Food web models to support decision making in sustainable pelagic fisheries

Martha Stevens (martha.stevens@vliz.be), Steven Pint (steven.pint@vliz.be),
Rutendo Musimwa (rutendo.musimwa@vliz.be), Ward Standaert (ward.standaert@vliz.be),
Gert Everaert (gert.everaert@vliz.be)

VLIZ, Flanders Marine Institute (Belgium)

Introduction

Ecosystem-based management requires comprehensive, quantitative assessment methods of the benefits and burdens of activities in the blue economy. Such an ecosystem-based decision framework is yet to be developed for the Southern Bight of the North Sea. Ecological models can bridge this gap, by integrating available data into decision-making tools for stakeholders and policymakers. For sustainable fisheries management in particular, food web models can be used to explore the effects of prospective policy changes.
Food web models describe the predator-prey interactions between a set of functional groups [Cohen, 1978; Drossel et al., 2003; Pimm, 1982]. This can then be used to answer questions ranging from fisheries production[4], to pollution [Mackay, 1989] and climate change effects [Zhang et al., 2017]. By simulating potential future scenarios, the impact of altered anthropogenic activities or potential policy changes can be investigated. However, to provide accurate predictions, a food web model must be tailored to reflect the local ecosystem. Currently, the most specific models available for our study area, the Southern Bight of the North Sea, have a spatial extent ranging from Skagerrak to the English Channel [Stäbler et al., 2016; Püts et al., 2020]. This area can be divided based on bathymetry and differing oceanographic conditions into the deeper central North Sea and the shallow Southern Bight of the North Sea [ICES, 2022]. Although the distinct environmental characteristics of the Southern Bight are well-described, to date, no food web model has been tailored to address questions concerning the sustainable management of fisheries for this particular ecosystem.

Methodology

Using Ecopath with Ecosim, a software to create mass-balanced food web models, two snapshots of the Southern Bight ecosystem have been developed for 1991 and 2018 respectively. These models describe the dietary relationships between 32 functional groups ranging from harbor porpoise to fish, invertebrates, plankton and detritus (Figure 1). Biomass estimates for these groups were obtained from various International Council for the Exploration of the Sea (ICES) reports (specified in technical report [Pint et al., (2023]). For species where this data was not available, biomass was either (1) estimated according to the method of Sparholt [1990], (2) extracted from scientific literature, or (3) estimated based on other models with overlapping study areas [Stäbler et al., 2016; Mackinson et al., 2008]. The relationships between functional groups are based on species diets, which were adjusted from Stäbler et al. [2016] based on fish stomach records from the UK Centre for Environment, Fisheries and Aquaculture (CEFAS). Other model parameters such as productivity and consumption rate, were estimated using empirical formulas [Möckeln et al., 1976; Pauly, 1980]. The impacts of fisheries fleets on ecosystem dynamics have also been incorporated in both models. Our approach also includes recreational fisheries, which have often been overlooked in the development of food web models even though these activities are highly impactful for certain species. For example, 27% of the total removals of European sea bass can be attributed to recreational fisheries [Hyder et al., 2018]. Hence, data on recreational fisheries activities in Belgium from Verleye et al. [2023]

were extrapolated to the Southern Bight of the North Sea. Whereas commercial fisheries landings and discard data were obtained from the Scientific, Technical and Economic Committee for Fisheries (STECF) and ICES reports. Finally, to obtain a model in equilibrium, i.e., an ecosystem where no more than the available biomass is being consumed, both models have been mass-balanced using pre-balance diagnostics as suggested by Link et al. [2010] and Heymans et al. [2016].

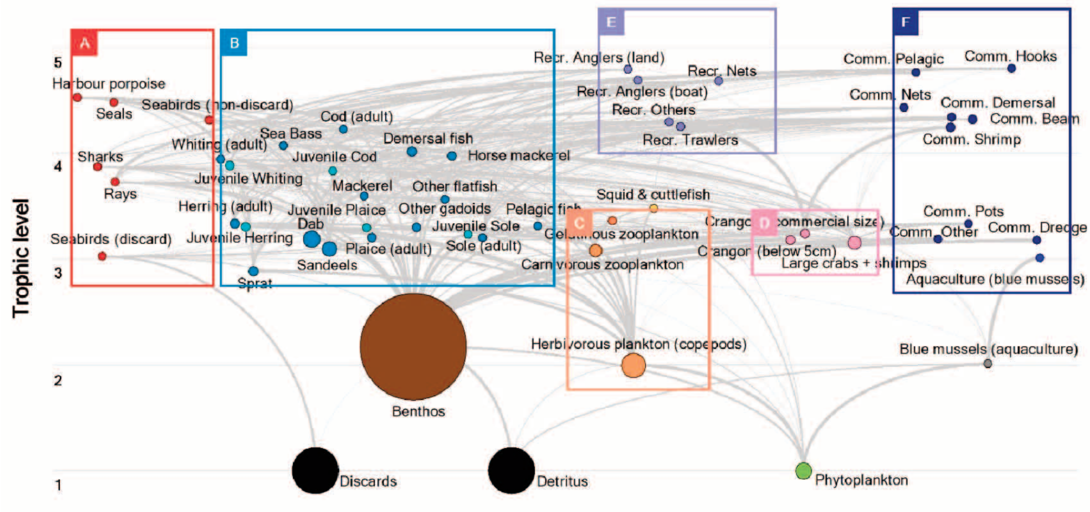

Figure 1 The 2018 Southern Bight of the North Sea food web model. Circles represent functional groups with their size indicating biomass. Rectangles highlight related functional groups or fisheries fleets: A. predators, B. commercial fish species, C. plankton, D. crabs and shrimp, E. Recreational fisheries and F. commercial fisheries.

Conclusion

A comparison of the 1991 and 2018 Ecopath models for the Southern Bight of the North Sea developed in this study shows that both the biomass and trophic level of catch have decreased, suggesting that the exploitation between these years has not been sustainable [Pauly et al., 1998]. Next, these models can serve as a base to run time-dynamic simulations in EcoSim, which allows the exploration of prospective policy impacts on food web dynamics. Insights obtained from these models can provide guidance for ecosystem-based fisheries management in this economically and ecologically important marine region.

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