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A TOOL TO PREDICT THE IMPACT OF ANTHROPOGENIC NOISE ON FISH

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ABSTRACT

Anthropogenic (man-made) noise is a global problem in aquatic and terrestrial environments. In the shallow seas around many countries, including the UK, large windfarms are being constructed using pile driving to create a solid base for the turbines. Offshore pile driving creates pulsating noises and vibrations of very high intensities, which has been shown to be deleterious to a variety of aquatic species.

Using a hydrodynamic model that predicts the propagation of underwater noise while taking into account bathymetry, tidal movements and currents, we integrated a numerical behavioural tool that models fish behaviour in response to noise. Using agent based modelling, scientifically published data and parameters obtained from carefully controlled experiments, we modelled the impact of noise on European sea bass (*Dicentrarchus labrax*) as they encountered pile driving during migration from the ocean to a spawning site close to the shore. Taking our empirical experiments into account - which showed a negative impact of noise on feeding behaviour and increased oxygen consumption - the model predicts that the fish took significantly longer to arrive at the spawning site.

This effect could have important implications at a population level, as fish would use more energy to reach the site and might desynchronize spawning behaviour, which in turn would influence larval survival and life history processes that reduce fitness. This tool not only shows the value of using numerical models to predict animal behaviour in a complex environment, but also highlights the merit of using such models to predict anthropogenic impacts that would otherwise be difficult or too costly to obtain.

INTRODUCTION

Man-made activities are present in all environments and can drastically increase noise levels. Moreover, noise is increasing due to activities such as construction, transport and resource exploitation [1, 2]. In 2007 the European Union agreed to sourcing a minimum of 20% of its energy needs from renewable sources by 2020. The UK intends to achieve these targets through the construction of offshore windfarms, wave and tidal energy hubs with the aim of delivering up to 33 GW of energy through marine renewables [3]. Although the noise associated with energy production can be significant, it is often the construction stage that creates most noise [4].

Anthropogenic noise in the aquatic environment results from a number of activities, but arguably shipping noise and piling noise are the most important polluters; shipping noise pervades the marine environment and pile driving consists of high-intensity pulsating sounds. An increasing body of literature demonstrates the potential impacts of acoustic disturbance on aquatic organisms, ranging from behavioural impacts on fish [e.g. 5-7] to physiological impacts on invertebrates [8] to impacts on marine mammals [9]. However, not all experiments studying the impact of noise on fish have shown negative responses, especially with regards to growth [10, 11].

Here, we use HR Wallingford's HAMMER model (Hydro-Acoustical Model for the Mitigation of Ecological Response [12]) to examine the impact of piling noise on European sea bass. The model was realised using information from peer-reviewed published articles and carefully controlled experiments designed to obtain essential parameters.

METHODOLOGY

Study Species & Noise Protocol

European sea bass (*Dicentrarchus labrax*) were obtained from an aquaculture facility in Anglesey (UK) and housed in two tanks at the University of Exeter. The fish participated in two experiments (see below) and were exposed to playbacks of ambient conditions in 3 UK harbours (standardised at ~123 dB RMS re 1μPa) and pile driving (~162 dB RMS re 1μPa on hammer strikes) using underwater speakers (UW-30, University Sound, Lubel Labs).

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Metabolic Rate Experiment

After 30 min habituation in a confined container, fish were exposed to playback of ambient harbour noise or pile driving noise for 30 min (n = 24 per treatment). At 0, 15 and 30 min water samples were taken and oxygen levels were established to determine metabolic rate.

Feeding Experiment

After 4 min habituation during playback of ambient harbour noise, fish were exposed to a different ambient harbour noise playback or to pile driving noise (n = 24 per treatment). Directly after switching of the track, fish received either a food or non-food item every 20 seconds (10 food and 5 non-food items given randomly). The number of food and non-food items that were eaten were recorded.

Noise Model

To establish the impact of pile driving noise on the behaviour of fish, we used the HAMMER model [12] which models noise propagation taking bathymetry and currents into account. The last step of the tool is an ecological response model that predicts the behaviour of fish in response to the noise.

OBSERVATIONS

The metabolic rate of the fish significantly increased during playback of pile driving noise compared to ambient harbour noise playbacks. Additionally, sea bass significantly decreased their feeding rate during pile driving playbacks.

These results were used in the HAMMER model by decreasing swimming speed – since metabolic rate increased and feeding decreased – in locations where the noise floor was above 120 dB re 1 µPa. This caused to the noise-sensitive fish to arrive later to the spawning site than the noise-insensitive fish.

CONCLUSIONS

Sea bass significantly increased metabolic rate and decreased feeding rates during playback of pile driving noise. These empirical results were used in an eco-hydro-acoustic model (HAMMER) to predict the impact of piling noise on sea bass behaviour. The model predicts that during pile driving the fish will take longer to arrive to the spawning site – due to an increased metabolic rate and simultaneous decrease in food intake - which might have serious consequences on spawning success and overall fitness.

The proof of concept shown here might be used in unison with additional behavioural and physiological data which would further strengthen the predictive power of the model. In summary, this tool shows the value of using numerical models to predict animal behaviour in a complex environment and highlights the merit of using such models to predict anthropogenic impacts that would otherwise be difficult or too costly to obtain.

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