Introduction

Underwater sound is characterized
1. directional particle motion
2. scalar pressure waves

Theoretically these are related and it is possible to estimate the particle velocity through measurements of pressure (e.g. Filiciotto et al. 2016, Nedelec 2016).

However, this relationship assumes that sound propagates as a plane wave, an assumption that is not met in shelf seas or shallow water regions, where a wide range of fish and invertebrate species have been shown to respond to both sound pressure and particle velocity (e.g. Radford et al. 2012).

Objectives

This work compares direct measurements of sound pressure level (SPL) and particle velocity generated by experimental pile driving.

Results

A total of 1214 pile driving strikes were analyzed (Figure 1), with:

- 467 strikes in the deep location, and;
- 747 strikes in the shallow location.

This difference is possibly due to the non-linear relationship of particle velocity in the nearfield as described by Nedelec et al (2016; Equation 1), which counteracts the attenuation of the low frequencies due to shallow depth limitation. Further work is required to verify this.

\[ u = \frac{p}{\rho c} \left[ 1 + \left( \frac{\lambda}{2\pi r} \right)^2 \right] \] (Equation 1)

Where: \( u \) = particle velocity (m/s), \( p \) = sound pressure (Pa), \( \rho \) = water density (kg/m\(^3\)), \( c \) = speed of sound (m/s), \( r \) = distance from sound source (m) and \( \lambda \) = wavelength of sound (m).

Data collection and analysis

Measurements of SPL and particle velocity were recorded during experimental pile driving conducted in a former shipbuilding dock (dimensions: 92 m x 18 m, average water depth 2.5 m with 3.5 m of seabed sediment). A 200 kg hammer (~1.6 kJ hammer energy) was used to strike a 7.5 m long, 0.17 m diameter, steel pile that rested on the simulated seabed, at a rate of 10 strikes per minute.

Trials were performed with the pile located in both the deep and shallow ends of the dock (Figure 1). Simultaneous recordings of sound pressure level (SPL - dB re 1μPa) and particle velocity were collected at 27 locations and at two depths (1 m and 1.8 m) (Figure 1).

The recordings from each trial were analysed using PaPAM software (Nedelec et al, 2016) to obtain:

1. the average single strike values for both SPL (SPLss) and particle velocity
2. the average single strike third-octave band Power Spectral Density (PSD) for both SPL and particle velocity

Note: The analysed PSD third-octave bands were 100 Hz to 2500 Hz.

Conclusions

- Few studies have analysed simultaneous direct measurements of sound pressure and particle motion (Lugli 2007).
- Initial analysis found a significant correlation between broadband SPL and particle velocity, but the correlation is poor for lower frequencies (<400Hz). This is probably caused by the non-linearity in the relationship between SPL and particle velocity in the near-field which counteracts the shallow water frequency cut-off.
- Estimates of particle velocity derived from SPL measurements should be considered as approximate estimates only, especially close to the source and in shallow water and/or confined environments.
- Further analysis of the results and additional studies are required at different locations to better understand this relationship between sound pressure and particle motion.

References


Institutions

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