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Evaluation of spatial management scenarios supporting an ecosystem-based approach to MSP - the German case

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Summary
Due to the implementation of spatial management measures such as the designation of areas for offshore wind development or fishing regulations within *Nature 2000* sites, fishing activities within the German *Exclusive Economic Zone* (EEZ) of the North Sea will be increasingly displaced. To support the implementation of an ecosystem approach to marine management, we assess the dynamics of both, ecosystem components such as modelled nursery grounds of flatfish species as well as human drivers such as German fishery fleets on temporal and spatial scales. Furthermore, different spatial co-use options for the coupling of offshore aquaculture and offshore wind farms are assessed to identify potential synergies between human activities. Based on these findings, spatial management scenarios are evaluated across the German management objectives using decision support software. Here, the procedure as well as the main findings are summarised in order to demonstrate the applicability of the tools and methods and the need for an ecosystem-based approach to *Marine Spatial Planning* (MSP) using the German EEZ as a case study area.

Introduction

To date ca. 15% of the total international large beam trawl effort in the German EEZ of the North Sea takes place in areas where offshore wind farms are planned (Stelzenmüller et al., submitted). Competition for maritime space and the need for sustainable food production highlight the need for efficient adaptive management, to avoid potential conflicts as well as create synergies between different activities (Gimpel et al., submitted; Stelzenmüller et al., 2013). The concept of Ecosystem Services is increasingly used to support ecosystem-based resource management (Grêt-Regamey et al., 2012). Assessing e.g. supporting services (habitats) or the provision of food quantitatively appropriates indicators for important European resource management targets such as e.g. the better management of fish stocks (EC, 2014). Within this study, multiple spatial management scenarios are developed to assess the (cumulative) effects of: (i) the implementation of offshore wind farms, (ii) the implementation of fishing regulations within *Nature 2000* sites and (iii) the implementation of co-use options such as offshore aquaculture in combination with offshore wind farms. All scenarios additionally comprise the nursery grounds of plaice *Pleuronectes platessa* as conservation feature. The changes in the ecosystem services affected are evaluated using decision support software.

Materials and Methods

The study area comprised the German territorial waters and EEZ of the North Sea. The main human activities regulated by the German MSP are safety and efficiency of navigation, oil and gas exploitation, cables and pipelines, renewable energy development, aggregate extraction as well as other uses. The allocation of fishing activities is not spatially managed by the MSP (Gimpel et al., 2013; Gimpel et al., submitted; Buck and Buchholz, 2004).
The *P. platessa* nursery grounds were modelled using a *Generalised Additive Model* (GAM) as described in detail in Gimpel et al. (2013). To display the dynamics of the fishery fleets, German VMS (vessel monitoring system) and logbook data from 2005 to 2008 were combined to calculate the average fishing effort (total hours fishing per year) and the catch as described in detail in Stelzenmüller et al.

(submitted). The co-use layers for the combination of offshore aquaculture with offshore wind farm areas were modelled for 13 species of seaweed, bivalves, fish, and crustaceans as described in detail in Gimpel et al. (submitted). Subsequently, decision support software such as Marxan was used to prioritise valuable habitats (i.e. nursery grounds). Furthermore, management options of natural resources were informed focussing on following objectives: to keep the habitat loss of the nursery grounds low while providing the area needed to (i) ensure stable food provision through fisheries (costs: Nature 2000 areas), (ii) ensure food provision through fisheries (costs: Nature 2000 areas + wind farms), and (iii) ensure efficient co-use sites for food production (costs: proximity to harbour). Finally, the sensitivity of solutions was tested by locking selected planning unit statuses.

Results and Discussion

The results illustrate how divergent management objectives can be balanced. The decision support software proved to be useful in identifying areas of concern and in providing decision support while producing a number of different options. Moreover, the trade off between the conservation feature and the (socio) economic targets was facilitated while overlaps among the scenarios including fishery activities were demonstrated. Nevertheless, it has to be mentioned that the cost layer was the strongest driver in determining the outputs. Within this study, we focused on the fishery effort per planning unit. The inclusion of spatial explicit measures between the nursery grounds biomass and the catch of the fishery fleets could indicate the quality of resource management. Therefore, the next step will be the assessment of plaice fishery revenues gained due to the conservation of plaice nursery grounds. Here, an ecological production function approach will be applied, using information about inputs i.e. juvenile fish (biomass) or habitat (m^2) to estimate the production of outputs i.e. fish (biomass or €) per area (m^2). Furthermore, the valuation of aquaculture revenues is envisaged. Assessing the effects of management measures quantitatively in flow of services (in economic and other terms) helps to provide a common language for decision making. Thus, interactions among ecosystem services might be recognised within an ecosystem-based approach to MSP in future.

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