

## Mitigation of Offshore Piling Noise Effects on Marine Mammals

**Authors :** Waled A. Dawoud, Abdelazim M. Negm, Nasser M. Saleh

**Abstract :** Offshore piling generates underwater sound at level high enough to cause physical damage or hearing impairment to the marine mammals. Several methods can be used to mitigate the effect of underwater noise from offshore pile driving on marine mammals which can be divided into three main approaches. The first approach is to keep the mammal out of the high-risk area by using aversive sound waves produced by acoustic mitigation devices such as playing-back of mammal's natural predator vocalization, alarm or distress sounds, and anthropogenic sound. The second approach is to reduce the amount of underwater noise from pile driving using noise mitigation techniques such as bubble curtains, isolation casing, and hydro-sound dampers. The third approach is to eliminate the overlap of underwater waves by using prolonged construction process. To investigate the effectiveness of different noise mitigation methods; a pile driven with 235 kJ rated energy diesel hammer near Jeddah Coast, Kingdom of Saudi Arabia was used. Using empirical sound exposure model based on Red Sea characteristics and limits of National Oceanic and Atmospheric Administration; it was found that the aversive sound waves should extend to 1.8 km around the pile location. Bubble curtains can reduce the behavioral disturbance area up to 28%; temporary threshold shift up to 36%; permanent threshold shift up to 50%; and physical injury up to 70%. Isolation casing can reduce the behavioral disturbance range up to 12%; temporary threshold shift up to 21%; permanent threshold shift up to 29%; and physical injury up to 46%. Hydro-sound dampers efficiency depends mainly on the used technology and it can reduce the behavioral disturbance range from 10% to 33%; temporary threshold shift from 18% to 25%; permanent threshold shift from 32% to 50%; and physical injury from 46% to 60%. To prolong the construction process, it was found that the single pile construction, use of soft start, and keep time between two successive hammer strikes more than 3 seconds are the most effective techniques.

**Keywords :** offshore pile driving, sound propagation models, noise effects on marine mammals, Underwater noise mitigation

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