

Agenda Item 14.5.2

Implementation of the ASCOBANS Triennial
Work Plan (2007-2009)

Review of New Information on Pollution,
Underwater Sound and Disturbance

Acoustic Disturbance

Document 42

**Auditory Studies on Harbour
Porpoises in Relation to Offshore Wind
Turbines**

Action Requested

- take note of the information submitted
- comment

Submitted by

AC Chair



NOTE:
**IN THE INTERESTS OF ECONOMY, DELEGATES ARE KINDLY REMINDED TO BRING THEIR OWN
COPIES OF DOCUMENTS TO THE MEETING**

Auditory studies on harbour porpoises in relation to offshore wind turbines

Lucke, K.¹, Lepper, P.A.², Blanchet, M.-A.³, Hoeve, B.⁴, Everaarts, E.⁴, van Elk, N.⁴
and Siebert, U.¹

¹ Forschungs- und Technologiezentrum Westkueste, University of Kiel, Buesum, Germany (lucke@ftz-west.uni-kiel.de)

² Applied Signal Processing Group, Loughborough University, Loughborough, UK

³ Fjord&Bælt, Kerteminde, Denmark

⁴ Dolfinarium Harderwijk, CE Harderwijk, The Netherlands

The effects of offshore wind turbines on harbour porpoises (*Phocoena phocoena*) can be studied from different perspectives. Line transect surveys and static or towed acoustic monitoring are valuable tools to describe the status or trend in distribution and abundance of these animals within certain areas and telemetry studies provide insight in the behaviour and habitat use of individual animals. These methods are indispensable in many respects but they are descriptive by nature and can not explain or predict why extend the observed effects occur. In this sense they are complimentary to studies on the cause-effect relationship of the presence of or emissions from offshore wind turbines (OWT's) and their direct effect on individual animals. Electromagnetic and visual inputs from OWT's are likely to be negligible in this context, either because of their low strength of emissions or comparatively low sensitivity of harbour porpoises to such stimuli. In contrast the OWT-related acoustic emissions can repeatedly reach extreme intensities. There is a direct and highly relevant link between acoustic emissions and harbour porpoises as these animals have a very acute hearing and rely vitally on this sense. The understanding of noise-induced effects and data on the tolerance of the animals hearing system to such sounds is critical for the assessment of the overall effect of OWT's on harbour porpoises.

A principal key for assessing the impact of these noise emissions on the harbour porpoises are data on the auditory sensitivity and perception capabilities of this species. In harbour porpoises, like in several other cetacean species, the auditory sense evolved to be the primary sensory modality. This is not only represented by the sophisticated sound production mechanism, but also by the auditory capabilities of these animals. Harbour porpoises are proven to actively use underwater sound by means of echolocation (Busnel et al., 1965; Møhl and Andersen, 1973; Akamatsu et al., 1994) to locate their prey as well as for spatial orientation and navigation. Their functional hearing range stretches at least from 250 Hz to 160 kHz with their most sensitive hearing range (32 dB re 1 μ Pa is at 100 to 140 kHz) (Kastelein et al., 2002) overlapping with frequency content of their echolocation clicks (i.e., between 125 kHz and 148 kHz) (Møhl and Andersen, 1973; Hatakeyama and Soeda, 1990; Goodson et al., 1995). So far it has only been scientifically proven that porpoises actively use the high frequency portion of their acoustic signals ('clicks') for echolocation. As communicative signals, comparable to the whistles emitted by dolphins e.g., have not been clearly documented for harbour porpoises so far and their echolocation signals contain a considerable amount of sound intensity also at low frequencies (1.4 – 2.5 kHz at a source level of 100dB re 1 μ Pa at 1m), it has been repeatedly hypothesized that these animals use their clicks also for communication (Schevill et al. 1969, Verboom and Kastelein 1995). Those

low frequencies portions of the clicks are almost omni directional and provide a higher range. Both aspects make these signals suitable for communicative purposes.

Using auditory evoked potential (AEP) methods, a study was conducted on a harbour porpoise at the Dolfinarium Harderwijk in The Netherlands. The aim of the study was to assess the potential masking effect of operational sounds of offshore wind turbines on the perception of important signals by the harbour porpoises in general and those probably used for communication purposes in particular. Operational sound is continuously emitted from OWT's at varying source levels (depending on the wind conditions) with its main acoustic energy below 1 kHz. There are tonal components within these sounds which can reach intensities of at least up to 125 dB re $1\mu\text{Pa}^2/\text{Hz}$. The measurement of AEP's was chosen as method for achieving the hearing data from the animal. A male harbour porpoise was trained to participate in the study, which involved an active participation of the animal. AEP's were evoked with two types of acoustic stimuli, click type signals and amplitude-modulated signals. The masking noise resembling the underwater sound emissions of an operational wind turbine was simulated. At first the animal's hearing threshold was measured at frequencies between 0.7 and 16 kHz. Subsequently these measurements were repeated at frequencies between 0.7 and 2.8 kHz in the presence of two different levels of masking noise (115 and 128 dB re $1\mu\text{Pa}$). The resulting data show a masking effect of the simulated wind turbine sound at a level of 128 dB re $1\mu\text{Pa}$ at 0.7, 1 and 2 kHz. This masking effect varied between 4.8 and 7.3 dB at those frequencies. No significant masking was measured at a masking level of 115 dB re $1\mu\text{Pa}$.

If the received level of the operational sounds on average drop below 120 dB within a range of 100 m from a wind turbine (Madsen et al. 2006) the higher level of the masking sound used in this study would have been received only at a short distance from an average type of offshore wind turbine (several tens of m). The difference between the effective masking intensity at the high masking level and the non-effective moderate masking level was approximately 13 dB. Thus the effective range of the observed masking would be comparatively small as the operational sound of an offshore wind turbine would be attenuated by 13 dB in shallow water within 20 m from the sound source (assuming spreading with a loss of $10 \log r$ [r = distance in m]) and at less than 10 m distance from the sound source in deep waters (assuming spherical spreading with a loss of $20 \log r$). Due to oceanographic or geological features the spreading loss can reach even higher levels thus decreasing the effective masking range of the wind turbine sounds. However, the actual sound measurements have been carried out at comparatively small wind turbines. Several offshore wind farms are currently planned to consist of turbines of up to 5 MW. It is unclear to which extent the sound emissions of these turbines will rise in level with increasing size. So far these emissions have only been modelled (DEWI 2004), but should be measured upon construction of the turbines. The available data indicate that the potential masking effect would be limited to short ranges in the open sea, but limitations exist to this conclusion and all estimates are based on existing turbine types, not taking into account future developments of larger and potentially noisier turbine types.

The tolerance of the hearing system of harbour porpoises to sound was studied in another male harbour porpoise, held at the Fjord & Baelt in Kerteminde, Denmark. It is known from studies on other toothed whale species (e.g. Finneran et al. 2002) that the exposure to impulsive sounds – as the ramming impulses emitted

during pile driving – can at high intensities lead to a temporary or even permanent reduction of the hearing sensitivity impair the hearing of the animals (temporary threshold shift, TTS vs. permanent threshold shift, PTS). Based on this data, it can be assumed that the ramming impulses measured during the installation of OWT's (which on average exceed peak pressures of 225 dB re 1 μ Pa at 1 m), will create a risk of at least TTS in the auditory system of harbour porpoises. As mentioned above, these animals are vitally dependent on their hearing system. Any impairment or damage to their hearing capabilities could have severe consequences for the affected animal.

Again all hearing data were collected by using the AEP-method. After achieving baseline hearing data over the animal's functional hearing range, the animal was subsequently exposed to single fatiguing sound impulse (produced by an airgun; with acoustic characteristics comparable to a ramming impulse) at increasing received levels in a controlled exposure experiment. Immediately after each exposure the animal's hearing threshold was tested again for any significant changes at three selected frequencies. The received levels of the airgun impulses were increased until TTS was reached at one of the frequencies.

The animal's hearing thresholds were elevated in comparison to published data from other studies. A systematic electrophysiological masking due to the active positioning of the animal at its underwater station and an acoustic masking due to the high background noise level in the enclosure are likely reasons for these elevated hearing thresholds. The acoustic characteristics of the auditory stimuli may also account for a systematic difference in the hearing sensitivity. The achieved harbour porpoise's hearing sensitivity does therefore not represent absolute but masked hearing threshold levels (MTTS). This, however, has no implication on the tolerance of the animal's hearing system for intense impulsive sounds.

At 4 kHz the TTS-criterion was exceeded when the animal was exposed to a single impulse at a received sound pressure of 200 dB_{peak-peak} re 1 μ Pa and a sound exposure level of 164 dB re 1 μ Pa²·2. The documented masked TTS level of the harbour porpoise is considerably lower than levels found in the other toothed whale species tested so far, thus supporting the hypothesis of mass-dependant differences in the tolerance of the auditory system in toothed whales. Also, the recovery from TTS, i.e. the return of the hearing sensitivity to pre-exposure levels took much longer in the harbour porpoise as compared to the other species. Modelling the impact range of multiple exposures reveals a risk for auditory effects in harbour porpoises over larger distances as compared to single exposures. The results provide the baseline to define the noise exposure limit for this species for single impulses, comparable to those proposed by Southall et al. (2008). Thus they are likely to have implications for regulatory procedures regarding the construction of offshore wind turbines as well as the use of other impulsive sound sources.

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