East Anglia ONE North and East Anglia TWO Offshore Windfarms

Underwater Noise Modelling Report Update

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Applicable to East Anglia ONE North and East Anglia TWO

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1 Introduction

This document is an update to that submitted at Deadline 8 (REP8-040) which now includes sequential modelling of monopiles within a 24-hour period as requested by the MMO in REP8-156.

The proposed East Anglia TWO and East Anglia ONE North (EA2/EA1N) offshore wind farms are proposed to consist of a wind turbine array, with the wind turbine generators (WTG) installed on foundations using either a single monopile or multi-leg jacket driven into the seabed in addition to several further foundation options that do not require piling. The pile driving proposed for this will generate noise, which has the potential to adversely affect marine life in the vicinity of the activity.

To identify the extent of the impact of this noise on marine mammals in the North Sea, underwater noise modelling was undertaken as part of the Environmental Impact Assessment. This uses the pile diameter, piling hammer blow energy and other environmental factors relevant to the WTG location to predict the extent of the subsea noise propagation, and how the exposure to this noise would affect marine mammals (as per guidance in NMFS, 2018[1]). This is generally expressed in terms of an adverse effect on the hearing of a receptor, either permanent (known as a permanent threshold shift, PTS) or short-term (a temporary threshold shift, TTS).

Modelling was originally based on a marine mammal receptor exposed to the high noise levels produced by installation of a pile. However, there is the potential that multiple piles could be driven in a day (the timescale over which the guidance recommends assessment) and the MMO has raised a concern that this could affect the ranges of impact that represent the extent of adverse effects on marine mammals.

It should be noted that no concurrent piling, that is multiple rigs on site each driving foundation piles simultaneously, is proposed and so concerns stem from the additional exposure to noise caused by multiple piles installed sequentially from adjacent WTG locations for monopiles adjacent to one another in different WTG rows as a worst case (see Section 3 for the basis of the assumption) or an effective single location for multi-leg jacket foundations.

2 Acoustic background and principles

The potential effect of underwater noise exposure on marine mammals is assessed using NMFS (2018) methodology. The pile driving generates a succession of discrete pulses in the water, which diminish in noise level as the pulse moves away from the source. At some point this pulse will reach a marine mammal receptor, where it will have a specific noise level, to which the receptor is exposed. It is assumed that under these conditions the receptor will move away from the noise source, and thus, in principle, each successive subsea pulse reaching the receptor will be slightly quieter than the previous

[1] National Marine Fisheries Service (NMFS) (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.

one[2]. This will continue for the duration of the piling activity. The exposure to each pulse accumulates to an overall exposure that the receptor reaches at the end of the event.

Although the strikes tend to get louder as the blow energy increases over the pile installation, particularly during the ‘ramp up’ period which follows the initial ‘soft start’, this is normally more than offset by the increasing distance of the receptor from the pile. The consequence of this is that the majority of the noise exposure occurs at the start of the piling event. It is for this reason that Marine Mammal Mitigation Protocols (MMMP) include for an initial soft start period followed by a ‘ramp up’ in blow energy. The draft MMMPs (REP8-029) for East Anglia ONE North and East Anglia TWO secure a 10-minute soft start (at a maximum 10% of maximum hammer energy) followed by a 20-minute ramp up where hammer energy increases from 10 to 80% of maximum hammer energy.

Where multiple piles must be considered, the model applies an additional pulse sequence to the receptor on completion of the first pile, adding to the overall exposure. However, at the start of this subsequent period of piling, the receptor is already a significant distance from the pile and this limits the additional exposure; any further piling periods will mean that the receptor will start further and further away. This assumption has been used for multi-leg jackets, where piles are installed in relatively quick succession.

In the case of monopiles, there will be a greater period of time between the installation of the piles to allow for the rig to relocate. The monopile worst case includes for a piling duration of over five hours, meaning that a receptor individual would be at least 25km away at the end[3]. The break between the installation of each pile does not confer any benefit to the animal, other than to allow it to move to another position and thus the noise level of each additional, accumulative, pulse would be different based on how far the individual is from the pile when the next pile starts.

Although the individual has additional time between piles to move further away, the modelling assumes that it remains where it is at the end of piling at the previous pile. The likelihood of the individual immediately turning around to move back to the high noise area, and then remaining there until piling at the next pile starts, is expected to be statistically low.

NMFS (2018) defines a series of noise exposure thresholds, which define the point at which onset of a particular effect – PTS or TTS – could occur to a particular species group. These species groups categorise species by their hearing capabilities, effectively a frequency range to which species in the group are sensitive. Four species groups are considered in the EA2/1N subsea noise impact assessment: “low frequency cetacean” (LF) species, generally baleen whales, “mid frequency cetacean” species (MF), e.g., common dolphins, “high frequency cetacean” species (HF), e.g., harbour porpoise, and pinnipeds (in water) (PW), e.g., seals.

The model outputs an exposure contour. If an individual is inside this contour at the start of piling, then the exposure has been modelled to exceed the threshold relevant to that particular criterion. As described above, modelling assumes the additional piles begin with the receptor individual starting at the position it was at when the previous pile finished, which represents a reasonable worst case for the position (given that moving further would reduce any additional exposure and turning around and returning to a relatively smaller area where higher noise levels were and will be present is unlikely).

NMFS guidelines propose criteria based on the SPL_{peak} and SEL_{cum} metrics for each species group. SPL_{peak} criteria use an effectively instantaneous noise level and so are unsuitable for a comparison using an exposure over time. Therefore, only the SEL_{cum} thresholds will be investigated herein.

[2] The modelling assumes a flee speed of 3.25 ms^{-1} for LF cetaceans and a flee speed of 1.5 ms^{-1} for MF cetaceans, HF cetaceans and PW pinnipeds.

3 Underwater noise modelling

Modelling has been undertaken to predict the noise exposure to marine mammal receptors from the installation of four sequential piles for a multi-leg jacket, and two monopiles in succession, for a WTG foundation, in comparison to a single driven foundation pile presented in the EA2/EA1N Environmental Statements. Based on the PTS thresholds defined in NMFS, 2018, the new contour has been overlaid on the original contour presented in the EA2/EA1N environmental statements. For the purposes of this demonstrative study, only PTS has been remodelled.

One location in EA2 and one location in EA1N have been chosen as a representative example to demonstrate the effect on contour size of installation of four sequential piles in comparison to a single pile. It should be noted that the location in EA1N is the same as used in the original impact assessment modelling to enable a direct comparison for the purposes of this study, although the latest EA1N boundary has moved slightly to accommodate a 2km buffer from the Outer Thames Estuary Special Protection Area. This small change in boundary will have little effect on the modelled contours, and no effect on the principle of identifying relative changes in contours from one pile installation to four sequentially for a multi-legged jacket foundation and from one pile installation to two sequentially at adjacent locations for monopile foundations.

Modelling two adjacent WTG monopile foundations within 24 hours as the worst case scenario is based on two key factors;

- The installation sequence; and
- Timescales between completion of piling at one location and commencement of piling at the next location.

WTG are typically installed in connected ‘strings’ with the installation vessel installing the foundations at the first WTG and then moving to the next WTG location on the string. There are a number of reasons for this, including installation efficiency, but the key reason is that this strategy allows for strings of WTG to start generating power once the string is complete and connected to the offshore substation. Once installation of foundations along the string is complete, the installation vessel will typically move across from the end of one string to the start of the next and then work down that string. Again, this provides for the greatest efficiency in the installation sequence. Whilst it may occasionally be necessary to deviate from this strategy and commence installation of foundations on the next string at the opposite end of the windfarm site, it would not be expected to typically occur within a 24 hour period due to the time required to transit across the windfarm site, in addition to the time required to demobilise from the previous foundation location and mobilise at the next location and implement the requirements of the MMMP.

The initial pre-piling set up period is approximately 4.5 hours. Following this, piling is estimated to take approximately 5.5 hours, including the soft-start and ramp up (as stated in the Table 11.2 ‘Worst-Case Parameters for Marine Mammal Receptors’ of ***chapter 11 – Marine Mammals*** of the Environmental Statement (APP-059)). Following completion of piling, the post-piling demobilisation is estimated to take a further 4.5 hours. The installation vessel would then need to traverse the windfarms site, which would take several hours before commencing the marine mammal search period required under the MMMP and pre-pile set up period.

To ensure a worst-case-scenario, the modelling has therefore assumed that piling at the second location within 24 hours would occur on an adjacent WTG string (rather than at an adjacent WTG location within a string) which would be a minimum of 1200m. This distance is based on the minimum spacing of WTG between rows as set out in ***chapter 6 – Project Description*** of the Environmental

Statement (APP-054). However, ***chapter 6 – Project Description*** also states that the nominal spacing of WTG could be greater than the minimum spacing. Therefore, it has been agreed with the MMO that if at the installation programme design stage a scenario is identified where two piles may be installed sequentially at a distance greater than 2500m in a 24-hour period, further modelling would be provided, if requested by the MMO.

Piling parameters are unchanged from those used in the EA2/1N Environmental Statement.

4 Results

The tables below present the modelling SEL_{cum} impact ranges for the noise from a single pile installation, along with the noise from four multi-leg foundation piles, installed sequentially (Table 1 and Table 2), and for two monopiles installed sequentially from two locations 1200 m apart (Table 3 and Table 4). All ranges are given to two significant figures.

NMFS (2018) – PTS, weighted SEL_{cum} EA2 Multi-leg foundation			**1 pile (from ES)**		**4 piles, sequential**	
			Maximum	**Mean**	**Maximum**	**Mean**
EA2	LF Cetacean	183 dB	20 km	16 km	20 km	16 km
	MF Cetacean	185 dB	< 100 m	< 100 m	< 100 m	< 100 m
	HF Cetacean	155 dB	21 km	18 km	21 km	18 km
	PW Pinniped	185 dB	6.9 km	5.9 km	7.1 km	6.0 km

Table 1 – PTS ranges comparison at East Anglia TWO (EA2) Offshore Wind Farm for sequential installation of multi-leg foundations

NMFS (2018) – PTS, weighted SEL_{cum} EA1N Multi-leg foundation			**1 pile (from ES)**		**4 piles, sequential**	
			Maximum	**Mean**	**Maximum**	**Mean**
EA1N	LF Cetacean	183 dB	21 km	17 km	21 km	17 km
	MF Cetacean	185 dB	< 100 m	< 100 m	< 100 m	< 100 m
	HF Cetacean	155 dB	21 km	18 km	21 km	18 km
	PW Pinniped	185 dB	7.0 km	5.8 km	7.2 km	5.9 km

Table 2 – PTS ranges comparison at East Anglia ONE North (EA1N) Offshore Wind Farm for sequential installation of multi-leg foundations

NMFS (2018) – PTS, weighted SEL_{cum} EA2 Monopile foundation			**1 pile (from ES)**		**2 piles, sequential, separate locations**	
			Maximum	**Mean**	**Maximum**	**Mean**
EA2	LF Cetacean	183 dB	17 km	14 km	17 km	14 km
	MF Cetacean	185 dB	< 100 m	< 100 m	< 100 m	< 100 m
	HF Cetacean	155 dB	6.5 km	5.5 km	6.8 km	5.5 km
	PW Pinniped	185 dB	5.0 km	4.3 km	5.3 km	4.2 km

Table 3 – PTS ranges comparison at East Anglia TWO (EA2) Offshore Wind Farm for sequential installation of monopile foundations at separate locations 1.2 km apart

NMFS (2018) – PTS, weighted SEL_{cum} EA1N Monopile foundation			**1 pile (from ES)**		**2 piles, sequential, separate locations**	
			Maximum	**Mean**	**Maximum**	**Mean**
EA1N	LF Cetacean	183 dB	16 km	13 km	16 km	13 km
	MF Cetacean	185 dB	< 100 m	< 100 m	< 100 m	< 100 m
	HF Cetacean	155 dB	6.6 km	5.4 km	6.6 km	5.4 km
	PW Pinniped	185 dB	5.1 km	4.2 km	5.1 km	4.2 km

Table 4 – PTS ranges comparison at East Anglia ONE North (EA1N) Offshore Wind Farm for sequential installation of monopile foundations at separate locations 1.2 km apart

Figures showing the effect on ranges are presented for the HF cetacean and PW pinniped species groups, as defined in NMFS (2018), are given at the end of the report (Figure 1 to Figure 8). For each figure, the yellow contour represents the SEL_{cum} impact ranges for one pile, and the red contour represents the SEL_{cum} contour for four pin-piles or two monopiles installed sequentially.

LF and MF cetacean plots have not been presented. The faster flee speed for LF cetaceans (3.25m/s vs 1.5 m/s for the other species groups) meant that the receptor has travelled much further from the noise source than the other species groups in the same time period, and the impact ranges for two or four piles were negligibly larger than for a single pile. The small impact ranges predicted for MF cetaceans would not be visible on a chart at this scale.

These results represent the effect of installation of multiple piles for a jacket foundation or two adjacent monopiles in a 24-hour period.

5 Conclusions

Remodelling of the underwater noise exposure for marine mammals at EA2 and EA1N has shown that there is a small increase in the PTS ranges when considering two or four sequential driven pile installations compared to a single installation. This is up to a 3% increase in range for the pinnipeds (in water) species hearing group, at most. The duration in time over which a pile is installed is sufficient for an individual to be able to move a sufficient distance from the noise source such that any additional exposure to noise does not contribute significantly to the animal's overall exposure in a day.

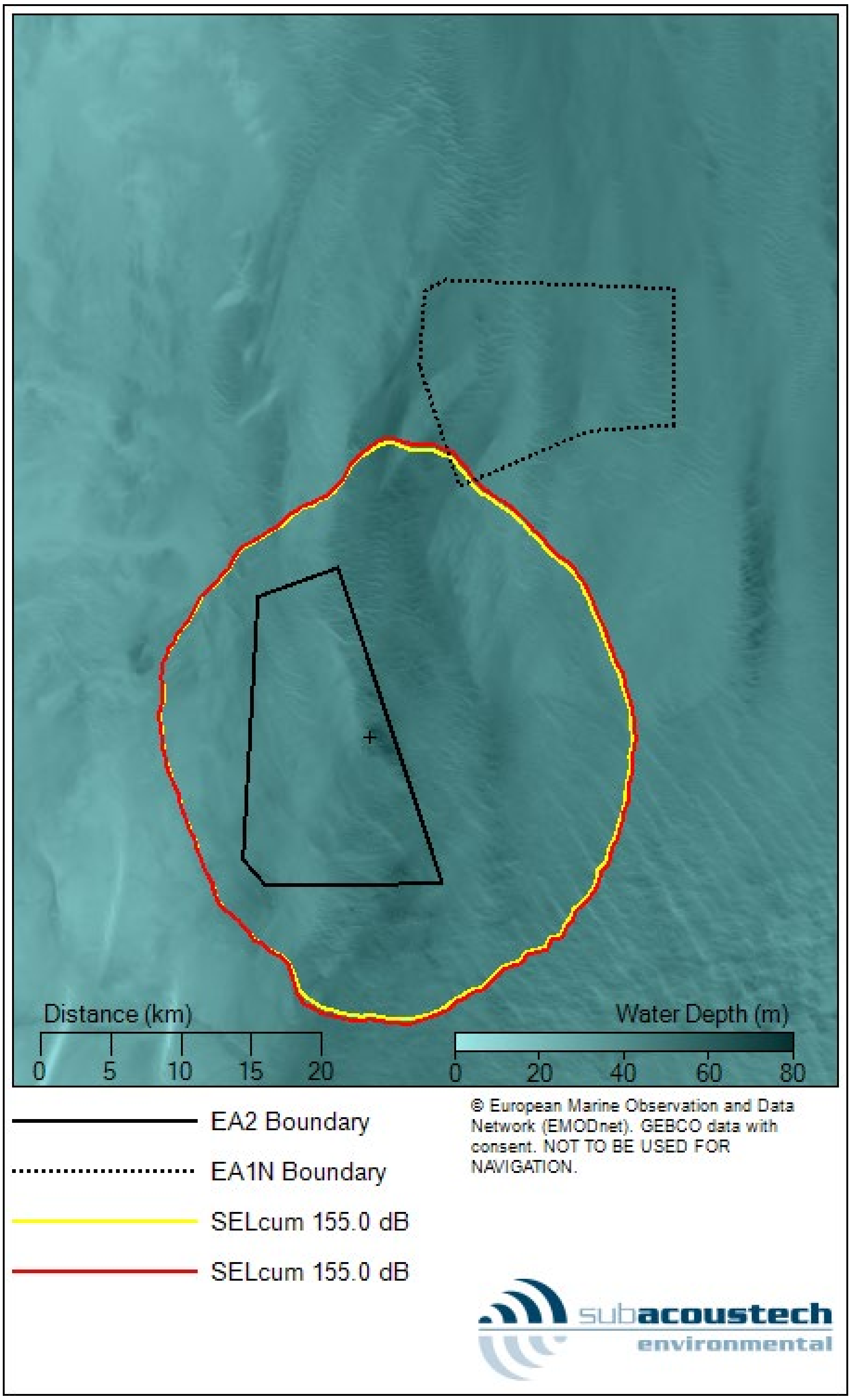

Figure 1 Contour plot showing the PTS ranges for High Frequency Cetaceans (HF) at EA2. The yellow contour represents the noise from a single multi-leg foundation pile installation, and the red contour represents the noise from four multi-leg foundation piles, installed sequentially.

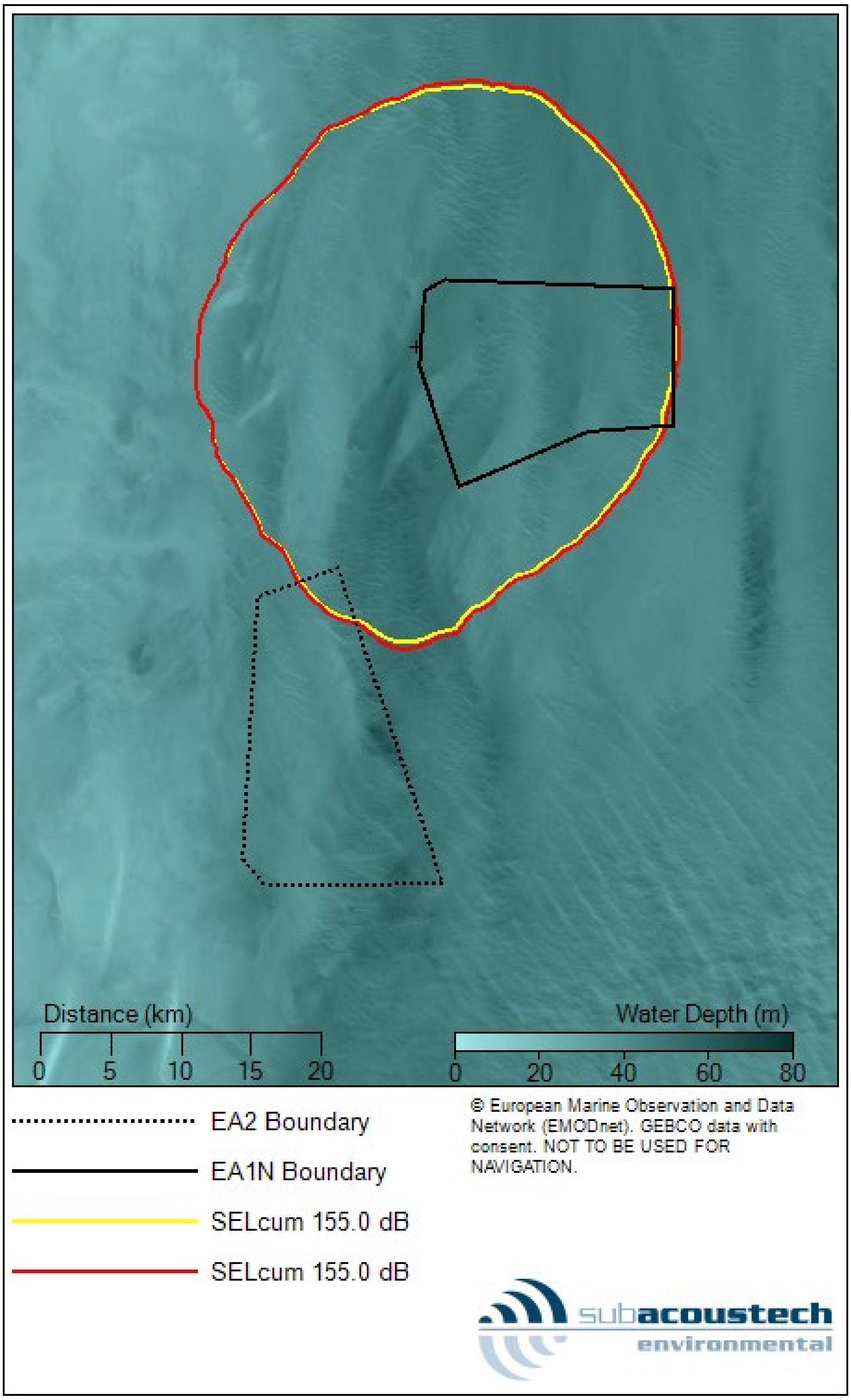

Figure 2 Contour plot showing the PTS ranges for High Frequency Cetaceans (HF) at EA1N. The yellow contour represents the noise from a single multi-leg foundation pile installation, and the red contour represents the noise from four multi-leg foundation piles, installed sequentially.

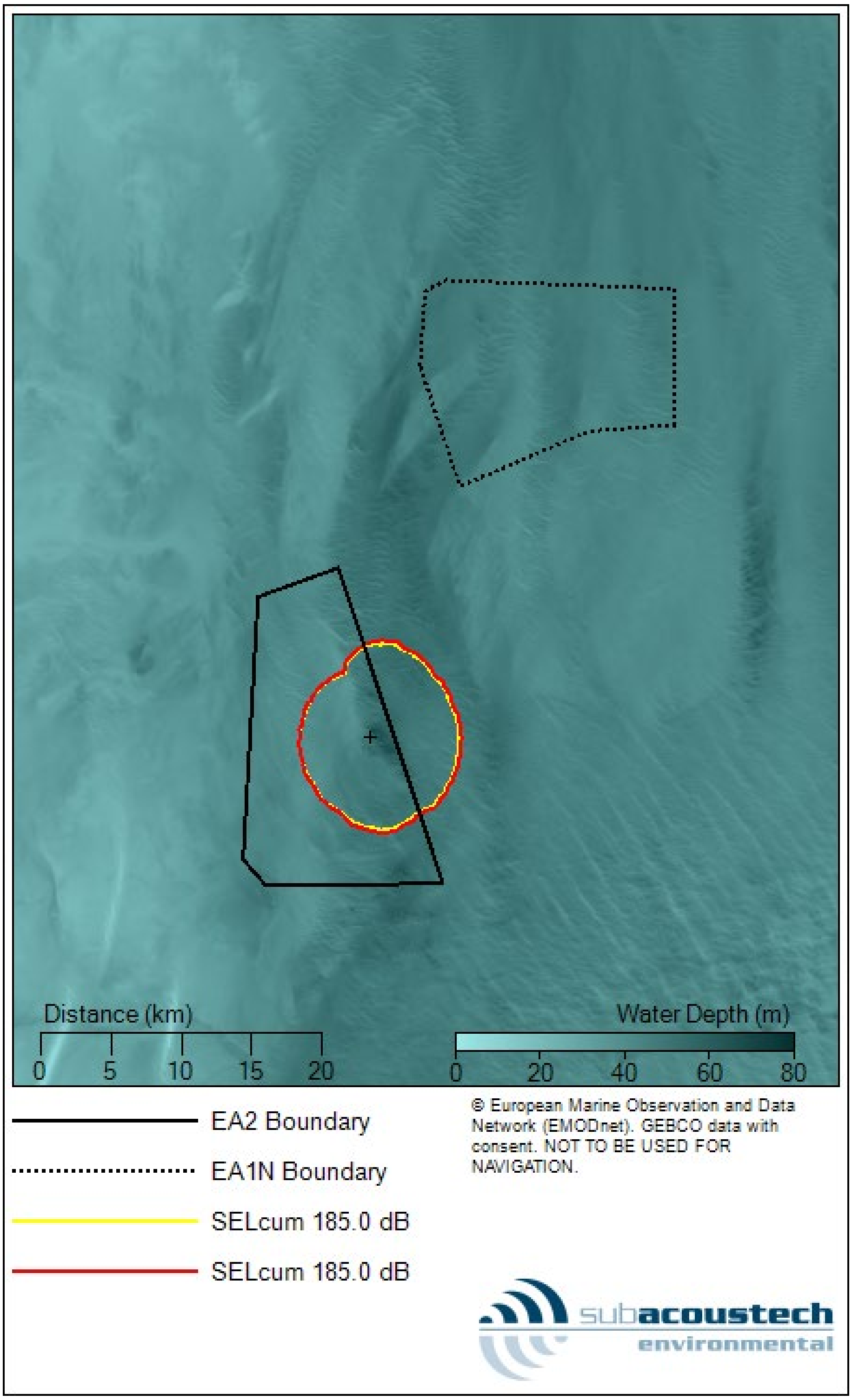

Figure 3 Contour plot showing the PTS ranges for Pinnipeds (in water) (PW) at EA2. The yellow contour represents the noise from a single multi-leg foundation pile installation, and the red contour represents the noise from four multi-leg foundation piles, installed sequentially.

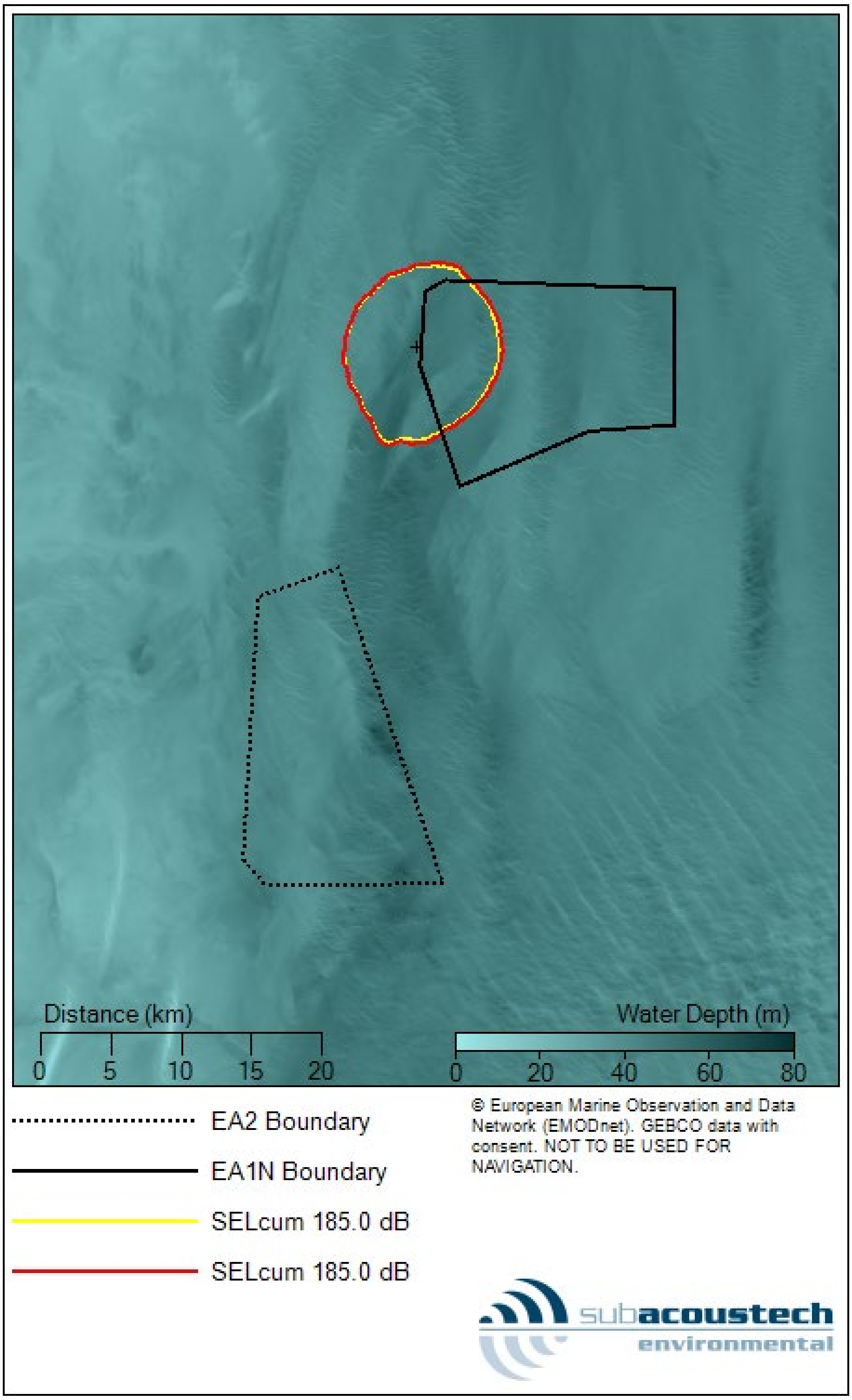

Figure 4 Contour plot showing the PTS ranges for Pinnipeds (in water) (PW) at EA2. The yellow contour represents the noise from a single multi-leg foundation pile installation, and the red contour represents the noise from four multi-leg foundation piles, installed sequentially.

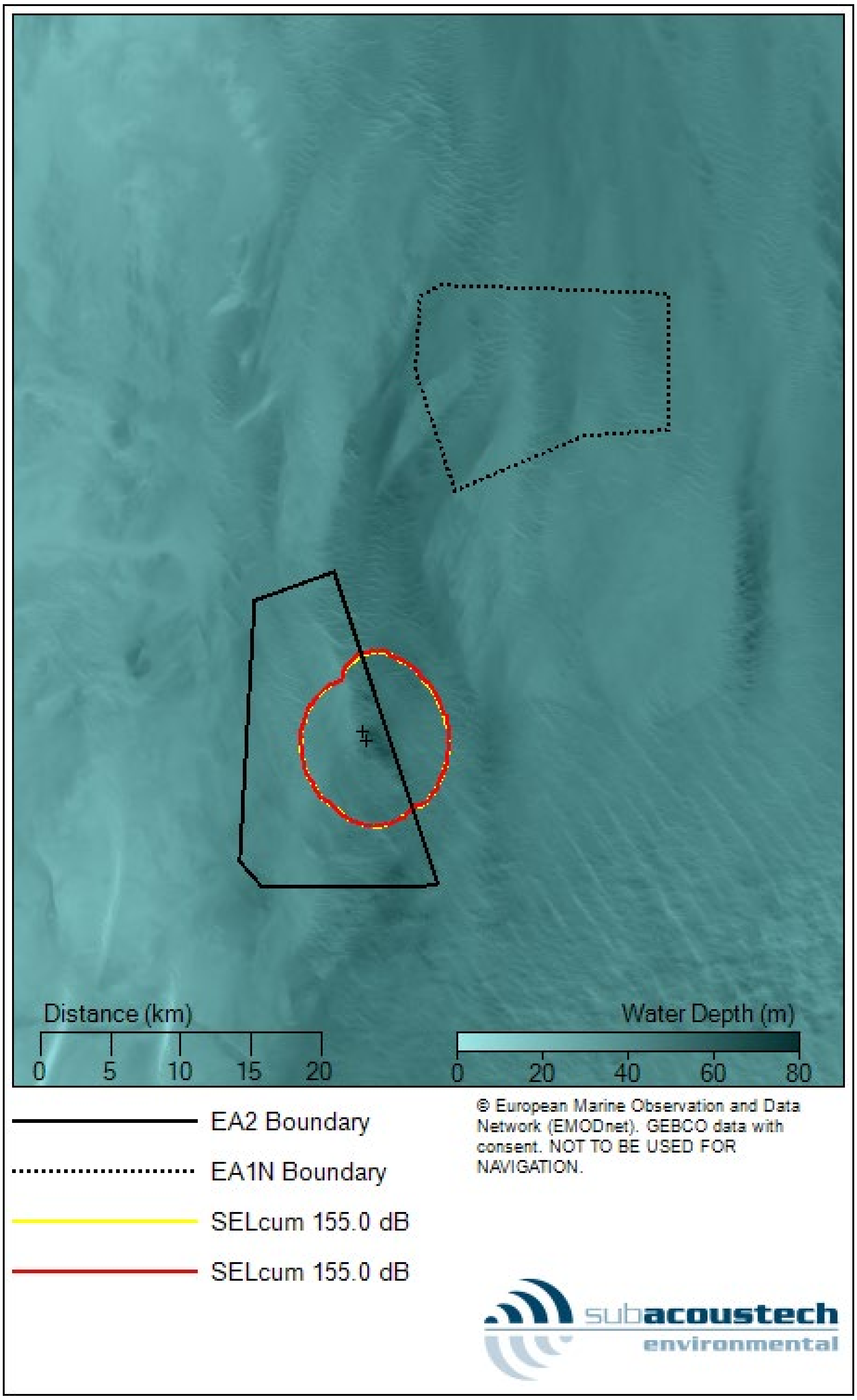

Figure 5 Contour plot showing the PTS ranges for High Frequency Cetaceans (HF) at EA2. The yellow contour represents the noise from a single pile installation, and the red contour represents the noise from two monopile foundations, installed sequentially from two different locations.

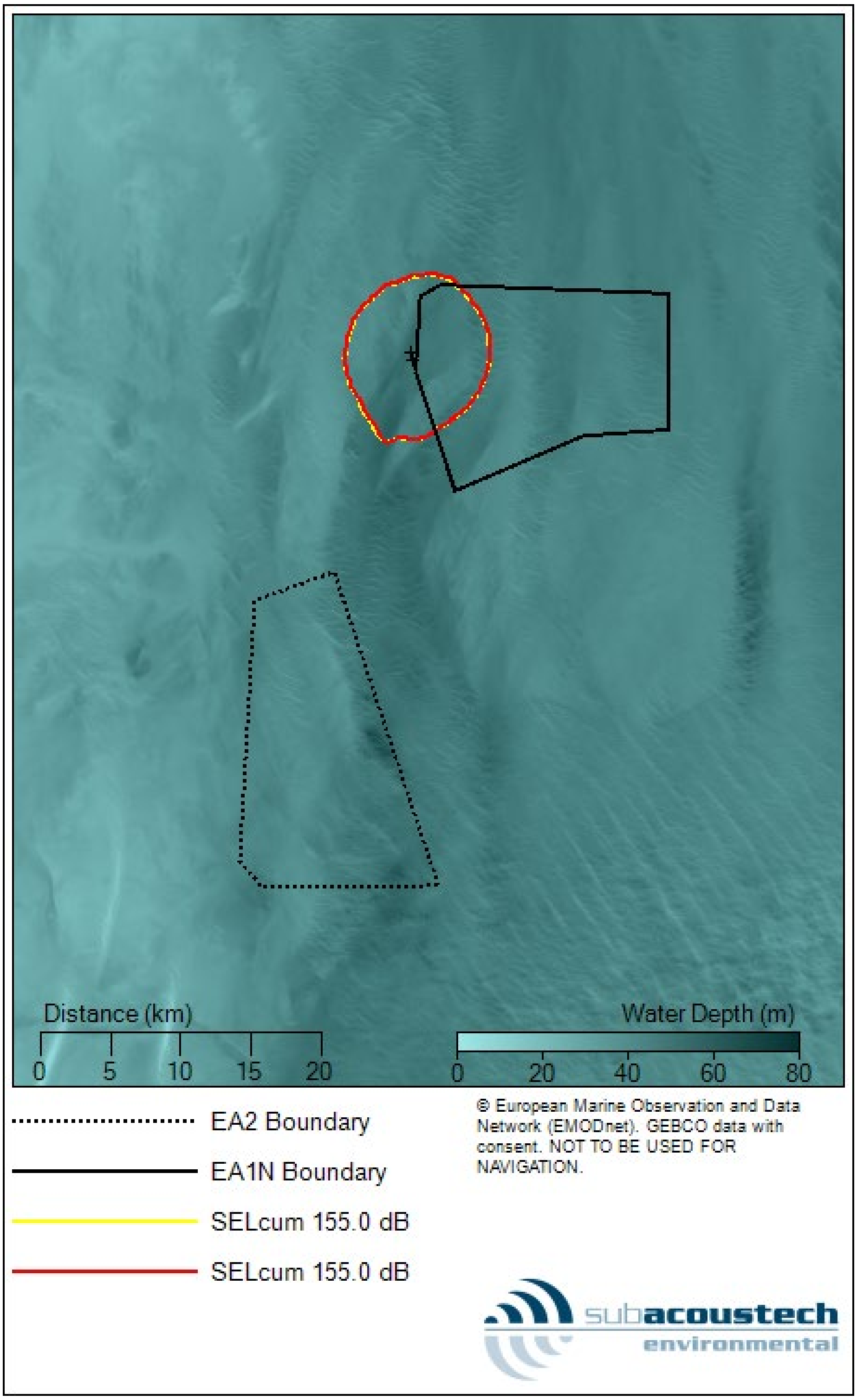

Figure 6 Contour plot showing the PTS ranges for High Frequency Cetaceans (HF) at EA1N. The yellow contour represents the noise from a single pile installation, and the red contour represents the noise from two monopile foundations, installed sequentially from two different locations.

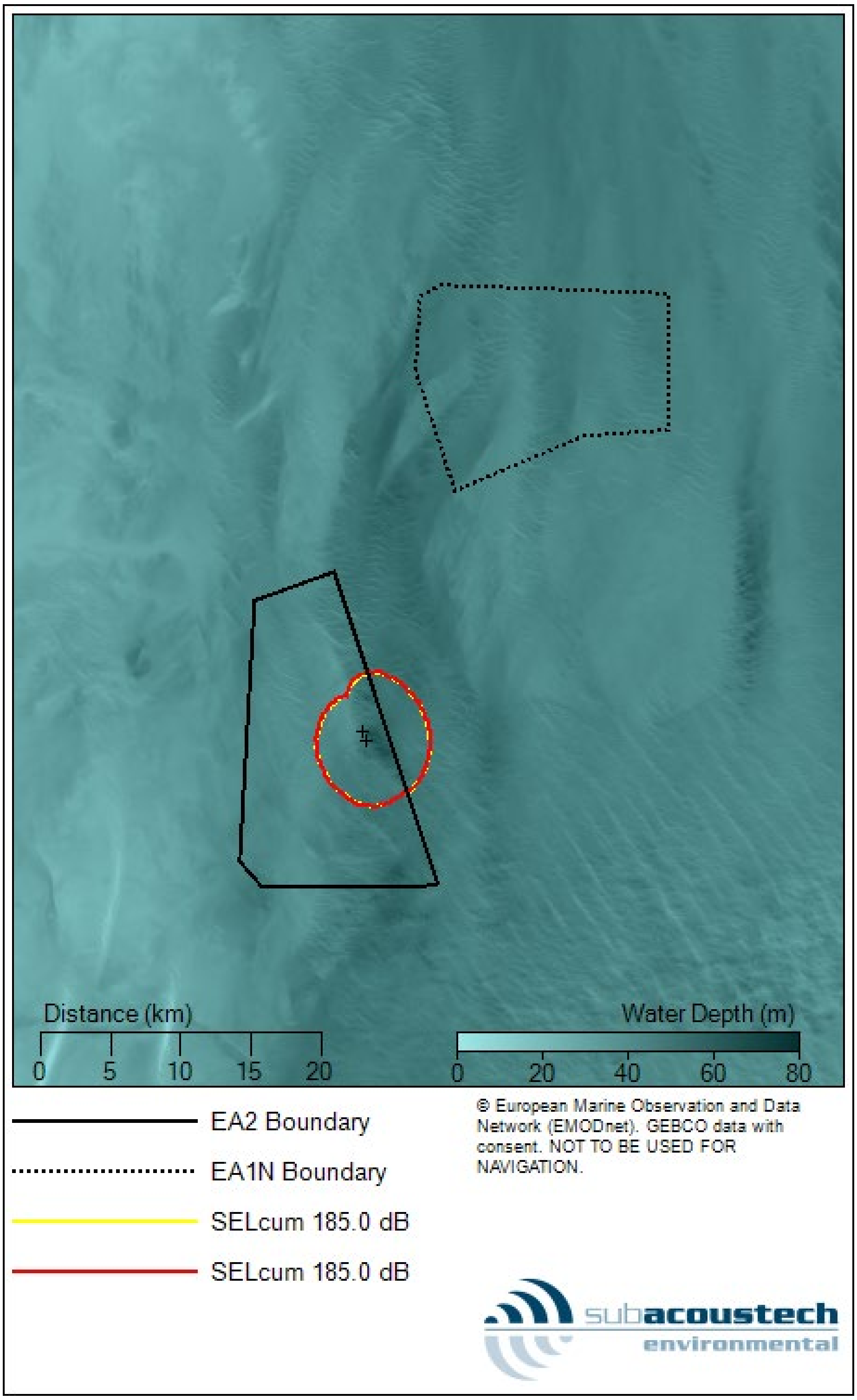

Figure 7 Contour plot showing the PTS ranges for Pinnipeds (in water) at EA2. The yellow contour represents the noise from a single pile installation, and the red contour represents the noise from two monopile foundations, installed sequentially from two different locations.

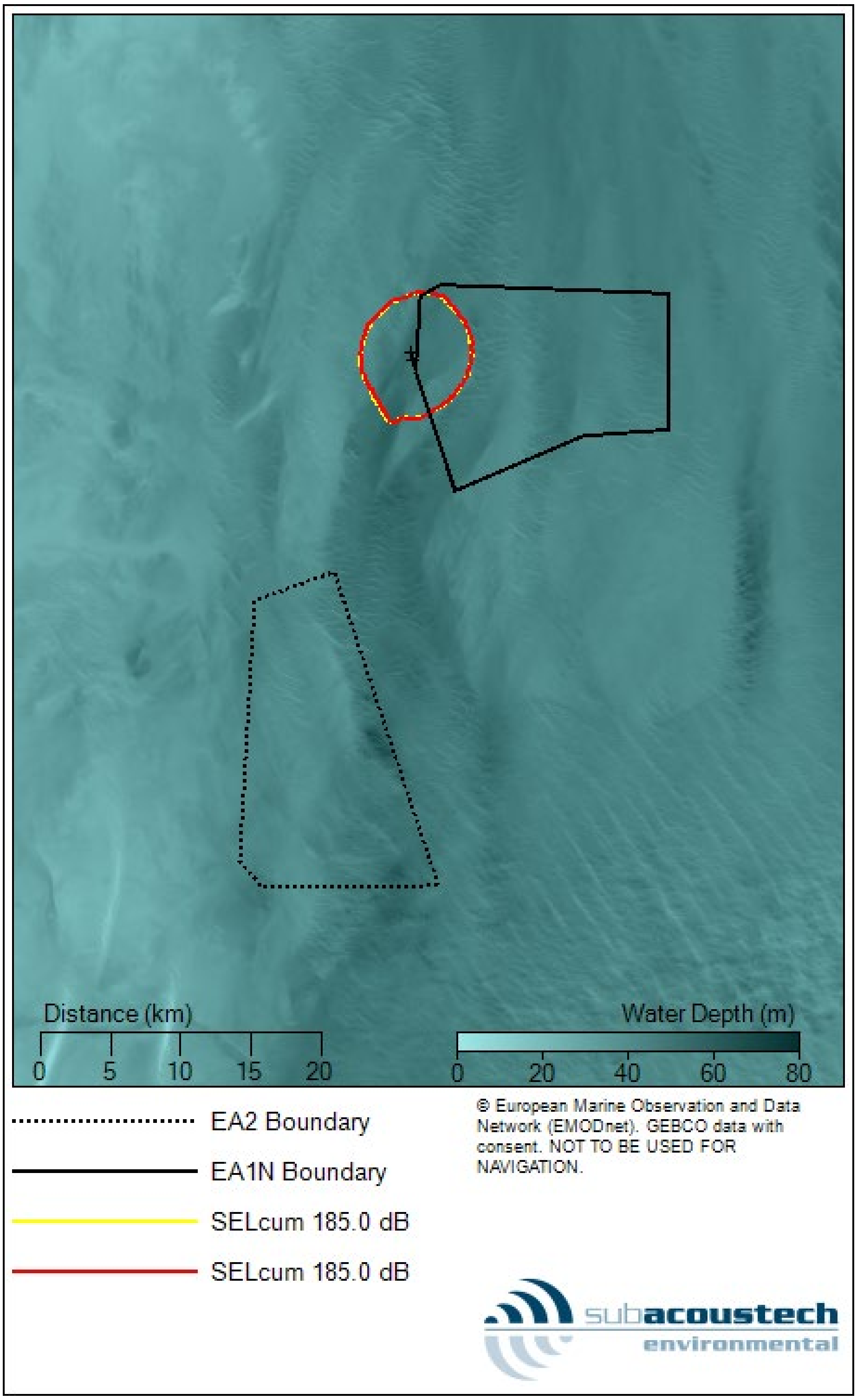

Figure 8 Contour plot showing the PTS ranges for Pinnipeds (in water) at EA1N. The yellow contour represents the noise from a single pile installation, and the red contour represents the noise from two monopile foundations, installed sequentially from two different locations.