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A comprehensive study to assess the impact of impulsive sound on juvenile sea bass

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Given the increasing amount of anthropogenically induced underwater sound into the marine environment, a better understanding of the impact of impulsive underwater sound on marine life is needed. This study tackles the impact of impulsive sound, related to pile-driving activities for offshore wind energy development, on the mortality, stress and behaviour of post-larval and juvenile European sea bass *Dicentrarchus labrax*. A 'worst-case scenario' field experiment was carried out on board of a piling vessel, exposing 68 and 115 days old fish (<2 g wet weight) to the sound generated during 1.5 hours of pile-driving. The number of strikes ranged from 1740 to 3070, with a single strike sound exposure level between 181 and 188 dB re 1µPa².s, resulting in cumulative sound exposure levels ranging from 215 to 222dB re 1µPa².s. Immediate and long-term survival of the exposed fish was high and comparable to the control groups. However, juvenile fish responded to the impulsive underwater sound by a 50% reduction in their oxygen consumption rates, an indicator of secondary stress response. Primary stress responses, measured through cortisol levels are still to be analysed. We didn't find any effect on the condition and fitness of the exposed fish on the long term. Lab experiments performed with a SIG Sparker and a larvaebrator, respectively producing mid-high and lower frequencies, were inadequate to distinguish the determining sound metric or to pursue the exact origin of the stress response.

Further away from the sound source, behavioural and masking effects can be expected. A lab experiment was carried out to study the behaviour of juvenile sea bass before, during and after one hour of impulsive sound exposure. In the aquaria, single strike sound levels reached 162dB re 1 µPa².s, leading to a cumulative sound exposure level of 196 dB re 1 µPa².s after 2400 strikes. We observed that normal behaviour was disturbed, with an increase in startle responses and stationary behaviour at the beginning of the sound exposure experiment. Also, fish dived to the bottom of the aquaria, which is a typical anxiety-related response. However, no spatial preference was observed and normal behaviour was re-established shortly after the sound exposure ceased.

These results indicate that impulsive sound close to the sound source creates sound pressure levels that are below the lethal threshold for fish, but above the stress threshold, at least for sea bass <2 g. Furthermore, lower sound levels at a distance from the sound source (in this case pile-driving) can disturb fish behaviour. Under optimal lab conditions, we did not see effects beyond the sound exposure period, but it remains unknown whether the reduced fitness of juvenile fish after exposure is limited in the real world as well.