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Environmental risk assessments in the context of marine spatial management: Current approaches and some perspectives

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Summary

We applied an environmental risk assessment (ERA) framework and linked spatial explicit information on the sensitivity of benthic communities in the German EEZ of the North Sea with the occurrence and magnitude of a governed pressure such as fisheries. We used a spatially resolved Bayesian Belief Network to showcase the steps of risk characterisation, risk analysis and risk evaluation, which are crucial for an informed decision process in marine spatial planning (MSP). The risk analysis produced spatial explicit relative measures of benthic disturbance accounting for bottom trawling frequencies and local frequencies of potential benthic recovery. To account for uncertainty in this step we also assessed different impact weights of the six fishing fleets distinguished and found great differences in spatial disturbance patterns. For the risk evaluation step we simulated a spatial shift of the international fishing effort of two beam trawl fleets, which are affected the most by future offshore wind development. Results showed an increase of local disturbance ratios in 9 % of the study area. In conclusion, MSP processes should embed ERA frameworks which allow for the integration of multiple risk assessments and the quantification of related uncertainties at a common spatial scale.

Introduction

For the development of ecosystem based marine spatial planning (MSP) it is crucial to have a robust estimates of the risks of adverse effects on the marine environment by cumulative human pressures at meaningful ecological scales (Halpern et al., 2008). Stelzenmüller et al. (2013), for instance, defined a risk analysis as a key step for evaluation of implemented or proposed spatial management plans. Thus spatial management objectives determine the contents of the environmental risk assessments (ERAs). Hence, ERAs that link spatial explicit information on the sensitivity of an environment with the occurrence and magnitude of a governed pressure are fundamental for the implementation of an ecosystem based MSP (Hope, 2006). We conducted a targeted review on current approaches of spatial explicit and quantitative ERAs in the context of spatial management and assessed the methods used for the steps of risk identification, risk analysis and risk evaluation. Based on the identified gaps we applied an ERA framework (Cormier et al., 2013) to assess the risk of shisft of fishing effort distributions due to MSP measures for benthic communities in the German EEZ of the North Sea with the help of a spatially resolved Bayesian Belief Network (BN) (McCann et al., 2006).

Materials and Methods

Risk identification and characterisation - We merged German, Dutch and Danish VMS and logbook data from 2005 to 2008 and calculated per 3 x 3 nm grid cell the frequency with which the seabed surface has been reworked by fishing (Fock 2011). Further we allocated to each grid cell the most dominant benthic community (Pesch et al., 2008). *Risk analysis* –For each grid cell the relative recovery for each benthic community to 90 % of the abundance previous to trawling was estimated as a function of the recovery time and recovery frequency (Fock 2011). The overall local mortality rate is the sum of the local mortality rates per fleet weighted by a respective impact sore (is); (is); $M_i = \sum_{k=1}^{n} M_{ik} * is_k$ (modified after Fock 2011). The overall relative local vulnerability of a benthic community to bottom trawling as the ratio between mortality and recovery (M_i/R_i) and we refer to this as disturbance indicator (DI_i). To assess the effect of different impact scores on local disturbance rates we calculated DI_i based on M_i with equal weights for each impact score ($is_k = 1$) and alternative impact weights (DI_wi). We compiled in a GIS for each grid cell the respective measures on recovery, mortality and disturbance in the attribute table of the vector grid for subsequent mapping. *Risk evaluation* – We developed a spatially resolved Bayesian Belief Network (BN) to demonstrate the risk evaluation in relation to the measure of vulnerability and used the above attribute table compiled in the GIS to both built the prior probabilities for each BN node and to populate the conditional probability tables (CPTs). Finally we inferred the trained BN to explore the effects of a MSP scenario: "What are the likely impacts of spatial shifts of 15 % of the total fishing frequency of large beam trawlers (Beam80lrg) and 3% of the small beam trawlers (Beam1631sml) on the local disturbance (assuming equal and weighted impacts of the different fishing fleets) due to the designation of offshore wind development sites".

Results

Risk analysis – The estimated values of DI revealed that 5.3 % of the total area resulted in values >1, indicating a relatively higher rate of mortality than recovery. In contrast, 0.74 was the maximum value estimated for the weighted disturbance indicator (DI_w). The spatial distributions of the two estimated disturbance indicators differed clearly in the prediction of areas with high values (Fig.1). *Risk evaluation* – Results of the BN for the weighted disturbance indicator indicated that roughly 9 % of the area will face an overall higher level of disturbance compared to the current state.

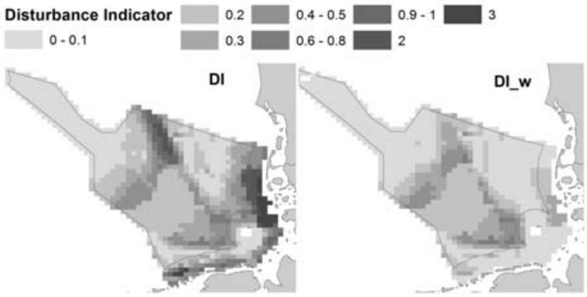

Fig 1: Estimated values of the disturbance indicator (DI) based on an overall local mortality rate with equal weight for the impact scores of the six fishing fleets; right: Estimated values of the disturbance indicator (DI_w) based on an overall local mortality rate with different weights for the impact scores of the six fishing fleets ($is_{BEAM80lrg} = 1$; $is_{BEAM80sml} = 1$; $is_{BEAM1631lrg} = 0.1$; $is_{BEAM1631sml} = 0.1$; $is_{OTTER80lrg} = 0.15$; $is_{OTTER80sml} = 0.15$).

Discussion

Our results likely provide very crude estimates since the benthic communities considered encompassed mainly infaunal species, while epifaunal species may be more vulnerable to fishing disturbance. The observed differences in spatial pattern of the two disturbance indicators were clearly a result of the weighting of the impact of the different fishing fleets. Hence DI and DI_w describe a range of likely outcomes of disturbance modelling with DI_w as lower and DI as upper bound. We identified a transparent assessment of uncertainty as clear shortcoming of many current approaches and conclude that the application of BNs is a promising approach to address this. In conclusion, marine spatial management or MSP processes should embed ERA frameworks which allow for the integration of multiple risk assessments and the quantification of related uncertainties at a common spatial scale.

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