Bayesian meta-analysis model for assessing bioeconomic impacts of oil spills on fisheries

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Introduction

Oil spill impact assessment on fish populations is done by integrating laboratory exposure study results to population dynamics models. The available data is however very unbalanced between different species and oil types. Furthermore, creating new data is time consuming and expensive. Therefore, it has been suggested that impact assessment models should utilize meta-analysis that combines existing data. Models should also enable borrowing of information so that information poor species and oil types learn from data rich ones. We developed a hierarchical Bayesian meta-analysis model that combines exposure studies into species and oil type specific estimates. The model structure allows borrowing of information. We concentrated on the effect of polycyclic aromatic hydrocarbons on the most sensitive fish life stages, eggs and larvae. The species and oil specific parameter estimates can be integrated into population dynamics models for predicting population level impacts of different oil spill scenarios.

Materials and methods

We conducted a systematic review of existing laboratory exposure studies using a predefined search strategy. The strategy included a comprehensive set of search terms and inclusion and exclusion criteria for the articles. We synthesized data from the included articles which we then analyzed using the Bayesian hierarchical meta-analysis model. Egg and larvae data were analyzed separately. In the model we assumed that mortalities of eggs or larvae follow beta distribution. Variances were weighted with the number of individuals exposed in each experiment. The expected mortalities were modelled as exponential mortalities over exposure time in days. The daily rates were modelled as functions of the concentrations of polycyclic aromatic hydrocarbons in water. The parameters of the daily rates were modelled as random effects and we used non-informative priors. We validated the model using posterior predictive check.

Results

After the systematic review we had included 74 articles for data synthesis. The included articles represented 9 species and 22 oil types. We excluded articles due to several reasons. Among the most common exclusion reasons were that the articles concentrated on the wrong life stages or wrong response variables. Articles were very heterogenic in terms of how the exposure concentrations were maintained. To prevent too much data loss, we homogenized exposure concentrations by calculating geometric means. At the time of writing this abstract we have only

acquired preliminary results from the meta-analysis model using egg mortality data. The model results showed differences in the sensitivities of eggs of different species as well as in the toxicities of different oils. Data poor species and oils borrowed information from data rich ones which became apparent as their estimates shrunk towards the common effects. The model performed well in posterior predictive check.

Implications on sustainable maritime operation

We believe that the methodology we used here serves as an important starting point for developing oil spill impact assessment models that are transparent in terms of uncertainty, are cost effective, and provide estimates fast for decision makers. In addition to serving differing risk attitudes of decision makers, Bayesian methods allow cumulative meta-analysis. The results of a previous analysis can be used as prior knowledge in a consecutive one when new data becomes available. In a future article we will use Baltic Sea herring as a case study by integrating the herring results into a Bayesian population dynamics model. Within the same integrated model, we will estimate biological and economic effects of different oil spill scenarios on Baltic Sea herring. Integration of the economic calculation method into the model allows the estimation of compensations to fishermen due to an oil spill.