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Evaluating multifunctional use of offshore wind farms in the German EEZ - a GIS modelling approach

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Summary

The concept of multifunctional use of marine offshore areas receives increased significance in the light of sustainable development in heavily used marine areas. Here we defined potential areas in the German EEZ for the co-utilization of offshore wind farms and offshore aquaculture applying integrated multi-trophic aquaculture (IMTA) approaches. We combined a geographic information system (GIS), spatial distribution models and multi-criteria evaluation (MCE) to index suitable multifunctional sites. The procedure as well as the main findings of the GIS-MCE modelling approach are summarised to demonstrate the applicability of the GIS-MCE and the need for modelling techniques for spatial optimisation using geo-spatial tools. Finally, different spatial multi-use scenarios for the coupling of offshore IMTA-systems and wind farms are evaluated in order to support efficient and sustainable marine spatial management (MSP) strategies.

Introduction

Facing the heavy exploitation of wild fish stocks and the increasing demand for aquatic products, aquaculture development needs further attention regarding increasing requirements for water resources (Godfray et al., 2010). Aquaculture poses a huge conflict potential in combination with fisheries related to space issues (Christie et al., in press). Competition for maritime space has highlighted the need for efficient management, to avoid potential conflicts and create synergies between different activities. Considering the German MSP initiatives in the EEZ of the North and Baltic Sea, the objectives are to integrate sustainable development with marine conservation (Gimpel et al., 2013). Integrated Multitrophic Aquaculture Systems (IMTA) ensure economic stability as well as environmental remediation and social acceptance. Multifunctional used sites, indexed in application of a geographic information system (GIS) based multi-criteria evaluation (MCE), reduce the conflict potential regarding space issues. The inclusion of the analytical hierarchy process (AHP) and ordered weighted averaging (OWA) techniques under GIS environment can provide a powerful multi criteria decision-making tool for structuring and solving decision problems including spatial decision problems (Boroushaki and Malczewski, 2008; Al-Yahyai et al., 2012). We developed criteria for the multi use of offshore aquaculture systems in combination with offshore wind farms accounting for these space issues in the German Exclusive Economic Zone (EEZ). The evaluation of different spatial multi-use scenarios regarding the applicability of IMTA systems aims to mitigate human effects and counterbalance the German MSP objectives towards the proposed European framework directive on MSP.

Materials and Methods

Our study area is located in German waters of the North Sea with a surface area of 28.539 km² (http://www.bfn.de/habitatmare/en/schutzgebiete-uebersicht.php). An extensive research regarding the local conditions in the study area and key environmental variables as well as constraints had to be conducted, generating parameters for the targeted species by taking into account the relationship between the spatial distribution of the species and important environmental variables. Altogether 21 possible aquaculture candidates (algea, molluscs, fishes and crustaceans) were selected for the scenario configuration. In order to define areas most suitable for multifunctional use, we extracted data from NOAA (National oceanic and atmospheric administration), and combined them with data provided by the BSH (Bundesamt für Seeschifffahrt und Hydrographie), covering the entire German EEZ. The data included temperature (°C), salinity (PSU), nitrate/nitrite (mg/L), phosphate (µM) and chlorophyll a (mg/m³). Furthermore, we used oxygen (mg/L) and ammonium (µM) data merely provided by the BSH. To complete the set of data, we consulted modelled current speed (m/s) and wave height (m) data, provided by the DKRZ (Deutsches Klimarechenzentrum). In a next step, geostatistical tools comprising a structural analysis and a subsequent interpolation with ordinary kriging (see details in e.g. (Stelzenmüller et al., 2006; Stelzenmüller et al., 2005), were used to compute continuous high resolution spatial layers of those variables for every season and different depth strata. In the course of the MCA, those layers are referred to as criteria. Next, we standardised these multiple criteria into suitability scores (1 – 10, 10 = most suitable) using fuzzy membership functions and reduced them, basing on expert knowledge, for individual suitability maps of each candidate by using the AHP. The AHP provided a pairwise comparison method and therefore a hierarchical structure of the respective criterions. Consequently, we made use of the OWA to generate a wide range of different suitability maps and predictive scenarios by reordering and changing criterion parameters (Gorsevski et al., 2012; Malczewski, 2006; Al-Yahyai et al., 2012), to analyse both: (i) the robustness of the GIS-MCE modelling approach and (ii) the different spatial multi-use scenarios for the coupling of offshore IMTA-systems and wind farms.

Results and Discussion

Analysing the different scenarios seasonally reflected the dependence of each candidate on local conditions in the study area and key environmental variables as exemplified in fig. 1. Moreover, a widespread distribution of the defined suitability scores in adjacent cells (see fig. 1) proved our kriging technique as well as the choice of factors. Common MCE methods involve a huge amount of uncertainty, e.g. sampling errors in raw data, subjective expert judgement, wrong choice of factors, standardisation errors due to linguistic descriptive variables, etc. Using the OWA technique yielded continuous scaling scenarios between the risk adverse and the risk taking operators. Additionally, it addresses the uncertainty from the interaction of ranked criteria. It has been successfully applied in a range of analyses using MCE (Boroushaki and Malczewski, 2008; Malczewski, 2006; Gorsevski et al., 2012). The GIS MCE approach is a tangible tool toward transparent spatial management and the reduction of conflicts regarding space issues among user groups, while demonstrating the need for an ecosystem approach to risk management techniques using geo-spatial tools. Multifunctional use of wind farms in combination with offshore IMTA-systems might be seen as a milestone towards MSP, ensuring the continuity of aquatic resources for future generations, but final decisions still need to be made by decision makers.

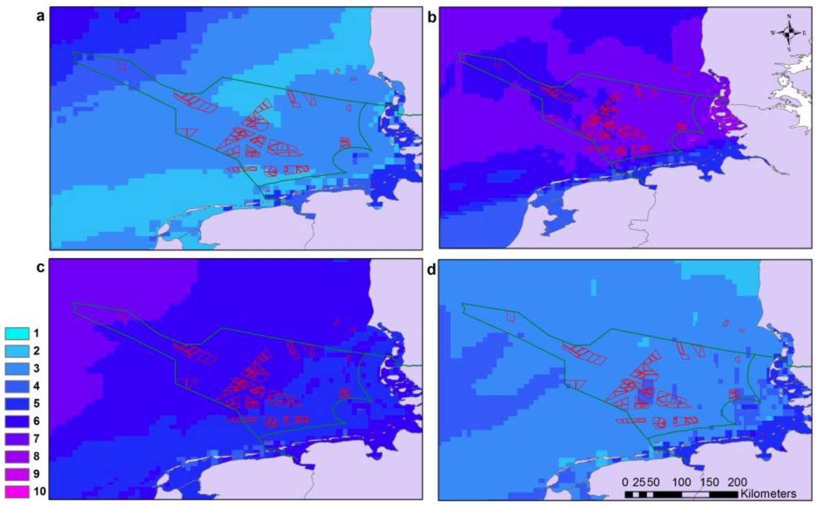

Fig. 1. Suitability maps for sea bass (Dicentrarchus labrax) in the German EEZ; depth: 00 - 10 m; derived by OWA method using the WCL solution (equal order weights); the red framed areas indicate priority areas for offshore wind farms. a) 1st quarter, b) 2nd quarter, c) 3rd quarter, d) 4th quarter; legend: 1 = less suitable; 10 = most suitable.

References

Al-Yahyai, S., Charabi, Y., Gastli, A., and Al-Badi, A. 2012. Wind farm land suitability indexing using multi-criteria analysis. Renewable Energy, 44: 80-87.

Boroushaki, S., and Malczewski, J. 2008. Implementing an extension of the analytical hierarchy process using ordered weighted averaging operators with fuzzy quantifiers in ArcGIS. Computers and Geosciences, 34: 399-410.

Christie, N., Smyth, K., Barnes, R., and Elliott, M. in press. Co-location of activities and designations: A means of solving or creating problems in marine spatial planning? Marine Policy.

Gimpel, A., Stelzenmuller, V., Cormier, R., Floeter, J., and Temming, A. 2013. A spatially explicit risk approach to support marine spatial planning in the German EEZ. Marine environmental research, 86: 56-69.

Godfray, H. C., Beddington, J. R., Crute, I. R., Haddad, L., Lawrence, D., Muir, J. F., Pretty, J., et al. 2010. Food security: the challenge of feeding 9 billion people. Science, 327: 812-818.

Gorsevski, P. V., Donevska, K. R., Mitrovski, C. D., and Frizado, J. P. 2012. Integrating multi-criteria evaluation techniques with geographic information systems for landfill site selection: a case study using ordered weighted average. Waste Management, 32: 287-296.

Malczewski, J. 2006. Ordered weighted averaging with fuzzy quantifiers: GIS-based multicriteria evaluation for land-use suitability analysis. International Journal of Applied Earth Observation and Geoinformation, 8: 270-277.

Stelzenmüller, V., Ehrich, S., and Zauke, G.-P. 2005. Impact of additional small-scale survey data on the geostatistical analyses of demersal fish species in the North Sea. Scientia Marina, 69: 587-602.

Stelzenmüller, V., Ehrich, S., and Zauke, G.-P. 2006. Analysis of meso scaled spatial distribution of dab Limanda limanda in the German Bight: does the type of fishing gear matter? Fisheries Science, 72: 95–104.