# Habitat suitability modelling of pelagic fish using a mechanistic approach: Insights for Sustainable Decision-Making in the Belgian part of the North Sea

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

VLIZ, Flanders Marine Institute (Belgium)

**Introduction**

The economic landscape of the North Sea is significantly impacted by pelagic species, making it crucial to thoroughly understand their migration patterns and habitat preferences to support sustainable fisheries management. After Brexit, Europe shifted its focus from demersal fisheries, prevalent before Brexit, to pelagic fisheries, primarily due to the closing of the United Kingdom's fishing grounds for foreign fishermen. Belgian fishermen, for instance, have been affected as they can no longer fish for flatfish e.g., *Solea solea* in UK waters. Consequently, the exploration of pelagic fisheries in the Belgian Part of the North Sea (BPNS) has gained prominence.

This transition necessitates ecological models like the mechanistic niche models which provide invaluable insights into environmental drivers and population dynamics. These models predict suitable habitats using the mathematical description of the species' niche by understanding their interaction with the environment. Furthermore, this tool can incorporate climate-induced habitat suitability, delving deep into the intricate relationship between changing environmental conditions and the distribution of pelagic fish. In the face of the challenges posed by a changing climate, this multifaceted research provides insights that pave the way for developing informed and sustainable management strategies.

**Mechanistic Model: Data and model**

The mechanistic modelling approach employed in this study was adapted from Westmeijer et al. [2019] for modelling pelagic fish distribution in the Belgian Part of the North Sea (BPNS). The study selected target fish species based on their economic importance and regional occurrence (i.e., Clupea *harengus* (Atlantic herring), *Scomber scombrus* (Atlantic mackerel), and *Dicentrarchus labrax* (European Seabass). Informed by fish niche ecology, we collected key influencing variables (as detailed in Table 1). To ensure data consistency and accuracy, a rigorous preprocessing phase was undertaken, involving the handling of missing data and standardizing units. Species-specific response curves were derived from a thorough review of existing literature and expert knowledge (see Figure 1), and these insights were integrated into our models using advanced population modelling techniques. The study employed fuzzy logic principles, which permit habitat suitability values to span any real number between 0 and 1, to explore the full spectrum of habitat conditions and their influence on fish distribution. These insights were integrated into the mechanistic models, allowing for predicting habitat suitability indices (HSI) under various conditions. To assess the impact of climate change on these species, the study utilised climate prediction data for temperature and salinity from Bio-Oracle [Assis Jet al., 2018; Tyberghein et al., 2011].

| Variable | Units | Clupeaharengus | Scomber scombrus | Dicentrarchus labrax |
|---|---|---|---|---|
| Sea surface temperature | °C | x | x | x |
| Sea surface salinity | PSU | x | x | x |
| Bathymetry | m | x | x | x |
| Human artefacts | m | x | x | x |
| Seabed energy | / | x | | |
| Seabed substrate | / | x | | |
| Sea surface velocity | m s-1 | | x | |
| Euphotic depth | m | | x | |
| Dissolved oxygen | mmol m-3 | | x | |
| Diet | g C m-2 | x | x | |

**Table 1** Variables included per species.

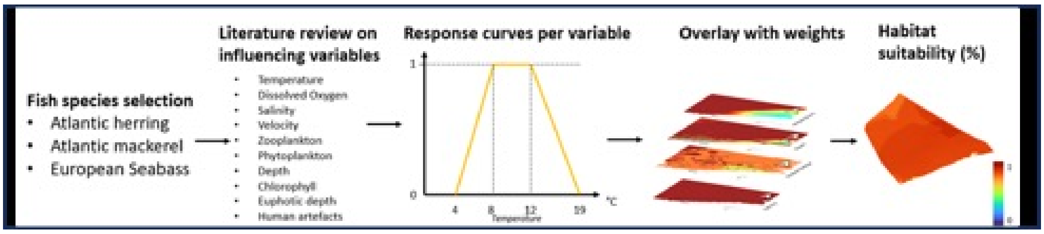


**Figure 1** Work plan for the mechanistic approach with an example of one of the response curves produced.

All habitat suitability maps were uniformly resampled at a resolution of 100 m x 100 m and subsequently analysed using R [R Core Team, 2018] Different models were developed for spawning and non-spawning adults, focusing on temporal variations achieved by modelling each month separately. What-if scenarios based on climate change scenarios were used to simulate the habitat suitability of the selected species. Our analysis covers the period from 2020 to 2090 and was first applied to the Belgian part of the North Sea and then extended to the European Seas. We validated our models with fish occurrence data from various literature and OBIS data (www.obis.org).

**Results**

Warming oceans and changing salinity levels due to climate change were projected by the study to push economically important fish species in opposite directions. Warmer waters will likely make northern areas more suitable, while changes in salinity may push these fish south as seen for Atlantic herring (Figure 2). Under the worst-case scenario, the suitable habitat for all three fish species could be moved over 500 kilometres north due to rising temperatures. This northward movement due to climate change has been documented [Hu L et al., 2022;

Overholtzet al., 2011; Perry et al., 2005]. Our study unveiled that, climate-driven migrations of pelagic fish in European seas create a dynamic but an unresolved environment with the post-Brexit landscape. To navigate this intricate challenge, innovative solutions and renewed international commitment are essential for securing a sustainable future for both the marine environment and dependent communities.

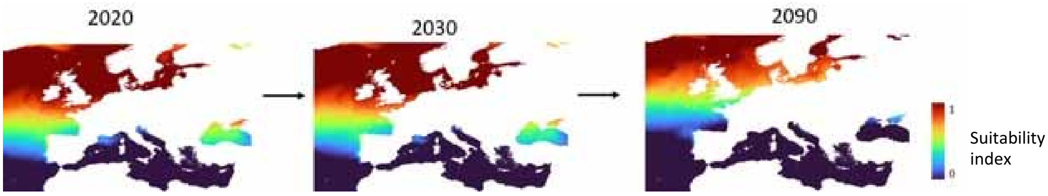


**Figure 2** Habitat suitability predictions for Atlantic herring for current (2020) and future (2030 & 2090) due to sea surface temperature SSP585 pathway predictions. Habitat suitability areas are shown to migrate more to northern latitudes. HSI Red is high habitat suitability and blue is low habitat suitability.

**Acknowledgements**
This work was supported by the Brexit Adjustment Reserve project (BAR) [0051] together with the Flanders Marine Institute (VLIZ) and the EU Public Infrastructure for the European Digital Twin project (EDITO-Infra).

**References**

Westmeijer G., Everaert G., Pirlet H., De Clerck O., Vandegehuchte M.B., (2019). *Mechanistic niche modelling to identify favorable growth sites of temperate macroalgae*. Algal Res 2019;41:101529.

Assis J., Tyberghein L., Bosch S., Verbruggen H., Serrão E.A., De Clerck O., (2018). *Bio-ORACLE v2.0: Extending marine data layers for bioclimatic modelling*. A Journal of Macroecology 2017;27:277–84.

Tyberghein L., Verbruggen H., Pauly K., Troupin C., Mineur F., De Clerck O., (2011). *Bio-ORACLE: A global environmental dataset for marine species distribution modelling*. Global Ecology and Biogeography 2012;21:272–81.

R Core Team, (2018). *R: A Language and Environment for Statistical Computing*. R Foundation for Statistical Computing [Internet] 2023 [cited 2023 Aug 11]; Available from: https://www.R-project.org/

Hu L sha, Dong Y wei, (2022). *Northward shift of a biogeographical barrier on China's coast*. Divers Distrib 2022;28:318–30.

Overholtz W.J., Hare J.A., Keith C.M., (2011). *Impacts of interannual environmental forcing and climate change on the distribution of atlantic mackerel on the U. S. northeast continental shelf.* Marine and Coastal Fisheries. 2011;3:219–32.

Perry A.L., Low P.J., Ellis J.R., Reynolds J.D., (2005). *Climate change and distribution shifts in marine fishes*. Science (1979) 2005;308:1912-1915.