Food web models for ecosystem-based management in the Southern Bight of the North Sea

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The Southern Bight of the North Sea is marked by a vast range of commercial activities and a growing Blue Economy. However, intensive exploitation in this multi-use environment exerts pressures on the marine environment. The impacts of blue economy activities could be mitigated by an ecosystem-based management approach, which has yet to be developed for our study area. Ecosystem-based management requires comprehensive, quantitative assessment methods for the environmental impact of commercial activities. Ecosystem models enable the evaluation of anthropogenic activities' effects on the marine environment across current and potential future scenarios, facilitating the development of an ecosystem-based decision framework. For sustainable fisheries management in particular, food web models can be used to explore and quantify the effects of prospective policy changes on food web dynamics.

Food web models describe the predator-prey interactions between a set of functional groups. Estimates calculated by these models can be interpreted as ecological indicators, providing quantitative assessments of ecosystem health. By simulating potential future scenarios, the impact of policy changes can be investigated. However, to provide accurate predictions, a food web model must be tailored to reflect local conditions. Currently, the most specific models available for our study area cover both the southern and central North Sea. To date, no food web model has been tailored to the Southern Bight of the North Sea.

To enable ecosystem-based management, two mass-balanced snapshots of the Southern Bight of the North Sea have been developed, i.e. for 1991 and 2018, using Ecopath. These models describe the relationships between 32 functional groups across different trophic levels, ranging from harbor porpoise to phytoplankton. Biomass estimates for these groups were obtained from International Council for the Exploration of the Sea (ICES) reports. All data was quality controlled, and for species where accurate biomass data was not available, biomass was either estimated using the method of Sparholt (1990), extracted from scientific literature, or obtained from other models with overlapping study areas. Biomass data was complemented with dietary information adjusted from a model developed by Stäbler *et al.* (2016) based on fish stomach data from the Centre for Environment, Fisheries and Aquaculture Science (CEFAS). Productivity and consumption rates were estimated using empirical formulas (i.e., Pauly (1980), Nilsson and Nilsson (1976)). Fisheries information was integrated into the model as nine commercial fleets, five recreational fleets and mussel aquaculture.

The 1991 and 2018 Ecopath models for the Southern Bight of the North Sea developed in this study provide valuable insight into the local food web and its interactions with commercial and recreational fisheries fleets. A first analysis of the 1991 model using thirteen ecological indicators, as well as two fisheries indicators, suggests that the Southern Bight of the North Sea had not yet recovered from historical overexploitation. A comparison with ecological indicators from the 2018 model will be a first step towards understanding how this ecosystem has evolved. Model predictions can then be used to explore prospective policies' impacts on food web dynamics. Insights obtained from these models will provide guidance for ecosystem-based fisheries management in this economically and ecologically important marine region.

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Keywords
Trophic Interactions; Ecopath With Ecosim; Fisheries Management; Multi-use