Project brief

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Fish Stocks and Fisheries in Transition: Adaptation and Sustainability of Coastal Seas

Anna Akimova[1], Tobias Lasner[1], Dario Fiorentino[1,2], Felix Albrecht[1], Ralf Döring[1], Tahereh Nakisa[1], Ismael Nunez-Riboni[1], Daniel Oesterwind[2], Maria Pierce[2]

- **Together with project partners, we developed an integrated coastal modeling system to realistically simulate the impacts of current and future climate change and human activities on marine ecosystems - particularly on fish and their offspring.**
- **Together with fishing companies, we examined the challenges posed by structural changes in fisheries and analyzed future opportunities for the industry.**
- **We examined whether the fisheries policy principle of relative stability allows fisheries to efficiently adapt to future ecosystem changes.**

Background and objectives

Coastal seas are of central importance to us: they provide food, energy, and raw materials, serve as major transport routes, and are popular touristic destinations. At the same time, they are increasingly under pressure from climate change and intensifying human use.

Within the research mission "Protection and Sustainable Use of Marine Areas" of the German Marine Research Alliance (DAM) (https://www.allianz-meeresforschung.de/en), more than 250 scientists were working to improve our understanding of the ecological, economic, and societal consequences of marine use. In particular, the mission project "CoastalFutures – Phase I" developed advanced models and assessment methods to explore various use scenarios and evaluate future options for sustainable management of the North and Baltic Seas. Such tools allow for a more robust assessment of the impacts of climate change and activities across different economic sectors on marine ecosystems. The Institute of Sea Fisheries and the Institute of Baltic Sea Fisheries contributed to the project with their extensive expertise on fish and fisheries.

Approach

The focus of "CoastalFutures – Phase I" was on developing innovative, integrated coastal modeling systems to explore and assess future use scenarios and conservation measures in collaboration with authorities and stakeholders. The Thünen Institute contributed to the development of two modules: individual-based models for fish larvae and species distribution models for juvenile and adult fishes. Both modeling approaches are particularly useful to study impacts of climate change and human activities, such as offshore wind farms, on fish stocks, their distribution, and reproductive success. This information is highly relevant for fisheries management, as these processes influence future fishing grounds and the sustainable level of harvesting of fish resources.

In three dialogue forums with fishing companies and officials, we critically reviewed the vision for multiple uses of the North and Baltic Seas. This vision has been developed at the Thünen foresight workshop "Coastal Fisheries 2045" (Fig. 1). The forums enabled us to better understand potential future pathways for sustainable fisheries. In addition to the dialogue forums, we conducted individual interviews with fishermen, mayors, fish traders, and restaurateurs. Our discussions in Büsum, Wittdün, Neuharlingersiel, and Greetsiel highlighted the local challenges faced by fisheries during the ongoing structural change.

Figure 1: Future Vision: Multiple Use of Coastal Fisheries 2045 (Source: Lasner und Barz 2023, ©Thünen Institute / Grosse-Adda).

Furthermore, we paid particular attention to the principle of relative stability as a key part of European fisheries policy. We assessed whether it still provides the fishing industry with enough flexibility to remain sustainable in the face of the future changes in the marine ecosystem.

Results

❖ Fish distribution models for the North and the Baltic Seas

Species distribution models are widely used to study species' past and present distributions and to predict how their habitats may shift in response to climate change. Our extensive literature review showed that common approaches often do not check whether the statistical models align with

the concept of the ecological niche. Our tests with different models demonstrated that predictions are more reliable when this criterion is taken into account (Fiorentino et al., 2025). We applied the improved modeling approach to 11 commercial fish species in the North Sea and 7 species in the Baltic Sea. We incorporated information on temperature, salinity, depth, and oxygen to analyze the past distributions of commercial fish and to project their distributions into the future. The results indicate that the southern North Sea is likely to become less suitable for cod, plaice, haddock, and whiting, while sole, saithe, and hake may expand their ranges there. In the western Baltic Sea, the future habitat is expected to be less suitable for cod, plaice, and turbot, but more favorable for flounder. We have integrated our models into the coastal modeling system and published the distribution maps in the Thünen-Atlas (https://atlas.thuenen.de/atlanten/meeresatlas) as an interactive, freely accessible tool for stakeholders and general public.

❖ Models of Fish Larvae

The larval stage is crucial for the recruitment success of marine fish, and it is particularly sensitive to changes in the ecosystem. To better understand these vulnerable processes, biologists use so-called individual-based models. We reviewed over 40 existing models for various fish species and examined which approaches are most suitable for simulating the impacts of offshore wind farms and climate change on larval survival. Building on this review study, we created an online library for fish larval models (Fig. 2). This freely accessible platform brings together computational models as well as key laboratory and field data needed for developing and validating individual-based physiological models.

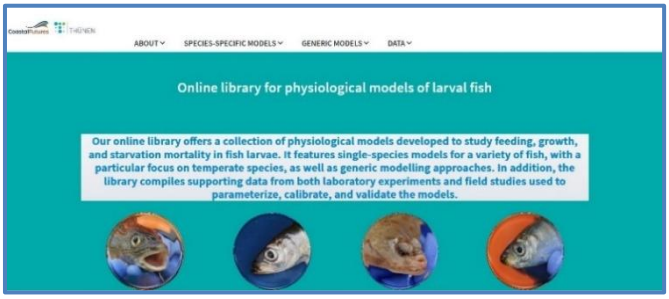

Figure 2: Homepage of the open-access Online model library of larval fish (https://larval-fish-library.thuenen.de /©Thünen Institute).

We have already published models for cod, herring, sprat, anchovy, smelt, and bluefin tuna. The online library is intended to be continuously expanded in collaboration with the research community to promote knowledge exchange and model development.

In the scope of "CoastalFutures – Phase I", models for cod, sprat, and herring larvae have been further integrated into the coastal modeling system and adapted for scenario simulations.

❖ The Future of Fisheries – Stakeholder Priorities and Institutional Frameworks

In the current vision for the future of fisheries (Fig. 1), spatial competition between offshore wind farms and their associated onshore infrastructure (e. g., cable routes) and fishing grounds is a central issue. At the same time, fisheries are affected by a wide range of additional pressures, including liquefied natural gas infrastructure, nutrient inputs from agriculture, growing tourism, conservation measures, predators such as cormorants and seals, and the impacts of climate change on the entire marine ecosystem.
All these factors are elements of a broader structural transformation of a complex social–ecological system linked to fisheries. They affect both offshore activities and onshore components of fisheries such as ports and value chains. On the path toward multiple use of the North and Baltic Seas, fisheries face several key challenges. These include the need for a clear legal framework to ensure planning security for fishing enterprises, modernization of the ageing fleet, access to external capital for necessary investments, and the recruitment of new employees to the sector.
Equally important are improving the public image of fisheries, developing new business opportunities beyond fishing itself, and increasing flexibility to target new species and fishing grounds. However, such flexibility is institutionally constrained by the relatively rigid principle of "relative stability" in quota allocation, which is a core element of the European Union's Common Fisheries Policy (CFP). Potential pathways toward greater flexibility could include reforms that expand the scope for action of producer organizations or adjustments to quota allocation keys based on social and ecological criteria (Article 17 of the CFP). The latter, however, would require sustained political commitment, which may struggle to keep pace with the speed of ongoing structural and ecosystem changes.

Conclusions

Climate change and the intensive use of coastal areas are placing increasing pressure on fish stocks and fisheries in the North Sea and the Baltic Sea. Models and socio-economic analyses help us assess possible future scenarios and evaluate management options. A future-oriented adaptation of fisheries must follow a two-pronged approach: in the short to medium term, measures are needed to make the sector more resilient; in the long term, reforms of the legal framework are required to ensure ecologically sustainable and economically viable fisheries in the future.

Further information

Contact
[1]Thünen Institute of Sea Fisheries
anna.akimova@thuenen.de

Partner
[2]Thünen Institute of Baltic Sea Fisheries
Helmholtz-Zentrum Hereon
Leibniz Institute for Baltic Sea Research Warnemünde - IOW

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Publications

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