

# Project *brief*

Thünen Institute of Sea Fisheries

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## Top predators, fisheries and climate change: Which environmental factor has the greatest impact on the food web in the southern North Sea?

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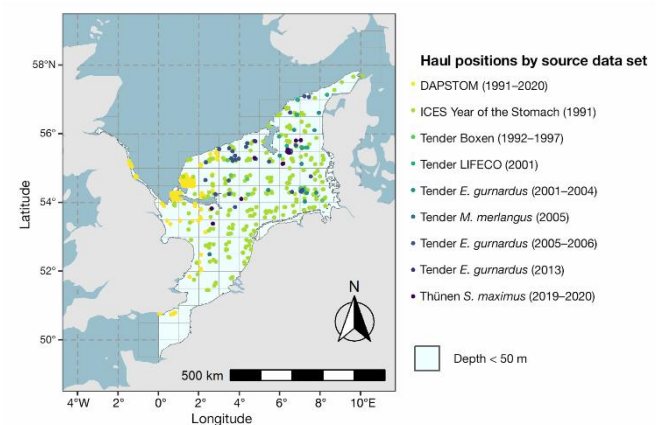
- A decline in fishing intensity and reduced nutrient inputs from the major rivers have altered the interactions within the North Sea food web over the past few decades.
- The biodiversity of the fish fauna has changed in both taxonomic and functional terms.
- An ecosystem model shows that, in order to assess the impacts of climate change, aside from temperatures, nutrient concentrations and primary production must be taken into account.

### Background and Objectives

Fishing pressure influences marine food webs by primarily targeting large predatory fish species. Whilst fishing intensity in the North Sea has declined over recent decades, predatory fish have become more numerous again and are increasing predation pressure from the top of the food chain ('top-down'). At the same time, nutrient loads from the Elbe and Rhine rivers have declined significantly. This has reduced the 'bottom-up' processes at the lower end of the food chains, namely the 'fertilisation' of the ecosystem and the production of planktonic algae. In the BioWeb project, we investigated what the food web of the southern North Sea looks like under these new conditions – and how it will respond to future changes.

### Approach

We were able to draw on comprehensive datasets from national and international research surveys spanning several decades, which were conducted under the leadership of the Thünen Institute. Our focus was on demersal fish communities i.e., those living on or above the seabed. We were particularly interested in their 'traits', which are fixed, measurable functional characteristics of the respective species. For our analyses, we supplemented an existing trait database of North Sea fish with additional traits relevant to their feeding relationships. We combined the trait profiles of individual fish species with datasets from various research investigations of stomach contents of North Sea fish (Fig. 1). To find out which traits are statistically significant in predator-prey relationships between fish, we used the complementary, multivariate methods of RLQ ordination and Fourth-Corner analysis. In a supplementary study, we examined the feeding relationships of squids, because these are currently becoming increasingly significant in the North Sea food web. To this end, we investigated their fatty acid composition to explore a meaningful detail: We wanted to know whether qualitative differences exist in the fatty acid patterns of the most common



**Figure 1:** Overview of stations with data on the stomach contents of demersal fish. Our analysis of predator-prey trait relationships and feeding selectivity is based on these data (Source: adapted from Ludwig et al. 2024).

squid species that would suggest they feed on different types of prey.

Finally, we optimised the 'Ecopath with Ecosim' ecosystem model. Our aim here was to enable as comprehensive a view as possible of the 'top-down' and 'bottom-up' dynamics in food webs across time and space.

### Results

We visualised spatiotemporal trends in the dominance of certain functional traits within fish communities using a series of maps. This enabled us to demonstrate shifts in the distribution patterns of ecological functions. A statistical comparison of the trait profiles (Fig. 2) of predatory fish and their prey revealed that, among the predators' traits, only their content of polyunsaturated omega-3 fatty acids was significantly linked to the traits 'energy content' and 'mobility' of the prey fish. This is reflected above all in the relationships between whiting or grey gurnard to the schooling fish herring and sprat, which form their prey. The fact that other trait

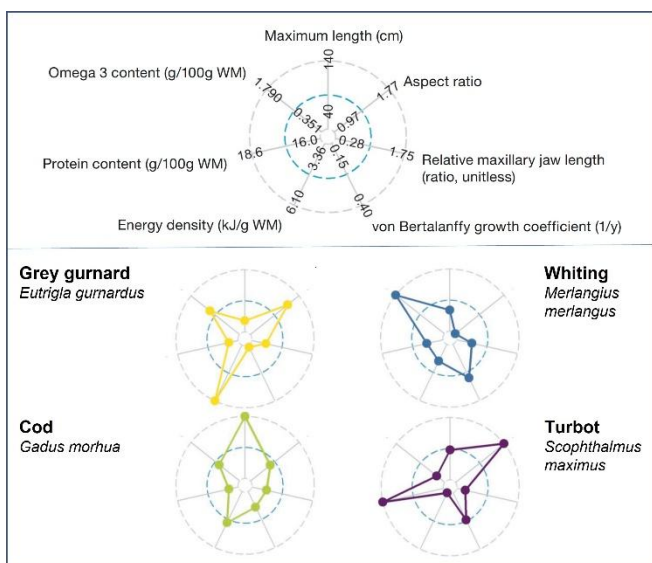
profiles were not clearly linked can be attributed to the variable and opportunistic prey selection of numerous predatory fish species (Ludwig et al. 2024). Selectivity analyses revealed a preference for sandeels in both, grey gurnard and whiting. Cod showed a preference for dab as well as for members of its own family (Gadidae), particularly whiting. However, there were also marked differences in prey preference among cod individuals. This was presumably the reason why no significant associations with the functional characteristics of the prey were found here.

The new, expanded version of the ecosystem model for the southern North Sea comprised 81 functional groups of organisms that shared overarching characteristics (for example, zooplankton). The model was adapted to better represent future climate scenarios. Using three ‘what-if’ scenarios, we tested four drivers simultaneously: (1) seawater temperature, (2) primary production intensity, (3) marine mammal biomass, and (4) fishing effort. The comparison clearly showed that ‘bottom-up’ driven processes dominate the dynamics: nutrient concentrations, or rather the reduction of nutrient loads, have a particularly strong effect on the ecosystem. By contrast, ‘top-down’ processes driven by marine mammals led to changes in the biomass of their direct prey only in a limited number of cases.

### Conclusions

The trait-based analysis of predator-prey relationships using RLQ and Fourth-Corner analyses offers new possibilities. It contributes to our understanding of the dynamics of food webs in the context of climate change and the resulting shifts in species distribution (Ludwig et al. 2024). However, this approach requires sufficient availability and quality of data on food-related traits.

Using the extended ecosystem model for the southern North Sea, we have demonstrated systemic changes resulting from individual drivers. It became clear that ‘bottom-up’ processes will play a decisive role in future changes of the ecosystem. Climate impact scenarios for the southern North Sea should therefore include not only the effect of rising temperatures but also the intensity of primary production.



**Figure 2:** Profiles of functional traits in selected North Sea fish. The polar plots in the lower panel show the trait profiles of the adult fish. The traits themselves and their ranges are shown in the upper panel (Source: adapted from Ludwig et al. 2024).

Together with scientists from the Thünen Institutes of Fisheries Ecology and Baltic Sea Fisheries, we analysed squid tissue samples. This revealed species-specific differences in the fatty acid patterns of the shortfin squid *Illex coindetii*, the northern squid *Loligo forbesii* and the small arrow squid *Todaropsis eblanae*, providing strong evidence that these cephalopods have different feeding habits (Schäfer et al. 2024). Furthermore, a correlation was demonstrated between the size of the squids and their fatty acid composition, which is associated with shifts in squid diet as the individuals grow.

## Further information

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### Publications

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