Monitoring and Assessment in Regard of Technical Sound Mitigation Developments – a Perspective from MarinEARS

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Introduction

Underwater sound is incessantly generated in the global oceans by a variety of acoustic sources. Wind, waves, sea ice and sediment movements are only some of the natural processes which form the underwater soundscape. A wide range of additional sounds is produced by several marine species for different purposes such as communication and foraging. But also human maritime activities contribute to the ocean's soundscape. Anthropogenic noise emissions may be characterized inter alia according to their intensity, frequency content and signal duration. A distiction between continuous and impulsive noise is commonly made when decribing the noise emission of persistent sources such as shipping.versus the emission of impulsive sources such as generated by seismic surveys or at some offshore construction sites. Due to the fact that many marine animals rely on sound for vital functions, there has been an increased awarenenss of scientists, law makers, governmental agencies and the public regarding potential impacts of anthropogenic underwater noise on the marine environment.

The Federal Maritime and Hydrographic Agency (BSH) is the authority responsible for the approval of offshore wind energy projects in the German Exclusive Economic Zone (EEZ), for monitoring and assessment of related underwater noise effects on the marine environment and for the implementation and operation of the national noise registry covering the German waters in the North Sea and Baltic Sea. As technical and scientfic support for these tasks, the dedicated expert information system MarinEARS (Marine Explorer and Registry of Sound) was established in 2016 at BSH. MarinEARS provides the backbone of the national noise registry, serves BSH as scientific platform for monitoring and assessment of underwater noise effects, enables the E-Reporting of offshore wind farm (OWF) monitoring data in the context of approval procedures and offers publicly accessible information including the location, date and duration of underwater noise events as well as on the application of noise abatement systems.

Here, we introduce the expert information system MarinEARS, unfold the extend of the comprehensive data basis and present the content and range of products available for the public. Further, we outline its role and capacity for regulatory and scientific purposes on national and regional level.

Monitoring of Underwater Noise

The expert information system MarinEARS is in operational service since 2017 and provides BSH with the necessary scientific platform regarding underwater noise effects for conducting Environmental Impact Assessments (EIA) in the framework of approval procedures for offshore wind energy projects as well as for the estimation of cumulative impacts in Strategic Environmental Assessment (SEA) for Maritime Spatial Planning and the Site Development Plan for Offshore Wind Energy. Regarding the German EEZ of the North Sea and the Baltic Sea, a major source of impulsive anthropogenic sound is pile driving during the construction of offshore energy projects. As of 2019, 24 OWF's have been successfully installed in the German EEZ. Importantly, the input of impulsive sound due to pile driving activities during OWF construction has to be technically mitigated, monitored and evaluated according to requirements of the BSH as responsible agency for the approval and monitoring of OWF's.

In order to avoid a temporal threshold shift (TTS) in harbour porpoises as the key species due to pile driving activities [1], the compliance with a sound pressure level threshold criterion has been a requirement for all wind farm construction projects in the German EEZ approved by BSH since 2008. The relevant metrics for the evaluation of pile driving noise in this context are the sound exposure level (SEL)

$$\mathrm{SEL} = 10 \log_{10} \left[\frac{1}{T_0} \int_{T_1}^{T_2} \frac{p(t)^2}{p_0^2} dt \right] [\mathrm{dB\ re\ 1\ \mu Pa^2 s}] \quad (1)$$

and the zero-to-peak sound pressure level ($L_{p,pk}$)

$$L_{p,pk} = 20 \log_{10} \left[\frac{\max(|p(t)|)}{p_0} \right] [\mathrm{dB\ re\ 1\ \mu Pa}] \quad (2)$$

where T_1 and T_2 indicate the start and end of the evaluated time span respectively, T_0 is commonly defined as 1 s and p_0 is defined as 1 µPa. The impulsive noise emissions from pile driving at a measuring distance of 750 m to the piling location must not exceed the dual threshold criterion given by

- a non-frequency weighted SEL_{05} of 160 dB re 1 $\mu Pa^2 s$,
- a zero-to-peak sound pressure level $L_{p,pk}$ of 190 dB re 1 µPa.

Here, the SEL_{05} describes the sound exposure level, exceeded by 5% of the total number of measurements.
Since 2011, the application of technical noise abatement systems has been mandatory at offshore construction sites in the German EEZ. The compliance with the threshold criteria is rigorously monitored according to the measuring instructions of BSH [2] and international measuring standards [3]. The monitoring data and corresponding technical data on noise abatement systems are delivered to BSH via the E-Reporting portal of MarinEARS, where they are subject to a comprehensive internal quality assurance before they are made available for further assessments. Underwater noise data can be further processed with

MarinEARS into specifically tailored products, addressing the needs of federal and state agencies, industry and public interest.

Marine Explorer and Registry of Sound

MarinEARS hosts data on underwater noise from more than 1500 offshore foundations in the German EEZ, corresponding to more than 2500 pile driving installations and several million pile strokes. This comprehensive data set provides an important knowledge base regarding acoustic measurements and data on the application of technical noise abatement systems. Hence, MarinEARS holds an important role in managing piling noise impacts and serves

- the fast, daily access for the construction supervision of offshore projects,
- the quality control of data and evaluations,
- the assessment of the efficiency of measures based on measurements,
- as basis for setting standards.

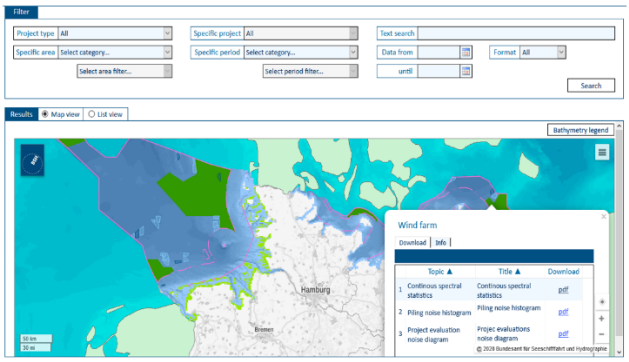

Figure 1: MarinEARS provides general information on underwater noise data in the context of offshore wind farm constructions and offers a data repository containing specifically tailored products available for download.

MarinEARS additionally offers publicly accessible general and technical information on underwater noise events including their location, date and duration. Moreover, it provides information on sound pressure levels as well as on the application of noise abatement systems. Available information and specifically tailored products can be accessed via the Web interface *marinears.bsh.de.* The searchable data repository and exemplary products of MarinEARS are shown in Figure 1 and 2 respectively.

The National Noise Registry

One of the two criteria elements for Descriptor 11 (energy, including underwater noise) that are defined in the EU Marine Strategy Framework Directive Commission Decision (2017/848/EU) concerns the spatial distribution, temporal extent and levels of anthropogenic impulsive sound in water. Within the context of the Marine Strategy Framework Directive (MSFD) a regional impulsive noise registry for the North and Baltic Sea hosted by ICES was established in 2015 on behalf of OSPAR and HELCOM. Member states are obligated to report their national impulsive noise events annually to the regional noise registry annually.

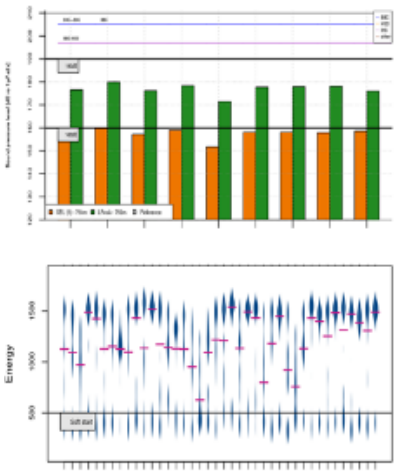

Figure 2: Top: Sequence of SEL_{05} and $L_{p,pk}$ for different piles of a wind farm: The threshold values at activity level were met. **Bottom:** Distribution of hammer energy applied during pile driving for different piles of a offshore wind farm.

In the framework of the implementation of the MSFD, Germany developed measures to achieve and maintain a Good Environmental Status regarding underwater noise emissions. These measures include the implementation of a national noise registry, which has been operated by BSH since 2016. MarinEARS provides the backbone of the national noise registry. An important product of MarinEARS is the obligatory report to the regional impulsive noise registry of North and Baltic Sea. The annual reporting compiled in MarinEARS concerns impulsive noise events in the German North and Baltic Sea from different sources including pile driving, detonations of non-transportable UXO's, naval noise and seismic surveys. The Noise Registry is publicly acessible at MarinEARS as shown in Figure 3. Possible filter parameters for searching the database include the year and type of the impulsive noise event, the application of noise abatement systems but also information on results from the acoustic measurements of the event where available.

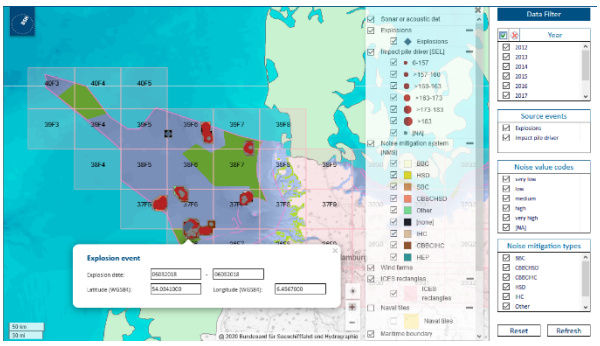

Figure 3: The national impulsive noise registry is publicly accessible through MarinEARS.

Conclusion from pile driving noise and abatement system application during German OWF constructions

From 2013 onwards pile installations in the German EEZ took place at two to five OWF's per year on average. Due to the increase in megawatt capacity of wind turbines, which approximately doubled within this period, the number of wind turbines per windfarm, and hereby the number of pile driving events decreased. However, pile diameter have reached values of up to 8 meters at the pile basis. Despite increasing pile diameters and water depths of up to 40 meters, a compliance with the mandatory threshold could has been achieved reliably since 2014.

The effectiveness of technical noise abatement systems applied is evaluated according to standards given by [4] and [5]. Efforts by the industry have significantly advanced technical noise mitigation systems in the past years. In the last eight years, three basic noise abatement systems have been applied successfully in German waters under real offshore conditions:

- Big Bubble Curtain systems (BBC), far field noise abatement at distances >= 60 m around the piling location,
- isolating casing systems from IHC noise mitigation screen (NMS) at near field with multiple functions (such as holding and positioning the piles and allowing for controlling verticality) and
- Hydro Sound Damper (HSD) at near field around the pile, mostly operated from the pile gripper system.

Data from the monitoring of these three noise abatement systems in the German EEZ of the North and Baltic Sea available in MarinEARS have been analyzed in the framework of a R&D project funded by the Federal Ministry of the Environment and Nuclear Safety (BMU). The results including current knowledge and field experiences are published in the final report of the project [6].

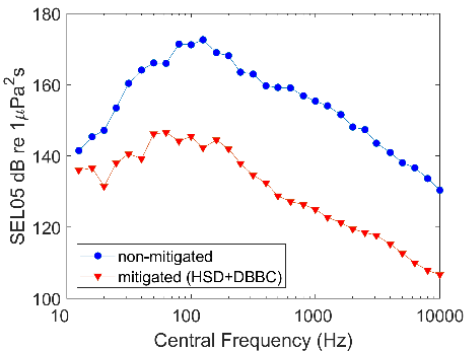

Figure 4: Example of an analysis with MarinEARS: comparison of the SEL_{05} measured for pile driving events in the German EEZ with and without the application of technical sound abatement systems.

Figure 4 shows an analysis from MarinEARS regarding the comparison of the SEL_{05} obtained for a pile driving event with and without the application of technical sound abatement systems. In addition to a temporal signature of a sound source, its spectral characteristic is a very important factor for the assessment of noise for marine life. Technical noise mitigation systems (singular or combined) are efficient as they are able to reduce the broadband SEL value by more than 20 dB. The noise reduction is however frequency dependent. Bubble curtain systems may provide an especially efficient mitigation of high frequency components of the piling noise, which is relevant for e.g. harbour porpoises.

Lessons learnt and Outlook

The noise generated by pile-driving can be significantly reduced by technical noise abatement systems. Level reductions (insertion loss) of up to 24 dB can be achieved compared to unmitigated pile-driving under the premise that technical sound mitigation concepts are applied successfully. Three different noise abatement systems were applied during the majority of the OWF construction in the German EEZ under real offshore conditions during the previous years. To date, technical developments regarding noise abatement systems by the industry have led to a reliable compliance with the threshold since 2014, despite increasing pile diameters and water depths at project sites. Cross-project evaluations regarding noise emissions and the application of technical solutions are facilitated by the comprehensive data basis of MarinEARS and provide a valuable knowledge base for future OWP projects.

Literature

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