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Exploring patterns of responsiveness to sonar exposure: a Bayesian approach applied to multiple cetacean species

Evaluating the impacts of anthropogenic underwater noise on cetacean populations has become a key requirement of contemporary environmental management across the world's oceans. Of particular interest is the ability to predict the nature, onset, and magnitude of species' responses to impulsive sound stimuli, such as those produced by naval sonar systems. Current noise exposure criteria for risk assessments are often based on classifications of species into functional hearing groups, yet increasing evidence for suites of complex responses that are both context-dependent and individually variable challenge the idea that sonar effects are universally mediated by species morphology and hearing sensitivity. We summarise the development and application of an alternative, data-driven approach for investigating mechanisms influencing behavioural responses within a Bayesian multi-species hierarchical dose-response framework. Our method relies on a "dimension-jumping" reversible-jump Markov chain Monte Carlo (rjMCMC) algorithm, and offers an objective, tractable, and computationally efficient way of identifying other biologically-relevant species groupings by assessing competing hypotheses regarding shared patterns of responsiveness to sonar and sonar-like signals. The method also accommodates: (1) the selection of explanatory covariates (e.g., sonar frequency, previous history of exposure, feeding behaviour, source-whale range), (2) the comparison of dose-response functional forms (i.e., monophasic or biphasic), and (3) the appropriate treatment of right-censored observations (i.e., when animals display no signs of behavioural response across the array of doses received). We demonstrate its potential using an existing dataset on the expert-scored response thresholds of thirteen cetacean species tagged during behavioural response studies conducted in the Atlantic and Pacific Oceans. Our results provide novel insights into how responsiveness to sound can be generalised within and across species to inform impact assessment processes.