Potential effects of offshore wind farm noise on fish

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Introduction

Assessing the potential effects of wind farm noise on fish is a key issue in environmental impact assessments because many of the proposed offshore wind farm sites in European waters are situated close to spawning grounds of commercially important fish species. Here, we assess the effects of offshore wind farm noise on relevant fish species.

Methods

Measurements of pile-driving noise were obtained as peak sound pressure levels and sound exposure levels in 1/3 octave bands from a jacket-pile construction in the German Bight, North Sea. Operational noise was measured in peak sound pressure levels and equivalent sound pressure levels in third-octave bands in 110-m distance from a 1.5-MW turbine in Sweden. Based on these measurements, sound levels at various distances from the source were calculated after Thiele (2002) (Figure 1), and zones of noise influences were assessed based on published data. We chose four target species that are of relevance in European offshore waters in this assessment and that had been investigated in previous hearing studies: cod, herring, salmon, and dab (References see Figure 2 and 3).

"Jumping Jack" pile driver

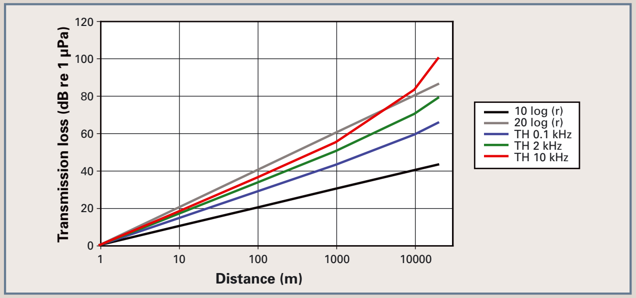

Figure 1: Transmission loss at distances 10 – 10,000 m calculated with different models (TH = Thiele 2002; 10 log (r) = cylindrical spreading, 20 log (r) = spherical spreading)

Results

The broadband peak sound pressure level during pile driving was 189 $dB_{0\text{-}p}$ re 1 µPa, at 400 m distance, resulting in a peak broadband source level of 228 $dB_{0\text{-}p}$ re 1 µPa at 1 m. The third-octave sound pressure level was highest at 315 Hz. Values for the impact assessments were extrapolated for larger pile diameters. During operation, the third-octave sound pressure levels ranged between <90 and 142 dB_{Leq} re 1 µPa at 1 m, with most energy at 50, 160, and 200 Hz at wind speeds of 12 m/s.

As indicated in Figure 2, cod and herring will be able to perceive construction noise at large distances, perhaps up to 80 km from the source. Dab and salmon might detect pile driving at considerable distances. Thresholds vary so the zone of responsiveness cannot be calculated. The zone of masking might, in some cases, match the zone of audibility. Injuries (temporary threshold shift, permanent threshold shift and other injuries) and mortality are possible in the close vicinity of pile driving. Operational noise of wind turbines will be detectable up to a distance of approximately 4 km for cod and herring and probably up to 1 km for dab and salmon (Figure 3). Within this zone, masking is possible. Behavioural and/or physiological effects should be restricted to very short ranges during operation.

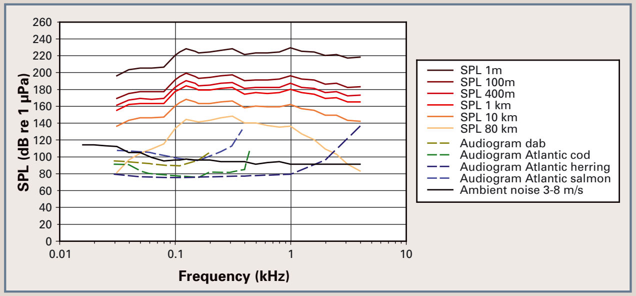

Figure 2: Attenuation of pile-driving noise at different distances from the source, ambient noise levels and audiograms of target fish species (Pile-driving noise after ITAP (2005) and Betke, pers. comm; values as $dB_{0\text{-}p}$ re 1 µPa in 1/3 octave-bands; TL-calculations after Thiele (2002); ambient noise levels in 1/3 octave-bands in dB re 1 µPa after DEWI (2004); audiograms after Enger 1967; Chapman and Hawkins 1973; Chapman and Sand 1974; Hawkins and Johnstone 1978).

Aerial view of offshore wind farm © Mike Page

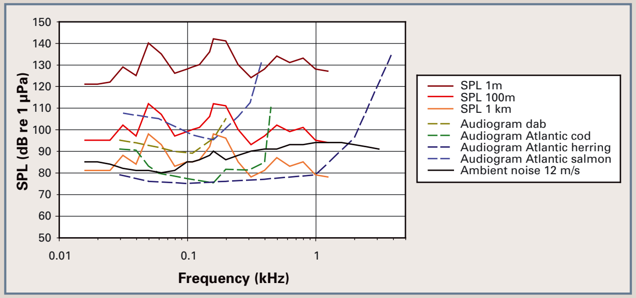

Figure 3: Attenuation of operational noise at different distances from the source, ambient noise levels and audiograms of target fish species (operational noise after ITAP (2005); values as dB_{rms} re 1 µPa in 1/3 octave-bands; TL-calculations after Thiele (2002); background noise levels in 1/3 octave-bands in dB_{rms} re 1 µPa after Betke et al. (2004); audiograms after Enger 1967; Chapman and Hawkins 1973; Chapman and Sand 1974; Hawkins and Johnstone 1978).

Discussion

Our attempt at assessing zones of influence for offshore wind farm noise should be viewed as a best possible estimation based on the data available, with all the uncertainties inherent in such an approach. More precise information on turbine emissions (sound pressure and particle acceleration), in situ measurements of attenuation, and of the hearing capabilities of different species are needed to provide a more detailed assessment in the future. We like to particularly point out that threshold values, for example, for behavioural reactions, cannot be solely defined on a theoretical basis. Although uncertainty exists, vulnerable times such as spawning should be protected (reviews by Hastings & Popper 2005; ICES 2005; Popper *et al.* 2004; Wahlberg & Westerberg 2005; Thomsen *et al.* 2006).

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