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An overview of a simulation approach to assessing environmental risk of sound exposure to marine mammals

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ABSTRACT

Underwater sounds caused by military sonar, seismic surveys and marine renewable construction/operational activities can harm/disturb acoustically sensitive marine mammals, and many jurisdictions require such activities to undergo environmental impact assessments to guide mitigation. The ability to assess impacts in a rigorous, quantitative way is hindered by large knowledge gaps on hearing ability, sensitivity and responses to noise. We will describe an analytical framework, called SAFESIMM (Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna) which partitions our knowledge of noise impacts into linked modules that collectively calculate the numbers of animals likely to be affected by noise. The simulation framework will be illustrated using two species that are relevant to marine renewable assessments in the UK, namely grey seal (*Halichoerus grypus*) and harbour porpoise (*Phocoena phocoena*). We have run a suite of simulations which consider sensitivity to uncertainty in three areas: how sound energy is perceived by animals with differing hearing apparatuses; how animals move in response to disturbance (i.e., the strength and directionality of evasive tactics); and the level of site fidelity effects. In particular we consider sensitivities over exposure scenarios of differing lengths. We will describe the main outcomes of these simulations and place the results in the context of the decisions that developers and regulators are faced with. Simulation frameworks offer a powerful way to explore, understand and estimate effects of cumulative sound exposure on marine mammals, but they can act as black boxes that hide important, but subjective, decisions. For example, we have found that the estimate of received sound exposure level (SEL) is influenced most strongly by the weighting function used to account for the species' presumed hearing ability and therefore tools that make different assumptions about auditory weighting will give contradictory recommendations to managers about sound exposure relative to allowable harm limits.

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INTRODUCTION

Regulatory agencies around the world are required routinely to approve or deny permit applications for industrial activities in important marine mammal habitats that are capable of generating impulsive sounds that are comparable to sonar. The two main activities that fall into this category are pile driving relating to offshore renewable energy construction (Bailey et al., 2010) and the use of airguns in offshore oil and gas exploration and extraction (McCauley et al, 2003). We developed a simulation framework, called 'SAFESIMM' (Statistical Algorithms For Estimating the Sonar Influence on Marine Megafauna), which uses agent-based models to quantify the extent to which marine mammals may be affected by proposed noise-generating activities and to explore sensitivity of our models to uncertainty in their various components. We will briefly outline the statistical derivation of the SAFESIMM and similar risk-assessment frameworks, identify where risk assessments are most vulnerable to knowledge gaps, and identify priority research areas. Given the reliance of the environmental impact assessment (EIA) community on risk assessment tools such as SAFESIMM, it is important to explore transparently the consequences of different parameterizations and model assumptions so that regulators can understand the EIAs being submitted and have confidence in their permitting decisions.

METHODOLOGY

SAFESIMM is an agent-based model which distributes animals through a sound field according to best estimates of density, with associated measures of uncertainty. Ultimately the movement of thousands of simulated animals and dozens of species are tracked through time within the simulation, with received sound levels recorded at each step by reference to the input sound field. Received levels of sound exposure are weighted to account for sensitivity of species to particular frequencies, and sound exposure is accumulated over time. Accumulated, weighted SELs then pass to dose-response curves or similar to determine potential physical and/or behavioural effects. At the end of the simulation process, the sound histories for the simulated animals and the probability of physical and/or behavioural effects can be summarized.

Three sets of simulations have been conducted to investigate sensitivity to:

i) Auditory weighting (M-weighting versus audiogram weighting)
ii) Responsive movement (ranging from no response to marked avoidance)
iii) Site fidelity as a constraint to movement

All of these simulations looked at effects of sound exposure over a range of timescales from hours up to 10 days. We focussed on two species of interest in the UK context, the harbour porpoise and grey seal.

OBSERVATIONS

The choice between M-weighting and audiogram weighting makes an immediate marked difference in the estimated amount of sound energy accumulated. Regardless of duration there are large (tens of dB) differences in estimated SEL for both species.

The magnitude and directionality of avoidance responses plays a large role in governing the estimated SEL, the significance of which was dependent on the duration of the scenario.

The degree to which movement is constrained by site fidelity has an effect on the resulting SEL when compared with unconstrained movement. This effect also becomes more significant as scenario duration increases, and the estimated SELs continue to diverge as time increases.

CONCLUSIONS

Simulation frameworks offer a powerful way to explore, understand and estimate effects of cumulative sound exposure on marine mammals, but they can act as black boxes that hide important, but subjective, decisions about parameter values that can dramatically alter predictions of sound exposure. This is very much true of the auditory weighting – we see very different results using the M-weighting compared to the audiogram weighting.

Our results also highlight that the sensitivity of results to certain inputs/assumptions is time dependent. Differences in parameterisations of responsive movement and site fidelity matter little in the short term but the estimated SELs for simulated individuals begin to diverge as scenario duration increases and therefore difference parameterisations can ultimately lead to different recommendations in risk assessments.

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