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Note

OX2 AB

Offshore Wind Farms, Sweden

Screening of Underwater Noise from Geotechnical Investigations

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1 Introduction

In connection with OX2's intentions to establish offshore wind farms in Swedish waters, it may be necessary to perform a number of geotechnical and geological investigations to gather required information about the seabed, for the installation of foundations and cables.

The purpose of this note is to conduct a screening of the underwater noise emissions from drilling, vibrocore and seismic CPT equipment used for geotechnical surveys, and to relate this to impact on relevant marine mammals species.

There are three species of seals (harbour seals, grey seals and ringed seals) and one species of cetacean, the harbour porpoise, that regularly occur in Swedish waters (HELCOM, 2021). Harbour porpoises are commonly considered more sensitive to underwater noise than the seal species. Thus, the calculated/estimated underwater noise emission from the suggested equipment is screened in relation to harbour porpoise hearing abilities and assumes that negligible/low impact noise levels for harbour porpoises also have negligible/low impact on seals.

Several studies have tested the hearing ability of harbour porpoises, and all studies show that harbour porpoises and can hear sounds over a wide frequency spectrum (Andersen, 1970; Kastelein, et al., 2002; Kastelein, et al., 2010). Mammals in general do not hear equally well at all frequencies, which is also the case for harbour porpoises. As shown in Figure 1.1, harbour porpoises hear well in the frequency range 10-140 kHz, but are most sensitive in the frequency range from 90-140 kHz, with a hearing threshold of approx. 40-60 dB re 1 µPa (Kastelein, et al., 2002). Though harbour porpoises also hear sounds at frequencies below 10 kHz, their hearing sensitivity decreases toward to the lower frequencies, and above 140 kHz there is a sharp drop in sensitivity (Figure 1.1).

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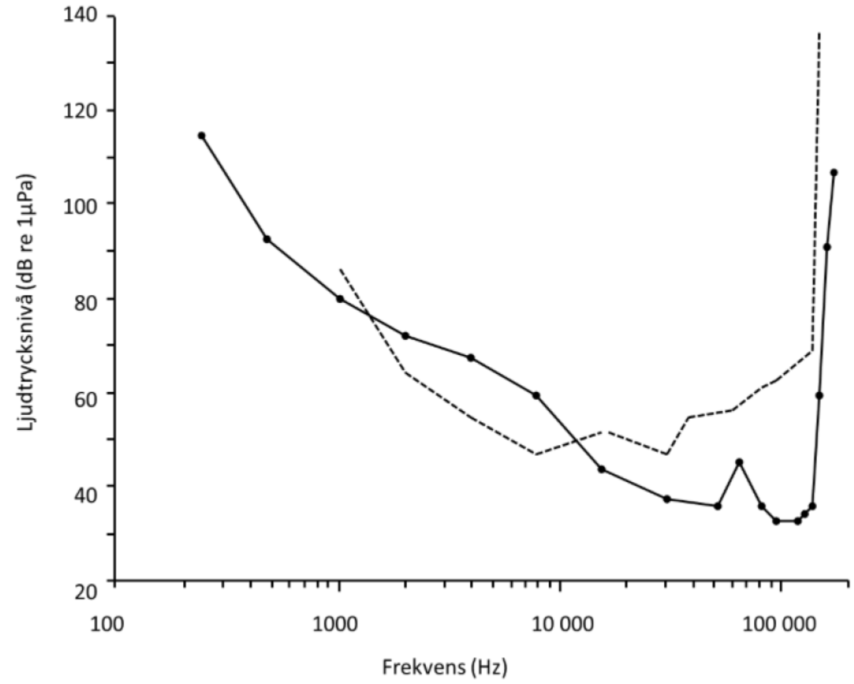


Figure 1.1: Audiogram for harbour porpoises modified after Kastelein et al. (2010) (solid line) and Andersen (1970) (dotted line). The frequency range with best sensitive is between 10-140 kHz (Tougaard & Michaelsen, 2018).

2 Description of activities

The seismic surveys have yet to be planned in detail, however it is assumed by OX2, that they will comprise either fully or partially of the following equipment types:

- Drilling
- Vibrocore
- Seismic CPT

In addition to these sources, the survey vessel contributes to the overall noise emission. Specific equipment types have not yet been selected. The following evaluation of the equipment types is therefore based on best available literature.

3 Underwater noise source levels

In the following, available literature on underwater noise emission for the described underwater noise sources is examined. After each activity is described in detail, a summary of source levels, frequency content, and assessed impact is provided in table form.

3.1 Drilling

There are very few measurements of underwater noise from drilling activities (Erbe & McPherson, 2017), but studies where underwater noise from geotechnical drilling activities have been measured, show that the noise is limited to the low-frequency range. Reported source levels are between $SPL_{RMS} = 142 - 145\ dB\ re. 1\ \mu Pa\ @\ 1m$, with primary frequency content located between 30 Hz – 2 kHz (Erbe & McPherson, 2017), see frequency spectrum as measured in Figure 1.1.

Figure 1.1: Frequency spectrum from underwater noise measurements of drilling (Erbe & McPherson, 2017).

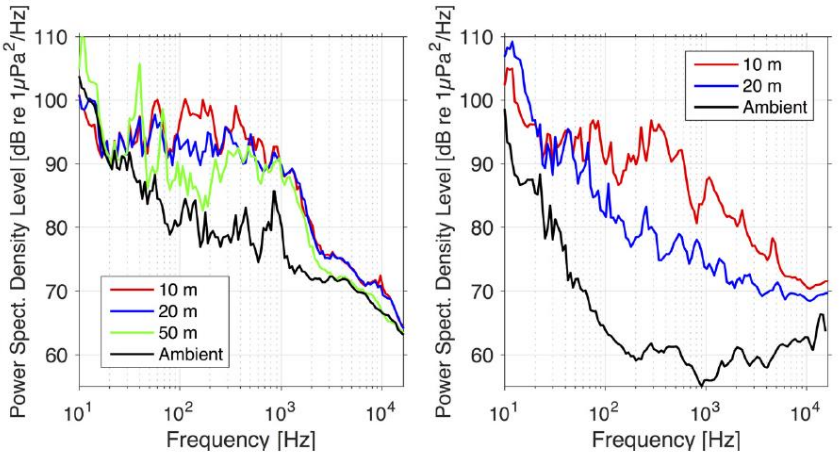


Fig. 2. (Color online) Power spectral density levels of drilling received at various ranges from the drill string at Geraldton (left) and James Price Point (right), compared to ambient noise at both sites—averaged over 10 min.

To understand the potential underwater noise emission in metrics relevant for the marine mammals of interest, the frequency spectrum shown in Figure 1.1, was frequency weighted (filtered) with the VHF-weighting curve proposed by the NMFS (2018) and Southall et al. (2019). The weighted noise levels should more accurately represent what harbour porpoises hear. Given an unweighted source level of $SPL_{RMS} = 145\ dB\ re.1\ \mu Pa\ @\ 1m$, the corresponding VHF-weighted source level was calculated to be $SPL_{RMS(VHF)} \sim 110 - 115\ dB\ re.1\ \mu Pa\ @\ 1m$. As the drilling noise source is considered to be a non-impulsive noise source or a continuous noise source, the SPL_{RMS} metric is equal to the commonly used $SEL_{SS(VHF)}$ for impulsive noise sources.

An underwater noise level of 131 dB re 1 μPa²s $SEL_{SS(VHF)}$ at 750 meters, was recently accepted by the Swedish authorities in relation to impulsive pile driving at an offshore wind farm. However, the 131 dB re 1 μPa²s $SEL_{SS(VHF)}$ cannot be directly related to the non-impulsive underwater noise from drilling as measurements have shown that mammals, including marine mammals, are affected differently by non-impulsive and impulsive sounds (Martin, et al., 2020). Regulations designed to mitigate the effects of sound on marine mammals have developed a set of sound exposure level (energy, SEL) thresholds for non-impulsive and impulsive sounds, where the impulsive TTS threshold (temporary threshold shift) for harbour porpoises is 13 dB below the non-impulsive threshold (Southall, et al., 2019). Using the 131 dB re 1 μPa²s $SEL_{SS(VHF)}$ at a distance at 750 meters is therefore a highly conservative limit for non-impulsive underwater noise.

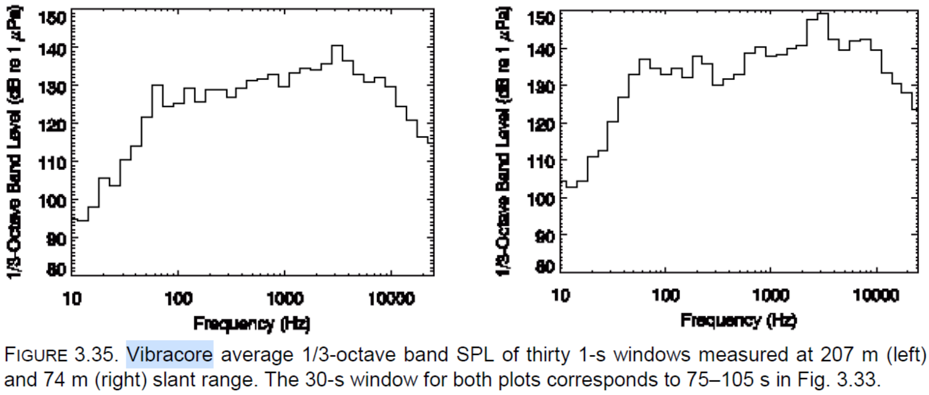
Based on calculations the underwater noise levels are well below the 131 dB re 1 μPa²s $SEL_{SS(VHF)}$ at 1 meter distance. Therefore, it is concluded that the underwater noise from drilling will cause a very limited/negligible impact on marine mammals.

3.2 Vibrocore

Vibrocore equipment may be used to gather core samples. A vibrocorer functions by means of a vibratory hammer driving a hollow steel cylinder into the seabed soil until a target depth is reached, after which the cylinder and vibratory hammer is pulled back up from the seabed and the core can be extracted from within the cylinder.

Measurements of underwater sound emissions from vibrocore equipment was investigated in (Reiser, et al., 2011), where a source level $SPL_{RMS} = 187.4\ dB\ re.1\ \mu Pa\ @\ 1m$ was back-calculated, and with frequency spectrum as shown in Figure 3.2.

Figure 3.2: Frequency spectrum in 1/3 octave bands from measurement of underwater noise from vibrocore operation, (Reiser, et al., 2011).



Using the same approach as for the drilling noise, a VHF-weighting was applied to the frequency spectrum of the vibrocore, resulting in a source level $SPL_{RMS(VHF)} = 174\ dB\ re.1\ \mu Pa\ @1m$. Using a conservative sound transmission loss, $TL = 15 \times log_{10}(r)$, where "$r$" is the distance from the source in meters, the distance to $SPL_{RMS(VHF)} = 131\ dB\ re.1\ \mu Pa$ (equal to the commonly used $SEL_{SS(VHF)}$ for impulsive noise sources) is approx. 750 m. According to GEO (one of the companies providing such services), the duration of a vibrocore sampling, has a duration of no more than 5 minutes, with equipment operating at 20-30 Hz.

The impact distance within which a harbour porpoise has a risk of being affected with a temporary threshold shift (TTS), is according to (NMFS, 2018), $SEL_{C(VHF)} = 173\ dB\ re.1\ \mu Pa^2 s$ for continuous noise sources such as a vibrocore. Using a simple conservative estimate of sound propagation, for a 30 Hz operation over 5 minutes without a soft start, the resulting TTS impact radius is 350 m, assuming the harbour porpoise swim away from the noise throughout the sampling.

The underwater noise level is therefore expected to be 131 dB re 1 μPa²s $SEL_{SS(VHF)}$ at a distance at 750 meters. However, as previously mentioned, using the 131 dB re 1 μPa²s $SEL_{SS(VHF)}$ at a distance at 750 meters as an underwater noise level for a non-impulsive sound source, is considered very conservative. It is therefore assessed that the underwater noise from vibrocore activities will only cause a limited and not significant impact on marine mammals.

3.3 Seismic Cone Penetration Test (SCPT)

Seismic CPT activities have also been suggested. Here a seismic wave is generated, typically by a seabed-mounted installation, which creates a motion and transfers it into the seabed. At a nearby location, a CPT cone is pushed into the seabed, and through sensors mounted in/on the cone, the vibration through the sediment is registered, and provides data on the sediment. There are different designs, one of which consist of a frame-mounted, cylinder-encapsuled, spring loaded weight that, on release, is accelerated against an end-cap. This creates an impact pulse. The pulse is then structurally transferred through the frame into the seabed. The noise source in this action consists of the noise from the impact itself, as well as from the vibration of the frame.

It has not been possible to acquire underwater noise measurements for this type of equipment, and according to GEO (one of the companies providing such services), no noise measurements have yet been carried out. It is therefore not possible to compare noise levels to any thresholds. A brief assessment, of the noise emission potential of the moving parts, is however provided.

Noise emission from the previously described design, is considered to have two potential noise sources. The impact of the weight against the end-cap, and the vibration of the frame.

The impact of the weight against the end-cap, occurs inside a closed metallic cylinder, and it is therefore assessed to be effectively attenuated, and insignificant relative to the previously mentioned $SEL_{SS(VHF)} = 131\ dB\ re. 1\ \mu Pa^2 s$ at any distance.

While the vibration of the frame occurs in direct contact with the water, it is not expected to result in a significant noise emission, rather a low amplitude "ringing" effect. It is not expected to cause noise levels above $SEL_{SS(VHF)} = 131\ dB\ re. 1\ \mu Pa^2 s$ at any distance beyond the immediate vicinity of the source. It must however be emphasized, that the above assessment relies only on the supplier's description of the equipment operation, and a qualified guess on the impact. If the supplier is able to provide underwater noise measurements, either before or during deployment of the equipment, a more accurate assessment of the noise emission should be carried out.

The Seismic CPT, is assessed to cause underwater noise levels at low levels in relation to the marine mammals hearing abilities. It is therefore assessed that the underwater noise from Seismic CPT will cause a very limited/negligible impact on marine mammals.

3.4 Vessel noise (Dynamic positioning)

While the geotechnical survey is undertaken, the survey vessel is expected to hold its position using "Dynamic Positioning", (DP mode), where vessel thrusters and propellers counteract the forces applied on the vessel by the environment. This action results in underwater noise emission, as documented by (Reiser, et al., 2011). Here, a source noise level of $SPL_{RMS} = 175.9\ dB\ re. 1\ \mu Pa\ @1m$ was back-calculated based on measurements at 207 m and 74 m, and with frequency content as shown in Figure 3.3.

Figure 3.3: Frequency spectrum from measurement of underwater noise from survey vessel in DP mode, (Reiser, et al., 2011).

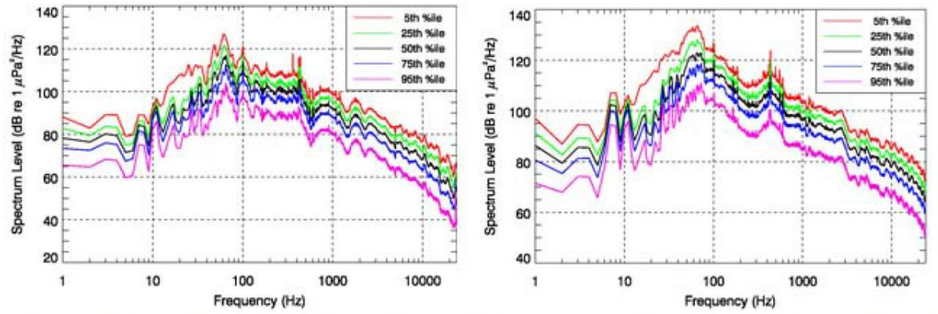


FIGURE 3.29. Percentile spectra of *Ocean Pioneer* in DP measured at 207 m (left) and 74 m (right) slant range, based on 1-s (48,000-pt) FFTs, 48-kHz sample rate, Hamming window, 50% overlap.

Using the same approach as for the vibrocorer, applying a VHF-weighting to the frequency spectrum, gives a source level of $SPL_{RMS(VHF)} = 146\ dB\ re.1\ \mu Pa\ @1m$. The distance to the $SPL_{RMS} = 131\ dB\ re.1\ \mu Pa$ then becomes ~10 m.

Based on the calculation the underwater noise levels are well below the 131 dB re 1 μPa²s $SEL_{SS(VHF)}$ at 750 meter. The (DP mode) from the survey vessel, is therefore assessed to cause underwater noise levels at low levels in relation to the marine mammals hearing abilities. It is therefore concluded that the underwater noise from the survey vessel (DP mode) will cause a very limited/negligible impact on marine mammals.

3.5 Summary of source characteristics and impact

In Table 3.1, the source characteristics of the different source types are summarized along with the assessed impact on marine mammals.

Source Type	Source Level @1m $[re\ 1\ \mu Pa]$		Frequency Range* [Hz]	Distance in [m] to $SEL_{SS(VHF)} = 131\ dB\ re\ 1\ \mu Pa$.	Assessed impact on marine mammals
	SPL_{RMS}	$SPL_{RMS(VHF)}$			
Drilling	142-145 dB	110-115 dB¤	30 Hz – 2 kHz	< 1 m	very limited/ negligible
Vibrocore	187.4 dB	174 dB¤	30 Hz – 30 kHz	750 m	limited and not significant
Seismic CPT	-	-	-	-	very limited/ negligible
Vessel (DP)	175.9 dB	146 dB¤	10 Hz – 3 kHz	10 m	very limited/ negligible

¤: Estimated source level based on literature frequency spectra
*: Range where amplitude is higher than -30 dB relative to maximum amplitude.
-: No source measurements are available, and assessment is therefore based on an evaluation of equipment operation

Table 3.1:Summary of source characteristics and assessed impact.

4 References

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