Bioacoustics 17:1-3 (2008): 143-146

UNDERWATER NOISE FROM CONSTRUCTION AND OPERATION OF OFFSHORE WIND FARMS

JAKOB TOUGAARD[1], PETER T. MADSEN[2], AND MAGNUS WAHLBERG[3]

[1]*National Environmental Research Institute, Aarhus University, DK-4000 Roskilde, Denmark. jat@dmu.dk*
[2]*Aarhus University, Department of Zoophysiology, DK-8000 Aarhus, Denmark. peter.madsen@biology.au.dk*
[3]*Fjord&Baelt, DK-5300 Kerteminde, Denmark. magnus@fjord-baelt.dk*

INTRODUCTION

Offshore wind energy is a new source of underwater noise in the marine environment. The noise comes from two fundamentally different contributions. The first is construction (and decommissioning) activities that can generate noise of considerable intensity but within a limited time period. The second is operation of the wind farm where turbine machinery (and service activities) creates a low-intensity, yet almost continuous, underwater noise.

CONSTRUCTION

Construction of offshore wind farms generates noise similar in nature to noise caused by other offshore activities such as oil and gas extraction and construction of piers and bridges. Construction activities can be very noisy, in particular percussive pile drivings of monopile foundations. These create impact sounds of considerable intensity, with peak levels well above 200 dB re 1 μPa close to the piling site. Most energy is at very low frequencies, but even at larger distances, considerable energy is present in the ultrasonic range where marine mammal hearing is best. The sounds are no doubt audible to fish and marine mammals at large distances (tens of kilometres or more). The impact of the pile-driving noise is unclear, however. Due to the fact that most energy is present at very low frequencies and the duration of the sounds is small (about 0.1 s), sound exposure levels do not exceed levels known to produce temporary or permanent damage to marine mammal hearing, except perhaps within a few hundred metres from the piling site. Mitigation in the form of ramp-up procedures or deployment of acoustic harassment devices is likely to be effective in preventing injury to animals in this zone.

Behavioural reactions on the other hand have been demonstrated at distances up to 15 km from the piling site (Carstensen et al. 2006; Tougaard et al. 2006). Whether these behavioural reactions have a detrimental impact on the local or regional population of marine

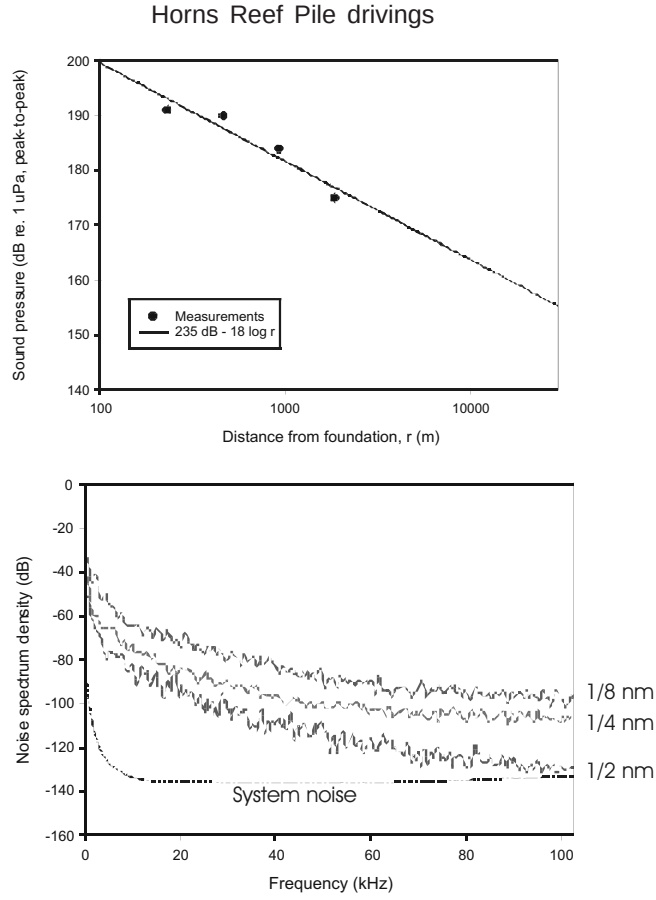

Figure 1. Sounds from piling of steel monopile foundations at Horns Rev offshore wind farm, North Sea. Top: sound pressure levels measured at various distances from the construction site and best fitting straight line. Bottom: power spectra of piling sounds at three different distances from the construction site (⅛, ¼, and ½ nautical mile, respectively). Data courtesy of Elsam A/S (Anon. 2002).

mammals cannot be stated in general. The answer will depend on a range of local factors such as density of animals, importance of the area to the animals, sound transmission characteristics, and possibility for the animals to withdraw temporarily to other areas during piling. It is thus important that new offshore wind farm projects be judged on a case-by-case basis and any impact judged in relation to and in combination with other activities of a similar type (oil and gas, piers and bridges) in the region.

OPERATION

Underwater noise from the operating turbines is generated in the machinery in the nacelle and is transmitted through the tower to the foundation, from which it is radiated into the water. Under normal conditions, the noise is of low intensity (by any standard; Madsen et al. 2005), with energy concentrated at low frequencies (below a few kilohertz). Third-octave levels of the noise from various types of turbines measured about 100 m from the foundation lie in the range of 100-120 dB re 1 μPa RMS. Despite the low intensity, the noise may contribute significantly to the local noise level because it is present almost continuously during the lifetime of the wind farm. Under favourable conditions (low background noise, low transmission loss), the sound may be audible to seals, odontocetes, and fish at distances up to some kilometres from the turbines. Due to the low intensity and low frequencies of the noise, the impact on marine mammals is considered marginal. Masking is irrelevant due to the low-frequency emphasis of the noise, and behavioural reactions, if any, are likely to be found only in the close vicinity of the foundation (a few hundred metres or less). Direct damage to the hearing of marine mammals is also unlikely because noise intensities, even right at the foundation, are unlikely to ever exceed known thresholds for inflicting damage.

A significant impact on fish is unlikely but cannot be ruled out. Masking in particular could be an issue for species that communicate with sound.

FINAL NOTE

Offshore wind turbines have increased considerably in size since the first were installed 10 years ago, and there is nothing that indicates that they will not increase even further in the future. Although no clear link has been seen so far between size and noise emissions, one must not rule out that more serious issues could arise with the introduction of larger turbines and introduction of new technology in the turbine machinery.

ACKNOWLEDGMENTS

These studies were supported by funding from the Danish Energy Authority through contracts with the power companies DONG and Vattenfall.

REFERENCES

Anon. (2002). *Horns Reef - Noise in the Sea During Pile Driving of a Turbine Foundation.* Fredericia, Denmark: Report from Tech-Wise A/S.

Betke, K. (2006). *Measurement of Underwater Noise Emitted by an Offshore Wind Turbine at Horns Rev*, pp. 1-19. Oldenburg, Germany: Institut für Technishe und Angewandte Physik GmbH.

Carstensen, J., Henriksen, O. D., & Teilmann, J. (2006). Impacts on harbour porpoises from offshore wind farm construction: Acoustic monitoring of echolocation activity using porpoise detectors (T-PODs). *Mar. Ecol. Prog. Ser.* **321**, 295-308.

Ingemansson Technology AB. (2003). *Utgrunden Offshore Wind Farm - Measurements of Underwater Noise.* Göteborg, Sweden: Report 11-00329-03012700.

Kastelein, R. A., Bunskoek, P., Hagedoorn, M., Au, W. W. L., & de Haan, D. (2002). Audiogram of a harbor porpoise (*Phocoena phocoena*) measured with narrow-band frequency modulated signals. *J. Acoust. Soc. Am.* **112**, 334-344.

Madsen, P. T., Wahlberg, M., Tougaard, J., Lucke, K., & Tyack, P. L. (2005). Wind turbine underwater noise and marine mammals: Implications of current knowledge and data needs. *Mar. Ecol. Prog. Ser.* **309**, 279-295.

Tougaard, J., Carstensen, J., Wisz, M. S., Teilmann, J., Bech, N. I., & Skov, H. (2006). *Harbour Porpoises on Horns Reef in Relation to Construction and Operation of Horns Rev Offshore Wind Farm.* Technical Report to Elsam Engineering A/S. Roskilde, Denmark: National Environmental Research Institute.

MARINE SEISMIC OPERATIONS

SARAH L. TSOFLIAS[1] AND JOHN V. YOUNG[2]

[1]International Association of Geophysical Contractors, Suite 104, 2550 North Loop West, Houston, TX 77092, USA. sarah.tsoflias@iagc.org
[2]ExxonMobil Exploration Company, 222 Benmar, Houston, TX 77060, USA. john.v.young@exxonmobil.com

INTRODUCTION

By 2030, it is widely estimated that global energy demand will increase approximately 50% from the 2005 level. Energy enhances the quality of human life, and, therefore, affordable energy is important to humankind. In order to address this need for energy, the petroleum industry explores for hydrocarbon deposits beneath the earth's surface including under oceans. Seismic surveys are the most accurate and efficient method currently available for hydrocarbon exploration. Today, the most common marine seismic operations include acoustic sources and receiver streamers towed behind a source vessel. The sources are activated, releasing sound energy directed downward through the water column and into the earth. As a result of acoustic differences between geologic strata, energy is reflected back to the streamers. The reflected energy is digitally recorded and processed to obtain a detailed image of the subsurface, which is used to select and drill exploration and production wells.