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An Integrated End-to-End Modeling Framework for Testing Ecosystem-Wide Effects of Human-Induced Pressures in the Baltic Sea

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Summary

We present an integrated end-to-end modeling framework that enables whole-of ecosystem climate, eutrophication, and spatial management scenario exploration in the Baltic Sea. The framework is built around the Baltic implementation of the spatially-explicit end-to-end Atlantis model, linked to the high-resolution coupled physical-biological model HBM-ERGOM and the fisheries bio-economic Fishrent model. We investigate ecosystem responses to changes in human-induced pressures by simulating several eutrophication scenarios relevant to Baltic Sea management plans. We present the structure and calibration of the Baltic Atlantis and its operational linkages to the other models. Using the results of eutrophication scenarios, and focusing on the relative changes in fish and fishery production, we discuss the robustness of the model linking with respect to the underlying assumptions, strengths and weaknesses of the individual models. Finally, we describe possible framework expansion to account for spatial impacts and economic consequences, by linking to the individual-fishing-vessel based DISPLACE model. We conclude that the proposed model integration forms a robust framework for management strategy evaluation that is of strategic importance to stakeholders from around the Baltic Sea.

Introduction

Due to around 85 million people living within the Baltic Sea catchment area, human-induced pressures in this region are (i) strong, (ii) long lasting, and (iii) affect multiple sectors and areas of the marine ecosystem, from hydrodynamics and nutrient cycling to fish production and broader socio-economic dynamics. In such a heavily perturbed system, evaluating biological and economic effects of single and multiple pressures on the entire ecosystem state is a challenge in relation to Baltic Sea management plans (e.g. EU Directives). To meet this challenge, our goal was to set-up a holistic modeling platform capable of simulating the likely structural and functional ecosystem responses to pressures (e.g. eutrophication) as well as the consequences for ecosystem goods and services. Accordingly, the holistic modeling tool Atlantis (Fulton et al., 2004), already successfully applied for medium to long-term strategic advice on management of marine resources in Australian waters (Fulton et al., 2011), has been implemented as the backbone in a broad Baltic model and management evaluation framework.

Material and Methods

A framework is built comprising the newly developed Baltic implementation of the spatially-explicit end-to-end Atlantis model, linked to the high-resolution coupled physical-biological model HBM-ERGOM (Maar et al., 2011) on the one end, and the fisheries bio-economic Fishrent model (Salz et al., 2011) on the other end (Fig. 1). The Baltic Atlantis contains 33 biological groups including age-structured vertebrates

and biomass pool invertebrates, plants, algae and detritus, the dynamics of which are simulated over 28 horizontal boxes and up to 9 vertical layers. HBM-ERGOM forces the hydrodynamic module of the Baltic Atlantis model, whose output in relative change in fish stock biomass and production given the scenarios drives the Fishrent bio-economic stock and fleet based bio-economic model for the Western Baltic and Kattegat areas. The linkage between Fishrent and the Cost-Benefit Analysis model is currently under development with evaluation of different ecosystem goods and services including fishery and tourism.

Results and Discussion

To investigate indirect consequences of alleviating eutrophication pressure on the Baltic Sea food-web, point source inputs of nitrogen were manipulated inside the Baltic Atlantis. Two scenarios of nutrient reduction compared to baseline resulted in reduced fish production in the Western Baltic and Kattegat region although the magnitude of effects was small (despite dramatic reductions in nutrient inputs). The quantified responses in primary production and phytoplankton community composition were comparable to similar plankton model numerical investigations. Given the nutrient load scenarios, Fishrent simulated 4 bio-economic scenarios for a system simulating 4 fishing fleets exploiting 7 commercial species. Revenue, cost and profit outcomes for each fleet were analyzed for the scenarios.

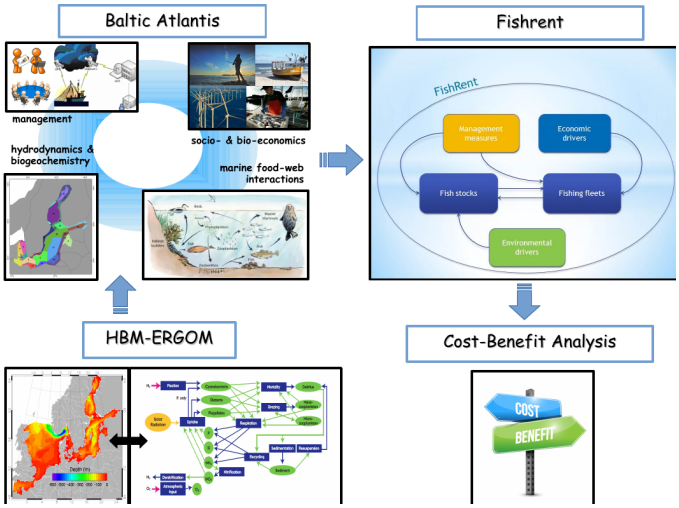

Figure 1: Conceptual model linking for eutrophication scenarios in the integrated end-to-end model framework.

The current analysis focused on the potential changes in fish and fishery production and did not examine other indirect effects of changes in eutrophication, e.g. oxygen related mortality on benthos. Furthermore, due to the so far one-way linking of models, the framework cannot capture all key feedback mechanisms and dynamics in the ecosystem. One future focus and development will be more precise two-way coupling especially between the HBM-ERGOM and the Baltic Atlantis models. The present framework establishes a tool for performing integrated biological/ecosystem and socio-economic simulations in the Baltic Sea systems. The tool provides a means of involving stakeholders in participatory modeling work discussing input and output of the scenarios and simulations in management context.

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