# Predictive modelling of Atlantic herring distribution in the North Sea for informed decision-making

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**Introduction**
Due to the withdrawal of the United Kingdom from the European Union, the Belgian fishing fleet lost access to part of their fishing waters in the southern North Sea and the English Channel and experiences diminished catches (estimated at a loss of 3.7 million euro in 2023). The Belgian fishing fleet currently targets bottom dwelling fish. One of the initiatives to overcome the loss of fishing grounds is to provide information about alternative fishing grounds and niche fisheries, such as pelagic fishing, as financed through the Brexit Adjustment Reserve. Because the Belgian fishing fleet targeted bottom dwelling fish in past decades, the whereabouts of pelagic fish are often unknown, anecdotical, or expert based. Habitat suitability models have been widely used to derive species-environment relationships and predict the geographical distribution of species. This study developed habitat suitability models for an important commercial pelagic fish species, Atlantic herring (*Clupea harengus*). Both adults and larvae were modelled separately.

**Materials & methods**
We retrieved occurrence data of both adult and larval Atlantic herring from DATRAS trawl surveys from 2000 to 2020 (21 023 records in total). To have sufficient data to create robust models, models spanned the spatial extent of the entire northwestern European Shelf, however model outcomes will focus on the southern North Sea. Occurrences were sampled to account for sampling bias and spatial autocorrelation to a final dataset of 800 occurrence records (400 for adults and larvae each).

Environmental variables were derived from the European Marine Observation and Data Network (EMODnet) and Copernicus Marine Service, including depth, sea surface temperature, sea surface salinity, zooplankton, phytoplankton, distance to windfarms and seabed characteristics. Preprocessing of the environmental variables involved aggregation to a 10 NM by 10 NM grid per month to match the spatiotemporal resolution of the occurrence data.

To create species-environment relationships, spatiotemporal maximum entropy (MaxEnt) models were developed in R. Eighteen unique combinations of model settings were tested using the corrected Akaike's Information Criterion (AICc). Model performance was evaluated using 5-fold cross-validation. Finally, spatial predictions were created for each month of the period January 2000 to December 2020.

**Results & Discussion**
Both models performed well with Area Under the Curve (AUC) values above 0.7. In 2020, habitat suitability indices for the southern North Sea ranged from 0.3 to 0.7 for adults and from 0 to 1 for larvae. Adult Atlantic herring are most likely to be present in the southern North Sea during January and February (average habitat suitability index, HSI, of 0.6 and 0.7 respectively). For larvae presence is most likely during December and January (average HSI 0.5 and 0.6 respectively). The model highlighted the generalistic character of adult herring, being tolerant to a wide range of environmental gradients. Depth explained 63% of the variability in the adult distribution, and SST explained 13%. Adult herring were present mostly along European continental shelf waters, at sea surface temperatures between 3 – 20 °C, with a preference for 7°C.

The larval model showed more specific needs and preferences, including specific seabed substrate and a dependency of spawning success on food sources (phyto- and zooplankton). In the spatiotemporal predictions a shift of spawning events can be seen from the north during summer to the south during winter.

In order to maintain a sustainable population of herring, it is important to preserve their spawning ground. Both larvae and adults are simulated to be present during winter months in the southern North Sea. Since trawling can alter the substrate of spawning grounds and destroy deposited eggs, fisheries need to be well managed during this period.

On top of this, due to Atlantic herring's preference towards colder water temperatures, global warming might disrupt their current migration patterns. A shift towards more northern spawning grounds might be hindered for autumn-spawning herring by shorter daylengths during winter in the north.

**Keywords**
Atlantic Herring; Species Distribution Modelling; Sustainable Blue Economy; Fishery; Northwest European Shelf