal	Weighted SEL Impulsive	1,110km^2 (based on 18.8km range for 365kg UXO + charge (486kg TNTeq))	255 (20%)	**High** (more than 10% of the reference population anticipated to be exposed to temporary effect)
		254.5km^2 (based on 9km range for 60kg UXO + charge (84kg TNTeq))	58.5 (4.7%)	Low
	Unweighted SPL_{peak} Impulsive	61km^2 (based on 4.4km range for 365kg UXO + charge (486kg TNTeq))	14 (1%)	Negligible
		19.6km^2 (based on 2.5km range for 60kg UXO	4.5 (0.4%)	Negligible

Species	Potential Impact Criteria	Maximum Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
		+ charge (84kg TNTeq))		
Harbour seal	Weighted SEL Impulsive	1,110km^2 (based on 18.8km range for 365kg UXO + charge (486kg TNTeq))	16 (1.7%)	Low
		254.5km^2 (based on 9km range for 60kg UXO + charge (84kg TNTeq))	4 (0.4%)	Negligible
	Unweighted SPL_{peak} Impulsive	61km^2 (based on 4.4km range for 365kg UXO + charge (486kg TNTeq))	0.9 (0.1%)	Negligible
		19.6km^2 (based on 2.5km range for 60kg UXO + charge (84kg TNTeq))	0.3 (0.03%)	Negligible

*Maximum area based on area of circle with maximum impact range for radius

4.3.1 Comparison with previous assessment of TTS

Table 11 summarises the previous assessment and **Table 12** summarises the updated assessment for the potential risk of TTS / fleeing response in marine mammals.

As outlined above, for TTS the most appropriate criteria to use is the weighted SEL, which takes into account the species hearing. However, for minke whale, grey and harbour seal the impulsive unweighted SPL_{peak} criteria may provide the more realistic TTS range. To allow comparison with the previous assessment, the unweighted SPL_{peak} criteria has been include **Table 12** in for all species.

The magnitude of effect in the updated assessment remains the same as the previous assessment for all species.

Table 11: Previous assessment of marine mammal species at potential risk from temporary auditory injury (TTS) / fleeing response

Species	Potential Impact Criteria	Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
Harbour porpoise	196 SPL_{peak} (dB re 1µPa)	804.25km^2	1,367.2 (0.4%)	Negligible

Species	Potential Impact Criteria	Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
Minke whale	213 SPL_{peak} (dB re 1µPa)	38.48km^2	1.2 (0.005%)	Negligible
Bottlenose dolphin	224 SPL_{peak} (dB re 1µPa)	3.46km^2	1.0 (0.5%)	Negligible
White-beaked dolphin			0.07 (0.0005%)	Negligible
Common dolphin			0.09 (0.0002%)	Negligible
Grey seal	212 SPL_{peak} (dB re 1µPa)	44.18km^2	10.2 (0.8%)	Negligible
Harbour seal			0.6 (0.07%)	Negligible

** Note that this is based on the area of a circle*

Table 12: Updated assessment of marine mammal species at potential risk temporary auditory injury (TTS) / fleeing response

Species	Potential Impact Criteria	Area of Potential Impact*	Number at Risk of Impact (% of Reference Population)	Magnitude of Effect (without mitigation)
Harbour porpoise	Weighted SEL Impulsive	47.8km^2	81.3 (0.02%)	Negligible
	Unweighted SPL_{peak} Impulsive	1,590km^2	2,703 (0.8%)	Negligible
Minke whale	Unweighted SPL_{peak} Impulsive	50.3km^2	1.5 (0.006%)	Negligible
Bottlenose dolphin	Weighted SEL Impulsive	0.82km^2	0.25 (0.1%)	Negligible
White-beaked dolphin			0.02 (0.0001%)	Negligible
Common dolphin			0.02 (0.00004%)	Negligible
Bottlenose dolphin	Unweighted SPL_{peak} Impulsive	0.0053km^2	0.0016 (0.008%	Negligible
White-beaked dolphin			0.001 (0.000006%)	Negligible
Common dolphin			0.001 (0.000002%)	Negligible
Grey seal	Unweighted SPL_{peak} Impulsive	61km^2	14 (1%)	Negligible
Harbour seal			0.9 (0.1%)	Negligible

** Note that this is based on the area of a circle*

5 Marine Mammal Mitigation

A UXO Clearance Marine Mammal Mitigation Plan (MMMP) has been prepared, to mitigate the potential risk for auditory injury to occur in marine mammals. The UXO MMMP, which has been updated in light of comments received from stakeholders, sets out the UXO mitigation procedure, the roles and responsibilities of personnel in the mitigation team, and the reporting requirements (see **Appendix 2**).

The mitigation follows the JNCC (2010) guidelines for minimising the risk of injury to marine mammals from using explosives. The mitigation sets out the need for two Marine Mammal Observers (MMOs) and one Passive Acoustic Monitoring Operator (PAM-Op) (if required and safe to do so) to carry out monitoring over a 1 km pre-detonation search zone for a minimum of a one hour period prior to the UXO detonation.

Alongside the monitoring to ensure no marine mammals are within 1km of the detonation site, there are additional measure to "deter" marine mammals beyond the area of potential PTS risk. This uses Acoustic Deterrent Devices (ADDs) and soft-start charges to encourage marine mammals to move beyond the 5km maximum PTS range.

Two ADDs will be activated for 25 minutes during the pre-detonation search, immediately prior to the detonation event and a sequence of small to large charge size in order (very small explosives with charges of 50 g, 100 g, 150 g and 200 g) will be implemented to allow additional time for marine mammals to leave the area of potential impact; this is known as a "soft-start" procedure. For the larger UXO greater than 270 kg, an additional small charge of 250 g will be added to the sequence. These small scare charges are separate to the donor charges used to detonate the UXO devices.

The four or five small charge detonations will commence at five minute intervals, with a further interval of five minutes before the detonation of the UXO. The total duration for the five small charge detonations would be 30 minutes, with 25 minutes for the four small charge detonations.

This gives a total deterrence time for the ADDs and soft-start sequences of 50 or 55 minutes, and based on a swimming speed of 1.5 m/s (Otani *et al*. 2000), marine mammals should clear a radius of 4.5 km or 4.95 km during this duration.

The pre-detonation search using MMOs and PAM will cover the ADD activation period and the duration of the small charge detonations.

5.1 Disturbance during proposed mitigation

Based on a 4.95 km radius (area of 77 km^2) for the proposed mitigation, it is estimated that:

- 131 harbour porpoise (0.04 % of the reference population) could be temporarily disturbed.
- 23 bottlenose dolphin (12 % of the reference population) could be temporarily disturbed.
- 2.3 minke whale (0.01 % of the reference population) could be temporarily disturbed.
- 1.6 white-beaked dolphin (0.01 % of the reference population) could be temporarily disturbed.

- 1.9 common dolphin (0.003 % of the reference population) could be temporarily disturbed.
- 18 grey seal (1.4 % of the reference population) could be temporarily disturbed.
- 1 harbour seal (0.1 % of the reference population) could be temporarily disturbed.

6 Residual Impact After Proposed Mitigation

Based on the proposed mitigation, bottlenose dolphin, white-beaked dolphin and common dolphin would be outwith the predicted maximum potential PTS range of 0.7 km, minke whale would be beyond the predicted maximum potential PTS range of 2.1 km, with grey and harbour seal beyond the predicted maximum potential PTS range of 2.4 km.

The maximum predicted PTS impact range for harbour porpoise is 5 km. The proposed mitigation is predicted to deter individuals from a range of at least 4.95 km for the large UXO detonation. Therefore, there is the possibility that some harbour porpoise could be exposed in the distance between 4.95 km and 5 km. It has been estimated that in this area (1.5 km^2) there could be up to 2.6 harbour porpoise (0.00075 % of reference population). When compared to the predicted number of individuals within the area pre-mitigation (134 harbour porpoise (0.04% of reference population)) as shown in Table 9, this is a significant reduction to the estimated number of harbour porpoise predicted to be within the 5 km radius.

7 Conclusions

A relatively small number of marine mammals and low percentage of the reference populations could be at risk of PTS, without mitigation, based on worst-case scenario:

- Up to 134 harbour porpoise (0.04 % of the reference population) could potentially be at risk, based on the recommended maximum 5 km range for PTS.
- Up to 0.5 bottlenose dolphin (0.3 % of reference population) could potentially be at risk of PTS based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq). However, for the majority of the UXO in the Development area (60 kg UXO and charge (84 kg TNTeq)), up to 0.2 bottlenose dolphin (0.1 % of reference population) could potentially be at risk.
- Up to 0.5 minke whale (0.002 % of reference population) could potentially be at risk, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq).
- Up to 0.03 white-beaked dolphin (0.0002 % of reference population) could potentially be at risk, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq).
- Up to 0.04 common dolphin (0.00007 % of reference population) could potentially be at risk, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq).
- Up to 4.2 grey seal (0.3 % of reference population) could potentially be at risk, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq). However, for the majority of the UXO in the Development area (60 kg UXO and charge (84 kg TNTeq)), up to 1.2 grey seal (0.1 % of reference population) could potentially be at risk.

- Up to 0.25 harbour seal (0.03 % of reference population) could potentially be at risk, based on the unweighted SPL_{peak} impulsive criteria for the 365 kg UXO and charge (486 kg TNTeq).

Based on the proposed mitigation (MMOs, PAM, ADDs and small scare charges), bottlenose dolphin, white-beaked dolphin and common dolphin would be outwith the predicted maximum potential PTS range of 0.7 km, minke whale would be beyond the predicted maximum potential PTS range of 2.1 km, with grey and harbour seal beyond the predicted maximum potential PTS range of 2.4 km. It is estimated, that after mitigation there could be up to 2.6 harbour porpoise (0.00075 % of reference population) at risk of PTS, based on worst-case scenario.

Taking into account the proposed mitigation and the very low number of harbour porpoise that could be at potential risk of PTS (residual impact), it is proposed that the EPS licence would be required for disturbance only and not risk of injury.

The information in this updated assessment for PTS and disturbance (based on TTS range) indicates that there will be no effect on the Favourable Conservation Status for all EPS species considered.

8 References

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Appendix 1: Estimated ranges of impact for various UXO detonations, Moray East OWF

Project title	Estimated ranges of impact for various UXO detonations, Moray East OWF
Project number	P253
Author(s)	Tim Mason
Company	Subacoustech Environmental Ltd.
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Introduction

The risk associated with clearance of unexploded ordnance (UXO) associated with the Moray East Offshore Windfarm (OWF) has been investigated by Subacoustech Environmental Ltd, in respect of the underwater noise produced. The range of impact in relation to marine mammals and fish injury from UXO detonation has been estimated.

A number of UXO devices with a range of charge weights (or quantity of contained explosive) may be present within the boundary of the Moray East site. These may need to be removed before construction can begin. There are expected to be a variety of explosive types, many of which are likely to have been subject to degradation or burying over time. Two otherwise identical explosive devices are likely to produce different blasts in the case where one has spent an extended period on the sea bed. A selection of explosive sizes has been considered based on site surveys and in each case, it has been assumed that the maximum explosive charge in each device is present and detonates with the clearance.

Estimation of underwater noise levels

The noise produced by the detonation of explosives is affected by several different elements, only one of which, the charge weight, can easily be factored into a calculation. In this case the charge weight used for calculations is based on the equivalent weight of TNT. Many other elements relating to its situation (e.g. its design, composition, age, position, orientation, whether it is covered by sediment) and exactly how they will affect the sound produced by detonation are usually unknown and cannot be directly considered in this type of assessment. This leads to a high degree of uncertainty in the estimation of the source noise level (i.e. the noise level at the position of the UXO). A worst-case estimation has therefore been used for calculations, assuming the UXO to be detonated is not buried, degraded or subject to any other significant attenuation from its ‘as new’ condition.

The consequence of this is that the noise levels produced, particularly by the larger explosives under consideration, are likely to be over-estimated as some degree of degradation would be expected.

The range of equivalent charge weights of the potential UXO devices that could be present within the Moray East site boundaries have been estimated as less than 1 kg to 365 kg (Table 1.1) of high explosive (HE). This is not intended to be a comprehensive list of all devices that could be found, although it includes a broad range of sizes of device which is unlikely to be exceeded. All devices will be detonated using a smaller donor explosive device, and this charge has been added onto the UXO charge weight for calculation.

Estimation of the source noise level for each combined charge weight was carried out in accordance with the methodology of Soloway and Dahl (2014)[1], which follows Arons (1954)[2] and MTD (1996)[3].

Table 1.1 – Range of charge weights, Net Explosive Quantity (NEQ) and TNT equivalent, of UXO devices potentially present at Moray East site

NEQ	Donor charge	Total	TNT Eq.
< 1 kg HE	5 kg	6 kg	8 kg
3 kg HE	5 kg	8 kg	10 kg
22 kg HE	10 kg	32 kg	39 kg
60 kg HE	10 kg	70 kg	84 kg
163 kg HE	25 kg	188 kg	226 kg
220 kg HE	25 kg	245 kg	294 kg
365 kg HE	25 kg	390 kg	468 kg

The calculation of the source noise levels is described in the following section.

Estimation of propagation of underwater noise

A basic knowledge of underwater acoustic theory and terminology is assumed in this study: a more detailed explanation of the concepts and terminology is contained within the underwater noise section in the Moray East Offshore Renewables Ltd Environmental Statement.

For this assessment, the attenuation of the noise from UXO detonation has been accounted for in calculations using geometric spreading and a sound absorption coefficient based on methodologies cited in Soloway and Dahl (2014). These establish a trend based on measurements of underwater blast in open water given by, for SPL:

$$SPL_{peak} = 52.4 \times 10^{6} \left(\frac{R}{W^{1/3}}\right)^{-1.13}$$

and for SEL:

$$SEL = 6.14 \times \log_{10}\left(W^{1/3}\left(\frac{R}{W^{1/3}}\right)^{-2.12}\right) + 219$$

These equations provide a relatively simple calculation which has been used to give an indication of the range of effect. Detailed modelling is not intended in this assessment. The equation does not take into account variable bathymetry or seabed type around the site, and thus calculation results will be the same regardless where it is used.

A summary of the unweighted UXO source levels calculated using this method for modelling are given in

[1] Soloway A G, Dahl P H (2014). *Peak sound pressure and sound exposure level from underwater explosions in shallow water.* The Journal of the Acoustical Society of America, 136(3), EL219-EL223. http://dx.doi.org/ 10.1121/1.4892668

[2] Arons A B (1954). *Underwater explosion shock wave parameters at large distances from the charge.* J. Acoust. Soc. Am. 26, 343–346

[3] The Marine Technology Directorate Ltd (MTD) (1996). *Guidelines for the safe use of explosives under water*. MTD Publication 96/101. ISBN 1 870553 23 3

Table *1.2*.

Table 1.2 - Summary of the unweighted SPL_{peak} and SEL source levels used for UXO modelling

Charge weight TNTeq	5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
SPL_{peak} dB re 1 µPa	279.6	281.9	286.3	288.8	292.1	292.9	294.4
SEL dB re 1 μPa^2s	223.5	225.4	229.1	231.3	234.0	234.7	236.0

The noise level based on these charge weights cannot take into account the range of variables noted above and thus will only provide an indication of the noise output from each detonation. They also assume a worst-case freely suspended charge, and that the blast from the main and donor charges are combined.

An attenuation correction has been added to the Soloway and Dahl (2014) equations for the absorption over long ranges (i.e. of the order of thousands of metres). The sound frequency of the noise and the species' hearing sensitivity (see the Impact Criteria section) has also been accounted for.

Despite this attenuation correction, the resulting noise levels still need to be considered carefully. For example, SPL_{peak} noise levels over larger distances are difficult to predict accurately (von Benda-Beckmann *et al*., 2015)[4]. Soloway and Dahl (2014) only verify results from the equation above for relatively small charges and at ranges of less than 1 km. However, the results achieved by this technique do agree with the measurements presented by von Benda-Beckmann *et al*. (2014), which sampled 263 kg charges, at longer range. At these ranges, greater confidence is expected with the calculations using the SEL metric rather than SPL_{peak}.

A further limitation in the Soloway and Dahl (2014) equation that must be considered are that variation in noise levels at different positions in the water column are not taken into account. Where animals are swimming near the surface, the acoustics can cause the noise level, and hence the exposure, to be lower (MTD, 1996). The risk to animals near the surface may therefore be lower than indicated by the impact ranges and so the results in this assessment can be considered conservative in respect of the impact at different depths.

Impact criteria

The prediction of impacts on marine fauna is split by how the noise affects marine mammals and fish.

Marine mammals

The selection of impact criteria uses thresholds and a weighting based on NMFS (2018)[5]. The thresholds indicate the onset of permanent threshold shift (PTS) and temporary threshold shift

[4] von Benda-Beckman A M, Aarts G, Sertlek H Ö, Lucke K, Verboom W C, Kastelein R A, Ketten D R, van Bemmelen R, Lam F-P A, Kirkwood R J, Ainslie M A (2015). *Assessing the impact of underwater clearance of unexploded ordnance on harbour porpoises (phocoena phocoena) in the southern North Sea.* Aquatic Mammals 2015, 41(4), 503-523, DOI 10.1578/AM.41.4.2015.503.

[5] National Marine Fisheries Service (NMFS) (2018). *2018 Revisions to: Technical guidance for Assessing the Effects of Anthropogenic Sound on Marine Mammal Hearing (Version 2.0): Underwater thresholds for Onset of Permanent and Temporary Threshold Shifts*. U.S. Dept. of Commer., NOAA. NOAA Technical Memorandum, NMFS-OPR-59.

(TTS) in various species of marine mammal. This is the point at which there is an increase in risk of hearing damage in an underwater receptor.

The thresholds group a selection of species based on their hearing capabilities, or their particular sensitivity to low or high frequency sound. Blast noise is fairly broadband at source, comprising a wide range of low to high frequency sound, although the majority is at low frequency (< 10 kHz).

The groupings and SEL thresholds for impulsive noise as given in the results are as follows:

- "LF": Low-frequency cetaceans, e.g. minke whale.
  183 dB re 1 μPa^2s (PTS), 168 (TTS) re 1 μPa^2s
- "MF": Mid-frequency cetaceans, e.g. dolphin species.
  185 dB re 1 μPa^2s (PTS), 170 (TTS) re 1 μPa^2s
- "HF": High-frequency cetaceans, e.g. harbour porpoise.
  155 dB re 1 μPa^2s (PTS), 140 (TTS) re 1 μPa^2s
- "PW": Phocid Pinnipeds (in water), e.g. harbour seal.
  185 dB re 1 μPa^2s (PTS), 170 (TTS) re 1 μPa^2s

The SEL criteria given in NMFS (2018) are weighted, which corrects the sound level based on the sensitivity of the receiver, e.g. harbour porpoise are less sensitive to low frequency sound than minke whale. The weighting takes that difference into account. NMFS (2018) also includes criteria based on SPL, which are unweighted and do not take species sensitivity into account.

Please note that both Sound Pressure Level (SPL) and Sound Exposure Level (SEL) values are included in the results, which are specific to respective criteria used, and should not be confused or compared directly. All decibel SPL values are referenced to 1 µPa; all SEL values are referenced to 1 μPa^2s.

These thresholds are defined for an 'impulsive' noise type. They are most relevant close to the blast. At greater ranges, and especially in shallow water, the sound pulse will spread out in time, becoming less 'sharp' and thus less injurious. The draft of NMFS (2018) suggested 3,000 m as an estimate of a distance at which transition away from this impulse to a more non-pulse type of noise could occur, although the sound will not go through a 'step change' and this distance will change depending on the type of sound and situation. This consideration is still under review. The relevant non-pulse criteria are available and results to these are included. These are less stringent than the impulsive criteria. Explosive noise is highly impulsive and an upper conservative estimate of 5,000 m is suggested for the transition.

Although the stricter impulsive ranges should be considered in the first instance, this study would draw attention to the above acoustical consideration for circumstances where impact ranges are modelled to be of the order of thousands of metres.

Fish

There is a vast variation between fish species; studies have only been done on the impacts of noise to a small number of them, which makes an assessment challenging. Criteria for marine mammals have been simplified by categorising them according to the hearing sensitivity of a species group; for fish Popper *et al*. (2014)[6] have proposed criteria for species divided into three groups:

[6] Popper A N, Hawkins A D, Fay R R, Mann D A, Bartol S, Carlson T J, Coombs S, Ellison W T, Gentry R L, Halvorsen M B, Løkkeborg S, Rogers P H, Southall B L, Zeddies D G, Tavolga W B (2014). *Sound Exposure Guidelines for Fishes and Sea Turtles: A Technical Report prepared by ANSI-Accredited Standards Committee S3/SC1 and registered with ANSI*, pp. 33–51. Springer, New York

- Fish with no swim bladder (e.g. dab and other flatfish)
- Fish where a swim bladder is not involved in hearing (e.g. Atlantic salmon)
- Fish where a swim bladder is involved in hearing (e.g. Atlantic cod and herring)

However, in consideration of explosives and potential mortality, all species groups are considered equivalent and there is no frequency weighting to account for variations in hearing sensitivity. Two thresholds are provided, 229 and 234 dB SPL_{peak}, which represent an upper and lower boundary for the potential impact.

It is also considered that there is insufficient data for a quantitative calculation of impact ranges for recoverable injury or hearing impairment in respect of blast. The risk of the effect is therefore considered as either 'low', 'moderate' or 'high' at range in the Popper *et al*. (2014) study.

Impact ranges

Table 1.1 to Table 1.4 present the impact ranges for UXO detonation, considering various charge weights and impact criteria. Ranges smaller than 50 m have not been presented.

Although the impact ranges presented in the following tables are large, the duration the noise is present must be taken into account. For detonation of UXO each explosion is only a single noise event, compared to the multiple pulse nature of impact piling, so there is no continued exposure nor the need to calculate cumulative effects.

All ranges are given in metres, all charge weights are TNTeq for the combined UXO and donor charge.

Table 1.1 - Summary of the PTS and TTS impact ranges (metres) for UXO detonation using the impulsive, unweighted SPL_{peak}, noise criteria from NMFS (2018) for marine mammals at Moray East

NMFS (2018) Unweighted SPL_{peak}		5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
PTS (Impulsive)	219 dB (LF)	470	600	950	1,200	1,700	1,800	2,100
	230 dB (MF)	150	190	300	400	550	600	700
	202 dB (HF)	2,700	3,400	5,300	6,900	9,600	10,500	12,200
	218 dB (PW)	530	660	1,000	1,300	1,800	2,000	2,400
TTS (Impulsive)	213 dB (LF)	880	1,100	1,700	2,200	3,100	3,400	4,000
	224 dB (MF)	280	360	570	730	1,000	1,100	1,300
	196 dB (HF)	4,900	6,200	9,800	12,700	17,600	19,300	22,500
	212 dB (PW)	970	1,200	1,900	2,500	3,400	3,700	4,400

Table 1.2 - Summary of the PTS and TTS impact ranges (metres) for UXO detonation using the impulsive, weighted SEL, noise criteria from NMFS (2018) for marine mammals at Moray East

NMFS (2018) Weighted SEL		5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
PTS (Impulsive)	183 dB (LF)	990	1,400	2,700	3,900	6,300	7,200	9,000
	185 dB (MF)	< 50	< 50	< 50	< 50	< 50	< 50	< 50
	155 dB (HF)	300	400	660	850	1,100	1,200	1,400

	185 dB (PW)	170	240	480	690	1,100	1,200	1,600
TTS (Impulsive)	168 dB (LF)	13,600	18,900	35,200	49,300	74,500	82,800	99,300
	170 dB (MF)	80	100	180	260	380	430	510
	140 dB (HF)	1,700	2,000	2,600	3,000	3,500	3,600	3,900
	170 dB (PW)	2,400	3,300	6,400	9,000	13,900	15,500	18,800

Table 1.3 - Summary of the PTS and TTS impact ranges (metres) for UXO detonation using the non-impulsive, weighted SEL, noise criteria from NMFS (2018) for marine mammals at Moray East

NMFS (2018) Weighted SEL		5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
PTS (Non-impulsive)	199 dB (LF)	60	90	160	230	380	430	540
	198 dB (MF)	< 50	< 50	< 50	< 50	< 50	< 50	< 50
	173 dB (HF)	< 50	< 50	< 50	60	90	100	130
	201 dB (PW)	< 50	< 50	< 50	< 50	70	80	100
TTS (Non-impulsive)	179 dB (LF)	2,000	2,800	5,400	7,900	12,600	14,300	17,800
	178 dB (MF)	< 50	< 50	< 50	80	110	120	150
	153 dB (HF)	400	530	840	1,000	1,400	1,400	1,600
	181 dB (PW)	350	500	970	1,400	2,200	2,500	3,200

It can be seen that the ranges of impact for PTS to LF and HF cetaceans using impulse-type criteria are in excess of 5 km. However, using the non-pulse criteria, the impact ranges for all species for PTS criteria are less than 1 km. Therefore it is suggested that 5 km is likely to be the limit of risk of PTS onset. Similarly, the prediction of TTS ranges, especially for LF cetaceans, are expected to be over-estimated in practice.

Table 1.4 - Summary of the impact ranges (metres) for UXO detonation using the unweighted SPL_{peak}, explosion noise criteria (upper and lower limit) from Popper et al. (2014) for marine mammals at Moray East

Popper *et al.* Unweighted SPL_{peak}	5 kg	10 kg	39 kg	84 kg	226 kg	294 kg	468 kg
234 dB (Potential mortal injury)	100	130	200	260	370	400	470
229 dB (Potential mortal injury)	170	210	340	440	610	670	780

There is the potential for mortal injury to fish up to 780 m from the largest UXO devices.

Conclusions

The impact ranges for a selection of charge weights have been presented, using a simplified assessment methodology. The large number of unknown variables that will affect the output of UXO located for an extended period on the seabed lead to a great degree of uncertainty which makes accuracy challenging in a desktop assessment. The assessment uses calculations based

on a methodology proposed by Soloway and Dahl (2014), following Arons (1954) and MTD (1996). It is expected that the presented ranges overestimate the actual ranges of impact that would occur in practice, both from physical sound propagation and biological perspective.

The calculation parameters are all chosen to be conservative, leading to an upper estimate for source noise levels, and the risk of impact will be reduced over increasing range as the initial shock wave dissipates. This is not only due to the reduction in absolute noise level, but also the changing characteristics of the propagating sound wave.

The sound levels have been converted to impact ranges using sets of criteria from NMFS (2018) for different marine mammal species groups, and Popper *et al*. (2014) for fish. The NMFS (2018) criteria describe nominally the same injury to the hearing of a species but use different thresholds for each group, leading to multiple estimates of the range of impact. No single set of criteria can be assumed to be definitive or 'correct'. It is worth noting also that the criteria refer only to the 'onset' of injury risk rather than a confident assessment of an occurrence of the effect. More research into the effects of noise on marine species will be required to increase confidence in the impacts in real open water circumstances.

Data presented in von Benda-Beckmann *et al.* (2015) show a level of 179 dB SEL re 1 μPa^2s (equivalent to the non-impulsive PTS threshold for LF cetaceans) will be reached, in depths of 10-20 m of water, at a range of the order of 10 km for a charge weight of approximately 500 kg. This suggests that the simple calculation methodology overestimates the noise propagation at long range.

There is little data available for the impact of different sized charges on fish species. However, calculated ranges for the risk of mortal injury to individuals have been provided. The risk of potential mortal injury to fish is predicted to be within 1,000 m of the UXO location, for the largest anticipated charge weight.

Appendix 2: Marine Mammal Mitigation Plan for UXO Clearance

2.1 Introduction

This UXO Marine Mammal Mitigation Plan (MMMP) has been prepared to support both the Marine License (ML) and EPS License application by Moray Offshore Windfarm (East) Ltd (Moray East) for the mitigation of Explosive Ordnance Disposal (EOD) operations within the Development area; comprised of the Moray East site and the OfTI Corridor.

Further details on the EOD operations planned, including the number and type expected to be found within the Development area, can be found in **Section 2**.

A worst-case of 18 UXO devices may require detonation, with up to 15 in the Moray East Site, and up to three in the OfTI Corridor. This is planned to take place over 18 non-consecutive days anytime from March to May 2019, excluding weather conditions.

The methods and procedures required for the effective mitigation of impacts associated with the clearance of any UXO for marine mammal species expected to found in the area. In particular, the MMMP will mitigate against the potential risk of physical injury and / or trauma, and PTS exposure for marine mammals.

The JNCC guidance for "*minimizing the risk of injury to marine mammal from use explosives*" (JNCC, 2010) has been consulted in the process of developing this MMMP to determine the best approach for mitigation, and to ensure best practice measures are followed (JNCC, 2010). In addition, this UXO MMMP has been informed by previous work undertaken for the Moray East and the Beatrice OWF piling protocol included in the Piling Strategy (Moray East, 2016).

The mitigation procedures outlined in this MMMP include;

- Establishment of a mitigation zone of 1km.
- The monitoring of the mitigation zone by dedicated and trained Marine Mammal Observers (MMOs) during daylight hours and when conditions allow suitable visibility, pre- and post-detonation.
- The deployment of Passive Acoustic Monitoring (PAM) devices, if required, and if the equipment can be safely deployed and retrieved.
- The activation of Acoustic Deterrent Devices (ADDs).
- A soft-start procedure using scare charges.
- All detonations to take place in daylight and, when possible, in favourable conditions with good visibility (sea state 3 or less).
- The controlled explosions of the UXO will be undertaken by specialist contractors, using the minimum amount of explosives required in order to achieve safe disposal of the device.
- The fusing of multiple devices; if there are multiple UXO in close proximity (e.g. within 20m of each other) then one may be moved to be detonated with the other. In this case, the charges should be fused together, allowing for a millisecond of delay between the device detonations in order to reduce the cumulative impact of the shock wave.

2.2 Technical Applicability of Bubble Curtains

In theory, the bubbles change the physical condition of the water and the outward propagation of the acoustic/shock waves. However, there is currently no evidence to show that bubble curtains can successfully mitigate the noise and pressures released during EOD operations. Although commonly used within Europe to mitigate long lasting operations such as percussive piling, the

high frequency pulse of noise and pressure released from a UXO detonation has not been shown to sufficiently be reduced by bubble curtain technology (Ordtek, 2018).

Current mitigation methods, for the protection of mammals and fish, are well established and have been shown to be effective in removing mammals and fish from the areas where they would be negatively affected by UXO detonations, providing them with sufficient protection and safeguarding from the noise of EOD operations.

Acoustic and explosive deterrent methods have been seen to disperse mammals to a distance of 1km from a scheduled detonation site (the mitigation zone), as shown below, as well as numerous reports from live operations where mammal observations are undertaken as standard procedure. In addition, it has been noted within JNCC literature (JNCC, 2010) that the limited exposure of noise and pressure caused by UXO detonations has not been seen to negatively affect marine mammals.

No marine mammal injuries or deaths have been observed or reported by UXO and EOD consultancies or contractors when not using bubble curtains, nor have any been reported within industry press (Ordtek, 2018). In addition, the cost and time associated with bubble curtain use should be considered against any merits to ensure the mitigation is reasonable in relation to the risk presented. The deployment of bubble curtains is costly, due to the requirement of an additional vessel, as well as being highly weather sensitive, which can cause delays to operations preventing additional stages of development progressing (Ordtek, 2018).

Therefore, the proposed mitigation, without the uses of bubble curtains is deemed adequate to reduce the risk to marine mammals.

2.3 UXO Mitigation Procedures

2.3.1 Mitigation Zone

The mitigation zone is the area at which a pre-detonation search is required to be undertaken for by MMOs and/or a PAM-Op. This is based on the minimum required distance as specified within the JNCC guidelines (2010) of 1km. See below for more information on MMO and PAM operations within the mitigation zone.

The mitigation zone (of 1km) is measured out from the detonation site with a 360° coverage, with the overall diameter of the mitigation zone being 2km. **Plate 2.1** below provides a simple diagram of the mitigation zone in relation to the detonation site.

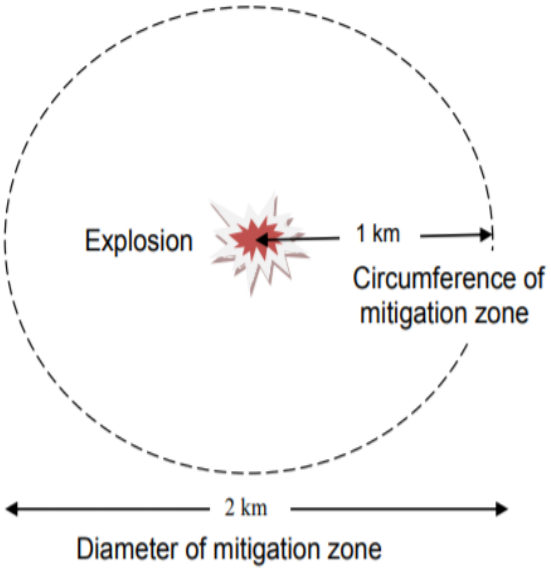


Plate 2.1 Representative mitigation zone of 1km (JNCC, 2010).

2.3.2 Pre-Detonation Search

The pre-detonation search is required to ensure that there are no marine mammals present within the mitigation zone (of 1km radius) prior to the detonation event.

The pre-detonation search should commence at least 1 hour prior to the detonation event, with at least 2 dedicated and trained MMOs to observe from two different viewing platforms at the closest location possible to the detonation site. This ensures that the entire mitigation zone can be monitored at all times. The MMOs should be in close contact to ensure any sighting of a marine mammal within the mitigation zone is communicated.

During periods of low visibility (due to adverse weather and/or sea states of 4 or higher), the use of PAM will be required as an additional measure to monitor the mitigation zone. The PAM hydrophones should be located as close as possible to the detonation site. It is possible to deploy from the vessels already located at the site, however it should be noted that they may be too far from the detonation site at point of explosion to provide effective monitoring of the entire mitigation zone. For the EOD operations the MMOs and PAM-Op will be either on the launch or the guard vessel, within a maximum distance of 300 m of the detonation location, during the pre-detonation search period.

A PAM system (the software PAM Guard should be used) may not always be able to determine the range of a marine mammal detection, or for all species expected to be present in the area. If this is the case, the PAM-Op will need to use experience and expert judgement to determine the range of the individual/s detected and whether it is within the 1km mitigation zone. If the PAM-Op is unsure of whether an individual/s is within the mitigation zone or not, the precautionary principle should always be applied and it therefore should be assumed that the marine mammal/s is within the mitigation zone.

A pre-detonation search should commence prior to all detonation events or sequences, or after any break in the detonation event or sequence, and at the end of a detonation event or sequence. The visual (by MMO) and/or acoustic watch (by PAM-Op if required due to poor conditions) will commence at least 1 hour prior to the detonation event, and across the entire mitigation zone using the methods outlined above. This will continue until 1 hour has passed and no marine mammals have been detected within the mitigation zone; the MMO/PAM-Op will then advise that detonation can commence.

If a marine mammal is detected within the mitigation zone during the pre-detonation search, then the commencement of the detonation will need to be delayed. Once a marine mammal has been sighted within the mitigation zone, it should be monitored and tracked until it is clear of the mitigation zone, and the relevant EOD technical advisor notified. It must be clear of the mitigation zone for at least 20 minutes before the soft start procedure can commence.

If the marine mammal/s remains clear of the zone for at least 20 minutes, and the 1 hour pre-search has also been completed, then the soft start procedure can commence. A precautionary approach should always be used, and if the MMO/PAM-Op cannot be sure whether the individual is within the zone or not, or whether there is a confirmed sighting/detection of a marine mammal within the mitigation, then the operation should be delayed accordingly until the MMO/PAM-Op is sure that there are no marine mammals are present within the 1km mitigation zone.

All MMOs and PAM-Ops present must move clear of the detonation site to a safe distance prior to soft-start detonation.

2.3.3 Deterrence Activities

Deterrence activities are required to reduce the risk of PTS in marine mammals, particularly harbour porpoise.

Acoustic Deterrence Devices (ADDs) will be used in conjunction with MMOs/PAM-Ops (who can act as the ADD operator) and will be operated for a short time to deter marine mammals from the

detonation area. The effectiveness of the ADDs for each species is provided in the Annex A of the MMMP and the ADD operating procedures are outlined below.

2.3.3.1 Acoustic Deterrence Activities

2.3.3.1.2 Acoustic Deterrent Device Procedure

An ADD should be positioned within the water column in close proximity to the detonation site; the ADD-Op will be either on the launch or guard vessel, within a maximum distance of 300m of the detonation location during the pre-detonation search. The ADD should be switched on for a set number of emissions (identified below) during the pre-detonation search and turned off immediately once the detonations have commenced in order to reduce the level of noise in the area. The MMOs and/or PAM-Op should maintain their pre-detonation search during ADD activation.

ADD activation will be for 25 minutes during the pre-detonation search, immediately prior to the detonation event to allow marine mammals to move outwith the area of potential PTS risk. The 25 minutes ADD activation, in addition to the small scare charge scenarios, will encourage marine mammals to move outwith the potential range for PTS. The 25 minutes has been determined based on the effective range of the ADDs and the maximum potential PTS ranges.

Two ADDs will be needed, with one on each end or side of the vessel. It is proposed that one ADD will be deployed on each end or side of the vessel, if possible, to prevent potential shadowing of the ADD sound pulses by the vessel. In addition, deploying two ADDs allows for any possible malfunctions or technical issue with one of the devices.

The best location to deploy the two ADDs, and the method to provide power to the devices, will be decided through a pre-deployment survey of the vessel by the operational manager, the rigger and an electrical supervisor. Once the best location/s for the ADDs have been determined, the control unit and power supply should be temporarily installed. For deployment of the ADDs, the transducer part of the device should be lowered over the side of the deck (they should not be activated at this time) to a water depth that is below the draft of the vessel to ensure the sound can be emitted in all directions and not dampened by the presence of the vessel.

Once the ADDs are in position, they should be tested for operational efficiency. A low sensitivity hydrophone should be lowered over the side of the vessel near the ADDs and the signals tested. The ADD-Op should also ensure that the communications are in place between themselves, the MMOs, the PAM-Op (if present) and the EOD technical advisor.

The ADD will be activated for 25 minutes directly prior to the soft start procedure, during the pre-detonation search. The ADD cannot be used during transit to another detonation event, and must be activated prior to the soft start procedure for any detonation event or sequence. Once the ADD has been activated for a period of 25 minutes, then the ADD-Op will recover the ADDs and undertaken routine checks to ensure all are still working correctly, ready for the next deployment and activation. If the MMO/PAM-Op and ADD-Op are the same person, then the ADD should be deployed and tested prior to the 1 hour pre-detonation search, and activated at the appropriate time.

The pre-detonation search procedures still apply during this time, and if any marine mammals are sighted within the 25 minute ADD activation time, the soft start procedure cannot commence until 20 minutes with no marine mammal presence within the mitigation zone, and until the 1 hour pre-detonation search has been completed (it should be noted that the ADD should not be activated for longer than the stated period of 25 minutes to limit the potential for additional noise impact, unless a marine mammal is detected within the soft-start procedure – see below for more information). The MMO/PAM-Op should maintain their pre-detonation search during the ADD activation time.

2.3.3.2 Soft-Start of UXO

A sequence of small to large charge size in order (very small explosives with charges of 50g, 100g, 150g and 200g) will be implemented to allow additional time for marine mammals to leave

the area of potential impact; this is known as a “soft-start” procedure. For the larger UXO greater than 270kg, an additional small charge of 250g will be added to the sequence. The small scare charges are in additional to the donor charges required to detonate the UXO device.

The introduction of additional small charges will ensure a balance between the deterrence of marine mammals beyond the potential range of injury, and minimizing the additional noise introduced into the environment.

When the EOD Technical Advisor provides notification that the soft-start is due to commence in 25 minutes, the ADD device will be deployed, five minutes after the ADD deactivation (or as soon as is reasonable considering safety constraints), the four or five small charge detonations should commence at five minute intervals, with a further interval of five minutes before the detonation of the UXO. This gives a total deterrence time of 50 or 55 minutes, and based on a swimming speed of 1.5 m/s (Otani et al. 2000), marine mammals should clear a radius of 4.5km or 4.95km during this duration.

Once the soft-start has commenced, and a marine mammal is detected within the 1km mitigation zone by the MMO and/or PAM-Op, the soft-start sequence should be paused, the ADD reactivated for up to 25 minutes until the marine mammal is clear of the mitigation zone for a period of 20 minutes. Once the MMO and/or PAM-Op has confirmed that the marine mammal has been clear for 20 minutes, then the soft-start procedure can recommence with the next charge.

Where charges are to be detonated together, then appropriate fusing should be used wherever practicable to allow for a functional delay (of a few milliseconds only) to reduce the cumulative impact of multiple charges.

Whilst the range of 4.95km due to ADD activation and scare charges is not beyond the predicted maximum impact range of 5km for the risk of PTS onset, it will significantly reduce the risk of PTS in all marine mammal species.

Observations will continue throughout the period that any scare charges are used to protect against the possibility of marine mammals coming into the mitigation zone to take advantage of stunned/killed fish.

2.3.5 Post-Detonation Search

The MMOs should maintain a post-detonation search within the mitigation zone for at least 15 minutes after the final detonation, to look for evidence of injury to marine life, including any fish kills (following the JNCC (2010) guidance). Any other unusual observations should be also noted within the report.

2.3.6 Reporting

Reports should be completed detailing the marine mammal mitigation activities and timings, and any detections, and should be submitted to JNCC after the operation has been completed. Reports should be sent directly to seismic@jncc.gov.uk. These reports should include information on the relevant UXO clearance activities, date and location, information on charge sizes, start times of detonations, start and end of pre and post-detonation watches (MMO) and acoustic monitoring (PAM-Ops), details of explosive activity during the relevant watches. The reports would be reviewed by Moray East and Moray East’s ECoW in the first instance prior to their formal issue to JNCC and/or MS-LOT.

Marine Mammal Recording Forms can be found on www.jncc.gov.uk/page-1534 and all parts should be completed (including the cover page, operations sheet, effort sheet, and sightings sheet). Deckforms can be used if preferred with the information transferred to the spreadsheet at the end of the watch. Details of any ADD used and observations of their efficacy, and any problems encountered and instances of non-compliance with the JNCC guidelines and variations form the agreed procedure should also be reported.

In the event of a marine mammal sighting and/or detection, the MMO and/or PAM-Op should report the following information;

- Species, number of individuals, age, sex and size (e.g. juvenile or adult);
- Physical description of individuals features if cannot be identified to species level;
- Behaviour when first sighted (e.g. travelling, foraging, resting);
- Bearing and distance;
- Time, vessel position, vessel speed, vessel activity;
- Water depth (if known), sea state, visibility, glare; and
- Any other vessels in the area.

The ADD-Op should maintain a detailed record of all ADD deployments, including all ADD deployment, activation and recovery times, a record of each verification of ADD activation and a note of any issues encountered with regard to the ADD deployment and activation.

2.4 Roles and Responsibilities

There are a number of people that would be required in the compliance with this MMMP for UXO detonation activities, including;

- Marine Mammal Observers (MMOs);
- Passive Acoustic Monitoring Operator (PAM-Op);
- Acoustic Deterrent Device Operator (ADD-Op); and
- Explosive Ordnance Disposal Technician.

More information on each of the above's specific responsibilities are outlined below, including information on the experience of each that would be required.

2.4.1 Marine Mammal Observers

Dedicated and JNCC accredited MMOs will need to be present and on-watch for the pre-detonation and for the post-detonation searches. Dedicated means that this should be the persons sole responsibility (however in this case it should be noted that the MMO could also act as the ADD operator, although the ADD procedure would more likely be undertaken by the PAM-Op). Two MMOs will be required to cover the entire mitigation zone, with good viewing platforms to allow for 360° coverage. The MMOs must be able to determine the extent of the 1km mitigation zone from their location, unless poor visibility does not allow.

The MMOs will need to be equipped with binoculars, a ranging stick and the JNCC reporting forms. The MMOs should scan the mitigation zone with the unaided eye, and use binoculars when needed to determine detail (such to look in detail at the area where a possible sighting has been made). Binoculars should not be used continually as they restrict peripheral vision and views close to the vessel.

Clear communication channels between the MMOs, the PAM-Op (if present), the ADD-Op and the EOD technical advisor are required, and the communication procedures should be established and agreed prior to any detonation event with regards to the communication of any detection within the mitigation zone, the deployment of ADDs, and when the mitigation zone is clear for detonation to take place. The EOD technical advisor team should assign a person responsible for communication with the mitigation team. The MMOs, PAM-Op (if present) and ADD-Op should be notified of a detonation even 24 hours prior to detonation, and should be on site at minimum 1.5 hours prior to detonation.

The MMOs specific responsibilities are:

- To commence a pre-detonation search at least 1 hour prior to detonation to ensure no marine mammal/s are within the 1 km mitigation zone prior to detonation.
- In the event that marine mammal/s is detected within the 1km mitigation zone during the pre-detonation search, to communicate to the named member of the EOD technical advisor, and to ensure no detonation commences until at least 20 minutes have passed since the marine mammal/s detection within the 1km mitigation zone and the 1 hour pre-detonation search has been completed.
- Notify the named member of the EOD technical advisor once the marine mammal/s has left the mitigation zone, and again once the mitigation zone is clear for detonation (i.e. there have been no marine mammals within the mitigation zone for 20 minutes and the 1 hour pre-detonation search has been completed).
- Complete a post-detonation search for at least 15 minutes after the last detonation to look for any evidence of injury to marine life, including fish kills. This will take place in the same location as the pre-detonation search.

2.4.2 Passive Acoustic Monitoring Operator

PAM is able to detect the vocalizations of marine mammals, and works best for echolocating species that are near-continually vocalizing such as harbour porpoise and dolphin species. The detection range of PAM (i.e. the distance up to which PAM can detect marine mammal vocalisations) varies for different species, according to the vocalisation frequencies of each species. Harbour porpoise produce high frequency echolocation clicks (with a peak at 130kHz), and sounds produced at this high frequency do not travel as far underwater as for low frequency vocalisations (such as from minke whale). It has been estimated that the typical range of harbour porpoise detectability for towed hydrophones is up to a maximum range of 200 to 250m (Gillespie, 2005). For dolphin species, with a mid-frequency vocalisation range, it is possible to detect vocalisations to at least 1km using a towed hydrophone array, and for minke whale this is considerably further, up to many km's depending on the ambient underwater noise levels.

PAM will be required in periods of low visibility to complement the monitoring by the MMOs. PAM-Ops should be experienced and trained in PAM hardware and software, as they will be required to determine the range of a detected marine mammal to the hydrophone location (note that this will be located between 100 and 300m from the EOD operation) if the PAM software is unable to, and to interpret the detected sounds.

The PAM-Ops responsibilities will be the same as those for the MMO outlined above. A dedicated PAM-Op will also be responsible for the deployment, maintenance and operation of the PAM hydrophone, including any spares, and notifying the ADD operator of any issues during the testing of the ADD.

2.4.3 Acoustic Deterrent Device Operator

A trained ADD-Op will be responsible for the ADD maintenance, operation and reporting procedures. This could be an existing member of the crew who has been specifically trained in the MMMP procedures and ADD operation who is available to carry out the ADD mitigation procedure in addition to their existing duties, or personnel specifically employed to operate the ADDs only, or this could be undertaken by the MMO and/or PAM-Op. The ADD-Op will need to ensure that the device has fully charged batteries, be available for the deployment and operation of the device, provide communication with all parties and to record all necessary information for the reporting.

The ADD-Op will be responsible for;

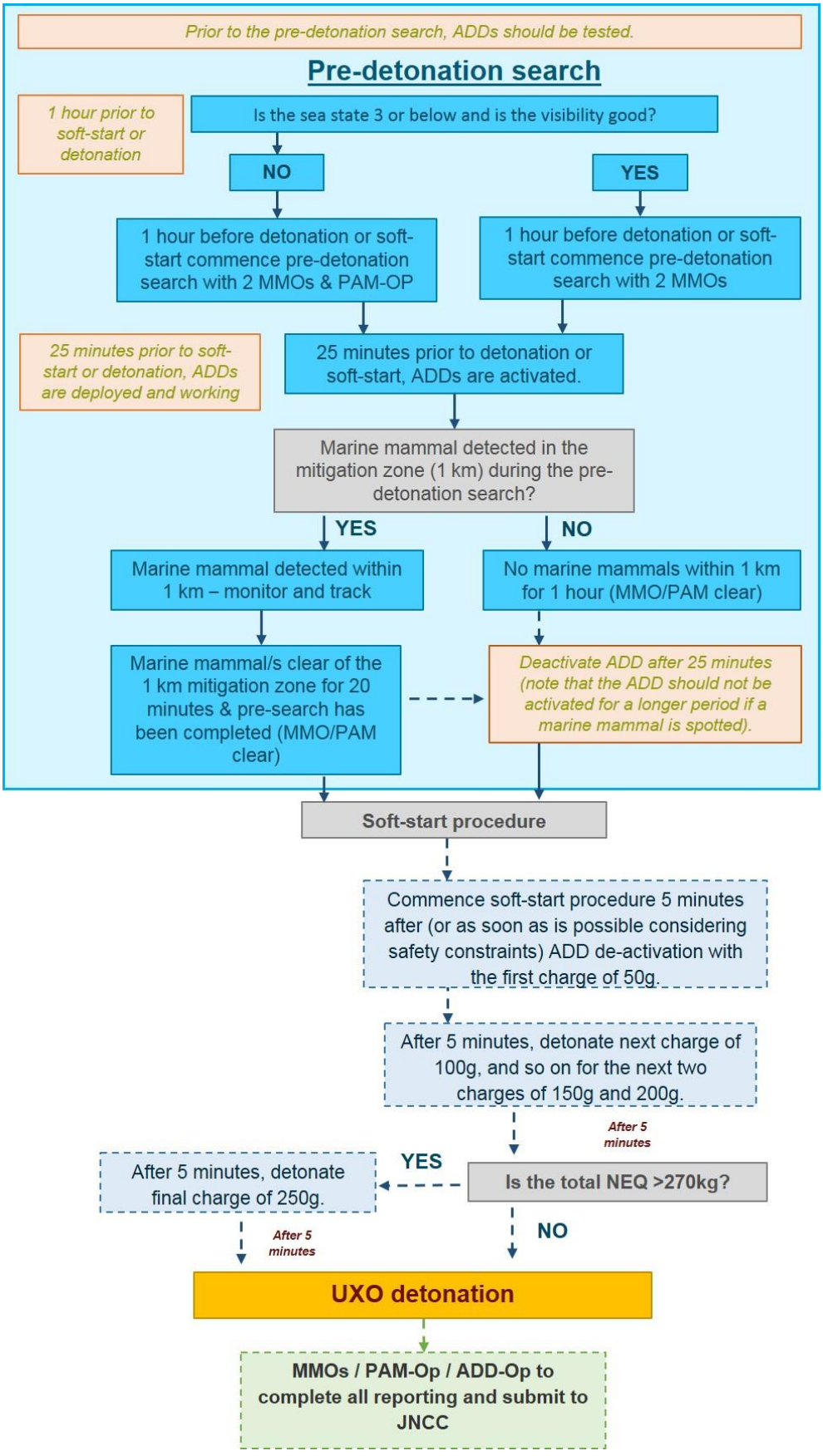
- Determining the best location for ADD deployment along with the operational manager, the rigger and an electrical supervisor, and ensuring the control unit and power supply are temporarily installed ready for deployment.
- Deploying the ADD over the side of the vessel, to a depth lower than the draft of the vessel, and testing the device is working using low sensitivity hydrophones ready for ADD activation 25 minutes prior to detonation. This can be done by the PAM-Op if present.
- Activate the ADD 25 minutes prior to the soft-start using small scare charges, during the pre-detonation search.
- Once the ADD has been activated for a period of 25 minutes, it should be recovered and routine checks on the device undertaken to ensure ready for the next deployment.

2.4.4 Explosive Ordnance Disposal Supervisor

The EOD Supervisor has the overall responsibility for the detonation operation, and to ensure that the soft-start charges are used, and will be based on the inspection vessel. The EOD Supervisor will be the main point of communication between the mitigation team (MMOs, PAM-Op (if present) and the ADD-Op) and the EOD support teams (who are responsible for carrying out the UXO clearance activities). The EOD Supervisor will be in control of initiating, delaying or pausing the detonation activities.

2.5 Outline Mitigation Procedure

The outline mitigation procedure (as outlined above) is summarised below in **Plate A**.2.


Prior to the pre-detonation search, ADDs should be tested.
Pre-detonation search
1 hour prior to soft-start or detonation
Is the sea state 3 or below and is the visibility good?
NO
YES
1 hour before detonation or soft-start commence pre-detonation search with 2 MMOs & PAM-OP
1 hour before detonation or soft-start commence pre-detonation search with 2 MMOs
25 minutes prior to soft-start or detonation, ADDs are deployed and working
25 minutes prior to detonation or soft-start, ADDs are activated.
Marine mammal detected in the mitigation zone (1 km) during the pre-detonation search?
YES
NO
Marine mammal detected within 1 km – monitor and track
No marine mammals within 1 km for 1 hour (MMO/PAM clear)
Marine mammal/s clear of the 1 km mitigation zone for 20 minutes & pre-search has been completed (MMO/PAM clear)
Deactivate ADD after 25 minutes (note that the ADD should not be activated for a longer period if a marine mammal is spotted).
Soft-start procedure
Commence soft-start procedure 5 minutes after (or as soon as is possible considering safety constraints) ADD de-activation with the first charge of 50g.
After 5 minutes, detonate next charge of 100g, and so on for the next two charges of 150g and 200g.
After 5 minutes
Is the total NEQ >270kg?
YES
After 5 minutes, detonate final charge of 250g.
NO
After 5 minutes
UXO detonation
MMOs / PAM-Op / ADD-Op to complete all reporting and submit to JNCC

Annex: A: Information on Acoustic Deterrent Device Effectiveness

The Lofitech seal scarer has been shown to be the most consistent and effective at deterring seal species from an area, as well as for harbour porpoise and more recently has been shown to be effective at deterring minke whale. The Lofitech seal scarer has successfully been used in a number of projects for a range of industries, including for aquaculture projects and the offshore wind industry. The Lofitech device has been designed to have a source noise level of 189 dB, with numerous field measurements confirming the device to have recorded source levels of 179 to 194 dB (Coram *et al.,* 2014).

A number of different trials have shown that the Lofitech Seal Scarer device is effective at deterring harbour and grey seals to a distance of 1 km from the device location (Brandt *et* al., 2012; 2013, Harris *et* al., 2014, Gordon *et al.*, 2015; Coram *et al.,* 2014); meeting the 1 km mitigation zone. There was no habituation of harbour seals in field trials that occured over several weeks (Gordon *et al*., 2015).

The noise source level from the Lofitech device (of a maximum 194 dB re 1 µPa) is also lower than the injury thresholds for seals in water, with PTS onset at 218 dB re 1µPa SPL_{peak} and TTS onset at 212 dB re 1µPa SPL_{peak} (NMFS, 2018). Cumulative exposure is not considered for the use of ADDs as the individuals would vacate the area before any risk of cumulative exposure.

Studies have also shown the device to be effective for harbour porpoise up to 7.5 km with an immediate response on activation of the device (Bradnt *et al*., 2012, 2013; Gordon *et al.*, 2015). Harbour porpoise were not habituated to the device over trials of 4-6 months (Brandt *et al*., 2012). The device noise source levels are below the sound level required for PTS onset in harbour porpoise (202 dB re 1µPa SPL_{peak}) and TTS onset (196 dB re 1µPa SPL_{peak}) under the NMFS criteria (NMFS, 2018).

The Lofitech seal scarer has been proven to effect minke whale behaviour up to 1 km from the source (McGarry *et al*., 2017). Within 15 minutes of ADD activation, minke whale were shown to travel to a minimum distance of 1.7 km from the ADD location, with a maximum deterrence range of 4.5 km detected. The device noise source levels are below the sound level required for PTS onset in minke whale (219 dB re 1µPa SPL_{peak}) and TTS onset (213 dB re 1µPa SPL_{peak}) under the NMFS criteria (NMFS, 2016; 2018). Mean swim speeds of minke whale away from the active device was found to be 15 km/h (± 4.7 km/h), which is significantly higher than the assumed 1.5 m/s used to determine the required ADD activation period (McGarry *et al*., 2017).

There is no information available on the effectiveness of the Lofitech Seal Scarer device on dolphin species. However, studies on the effectiveness of ADDs in captive dolphins has shown startle responses in bottlenose dolphins at ADD source levels of 135 dB re 1µPa RMS (Janik and Götz, 2015). It could therefore be assumed that the deterrence range of bottlenose dolphins from an ADD emitting a sound source level of 190 dB re 1 µPa with a high frequency could be more than 4 km ((McGarry *et al*., 2017). However it should be noted that this is untested.

In light of the scientific evidence of its effectiveness as shown above, it is proposed that the Lofitech seal scarer will be used for the mitigation of the EOD operations. If a different ADD is chosen to be used at a later date, agreement would be sought from MS-LOT prior to the commencement of any EOD operations.

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