Does underwater noise from offshore wind farms potentially affect seals and harbour porpoises?

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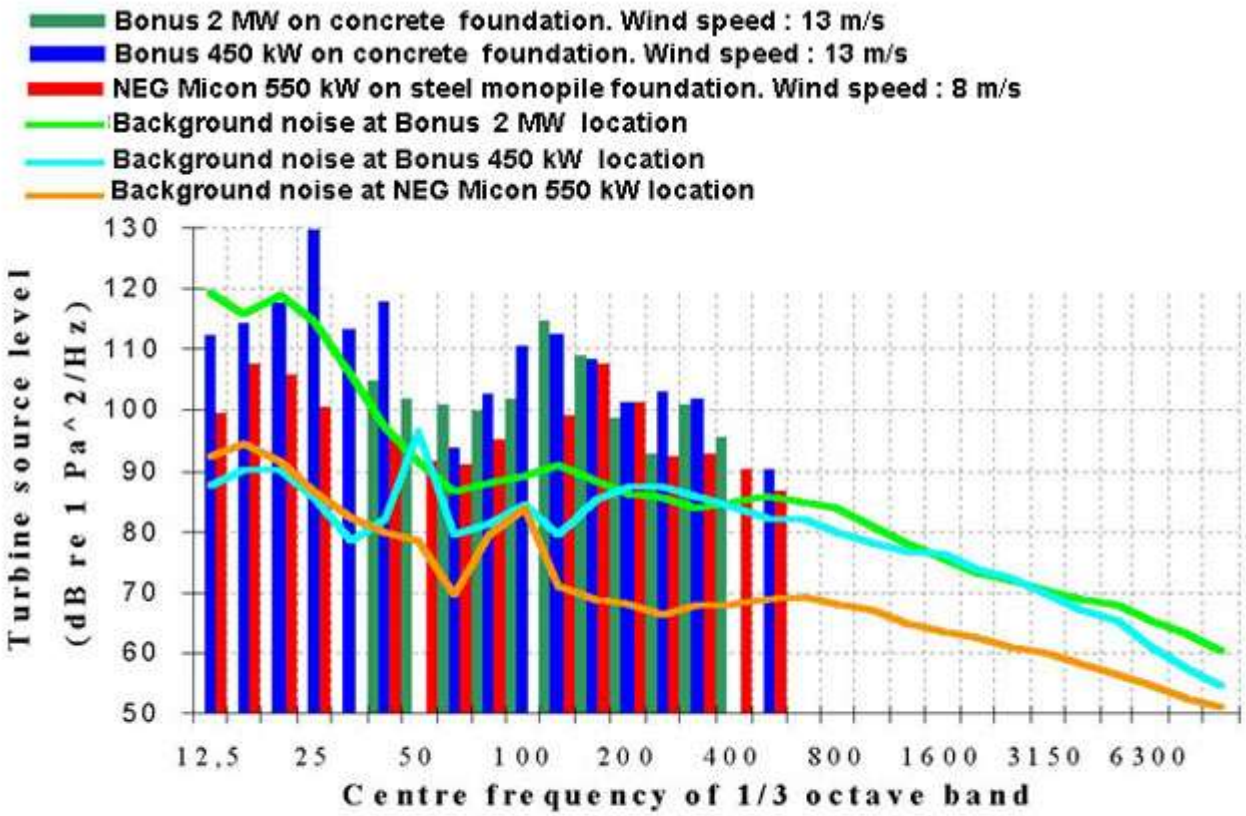
Abstract
An investigation has been made into the ability of harbour seals (Phoca vitulina), grey seals (Halichoerus grypus), and harbour porpoises (Phocoena phocoena) to hear underwater noise emitted through the foundations of offshore wind turbines.
Noise from 3 types of offshore wind turbine has been measured, and source levels calculated. The source levels have been compared with the audiograms of seals and harbour porpoises and the maximum detection distance have been calculated to 1000 m for seals and 50 m for harbour porpoises.
Despite the low frequency it is concluded that due to the high level all three species will be able to hear the noise.
The effects on the three species from the noise is under investigation.

Background
In order to fulfill the requirement of the Kyoto agreement stating that the CO2 emissions must be cut to half of 1998 levels by 2030 the Danish government has passed legislation for the establishment of large offshore wind farms in Danish waters comprising more than 2000 wind turbines, of which the first 100 are under construction. Many of the areas designated for the wind farms are in shallow waters near seal sanctuaries and in densely populated harbour porpoise areas.
The construction of the large offshore wind farms will benefit the global environment but the effects on the local environment are not necessarily positive. An EIA study has been made (Dietz et al 2000 & Bach et al 2000) and base line studies established for further investigation.

Underwater noise from off-shore wind turbines
Underwater noise emitted from three different types of off shore wind turbines during normal operation has been recorded and converted into source levels. Underwater noise from these offshore wind turbines has been measured in the frequency range between 12 Hz and 500 Hz. The maximum source level is 130 dB re 1µPa2/Hz at 25 Hz (1/3-octave band centre frequency) and 115 dB re 1 µPa2/Hz at 125 Hz (1/3-octave band centre frequency).



Underwater noise recorded from three offshore wind turbines. The noise levels is presented as sound spectrum density levels, which is a standardised method for describing broad band noise measurements.

Comparing broad band noise with audiograms

As audiograms and broadband noise are recorded and analysed using different methods, the comparison of the two is not a straightforward task. A major problem is that the mammalian ear and electronic equipment for sound recording does not behave in the same way.

In this work the "Equal power method" (Fletcher, 1940) is used for the comparison between broad band noise and the audiograms of the three species. Fletcher uses the knowledge about masking bands to describe how pure tones will be masked by broad band noise.

A masking band is the frequency area near a pure tone where it is very easy to mask the tone with another tone or noise. Outside the masking band, further away on the frequency scale is it very hard to mask the tone using another tone or noise. The width of the masking bands varies with frequency in most marine mammals, but it is assumed that the masking bands in all three species in this low frequency area are 1/3-octave wide. The width of a masking band can be measured by different techniques (See Au 1993 or Richardson et al 1997 for a review).

To convert the sound spectrum density levels (dB re 1 µPa2/Hz) into levels that are directly comparable with the hearing thresholds, the intensity measured must be converted from 1 Hz bands to bands having the same width as the masking bands. It can simply be done using the formula:

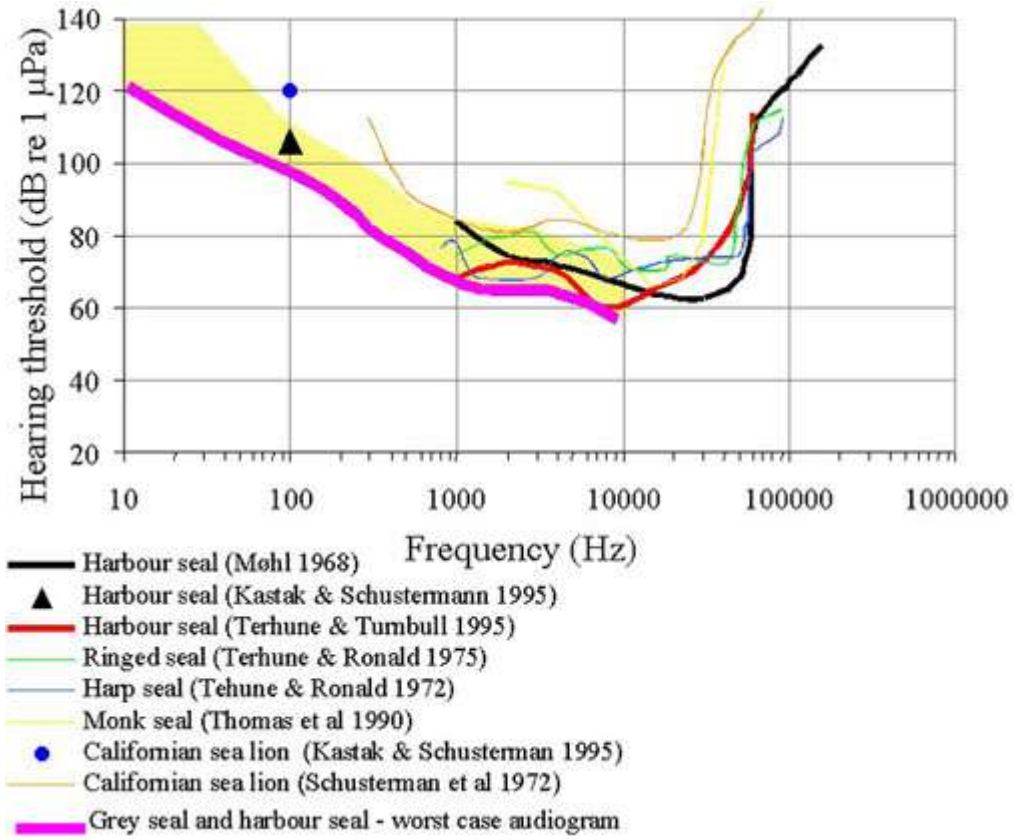
$$SPL(BW) = SPL(1\ Hz) + 10*\log BW$$

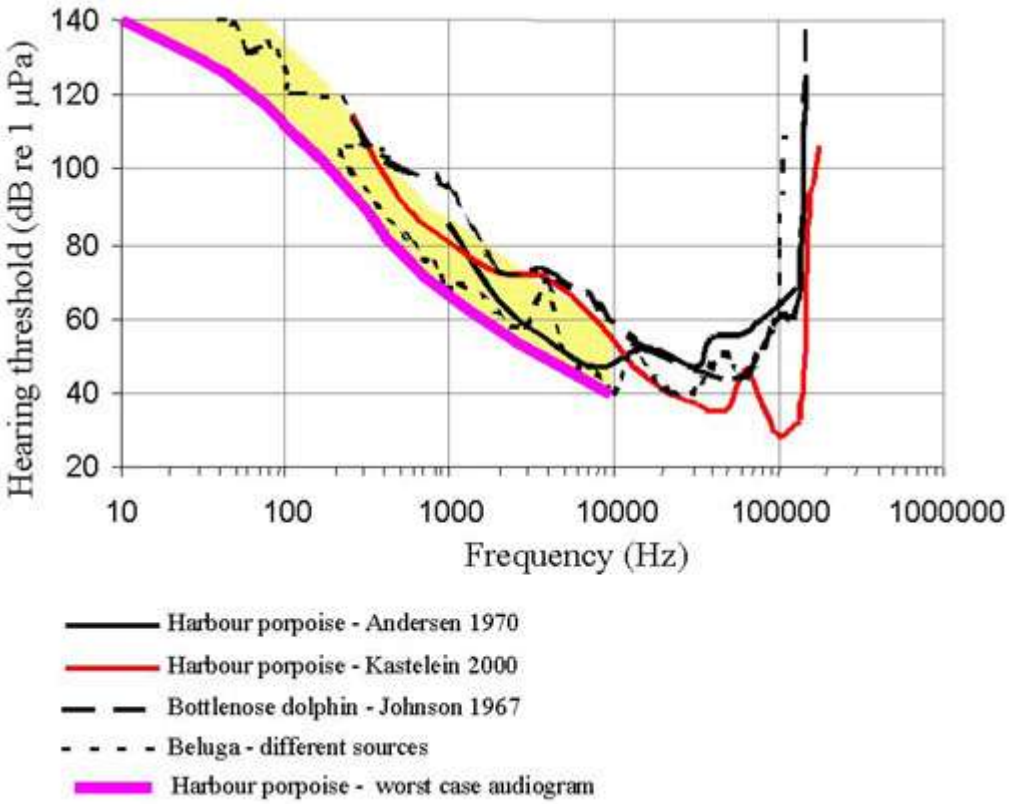
where SPL(BW) is the intensity in each masking band, SPL(1 Hz) is the sound spectrum density level and BW is the band width of each masking band.

Marine mammal low frequency hearing

The audiograms of harbour porpoises, harbour seals and grey seals have only been measured for frequencies above 250 Hz. In order to investigate whether the three species can hear the noise it is

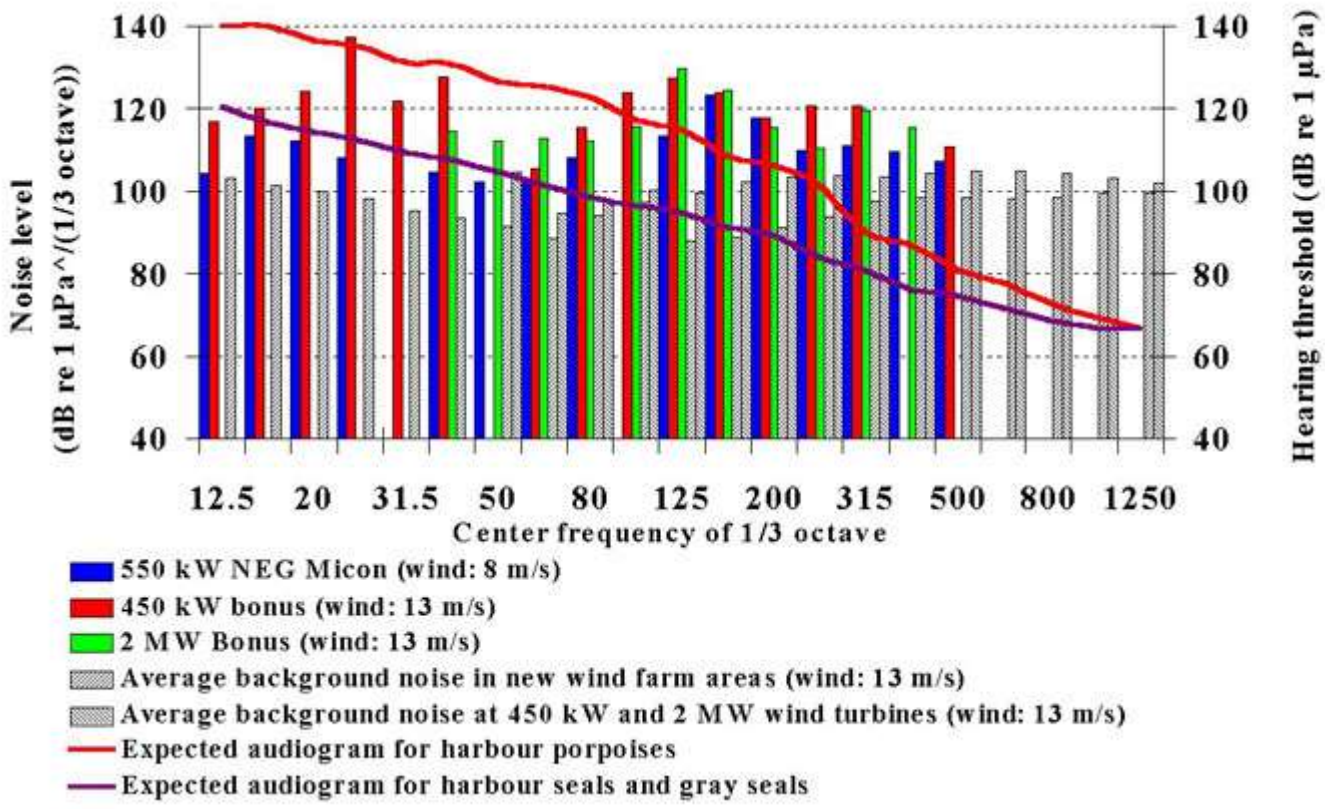
necessary to extrapolate the known audiograms assuming the slopes of the audiograms below 250 Hz to be similar to those of closely related species. Audiograms for the grey seal are yet to be made and are here assumed to be similar to that of the harbour seal.





The hatchings in the graphs are the areas where the hearing curves for porpoises and seals are expected to be found. To create a worst case scenario, the lower limit of the hatching represents the hearing curves chosen for estimating the detection range of the turbine noise.

Conclusion:
The strongest noise from the wind turbines is 17 dB above the hearing threshold of the harbour porpoise. The turbines will thus be audible to the porpoises within a distance of 50 meters assuming cylindrical spreading where the noise is attenuated by 3 dB when the distance to the source is doubled. As the porpoises can only hear the turbines in a very small fraction of the wind farm areas it is assumed that they will not be affected by the noise.
To the seals the detection range of the wind turbines is 1000 m corresponding to a noise level 30 dB above their hearing threshold. The area where the seals can hear the wind turbines is thus significantly larger than the porpoises. The effects on seals are unknown but currently under investigation.



The coloured bars indicate source levels of the noise converted to be directly comparable to the audiograms. The lines are the expected audiograms for harbour porpoises, harbour seals and grey seals. The turbine noise level at 315 Hz (450 kW Bonus) is 17 dB above the porpoise audiogram and the noise level at 125 Hz (2 MW Bonus) is 30 dB above the seal audiogram.

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