Abundance indices of the chub mackerel (Scomber japonicus) in the EEZ of the Russian Federation

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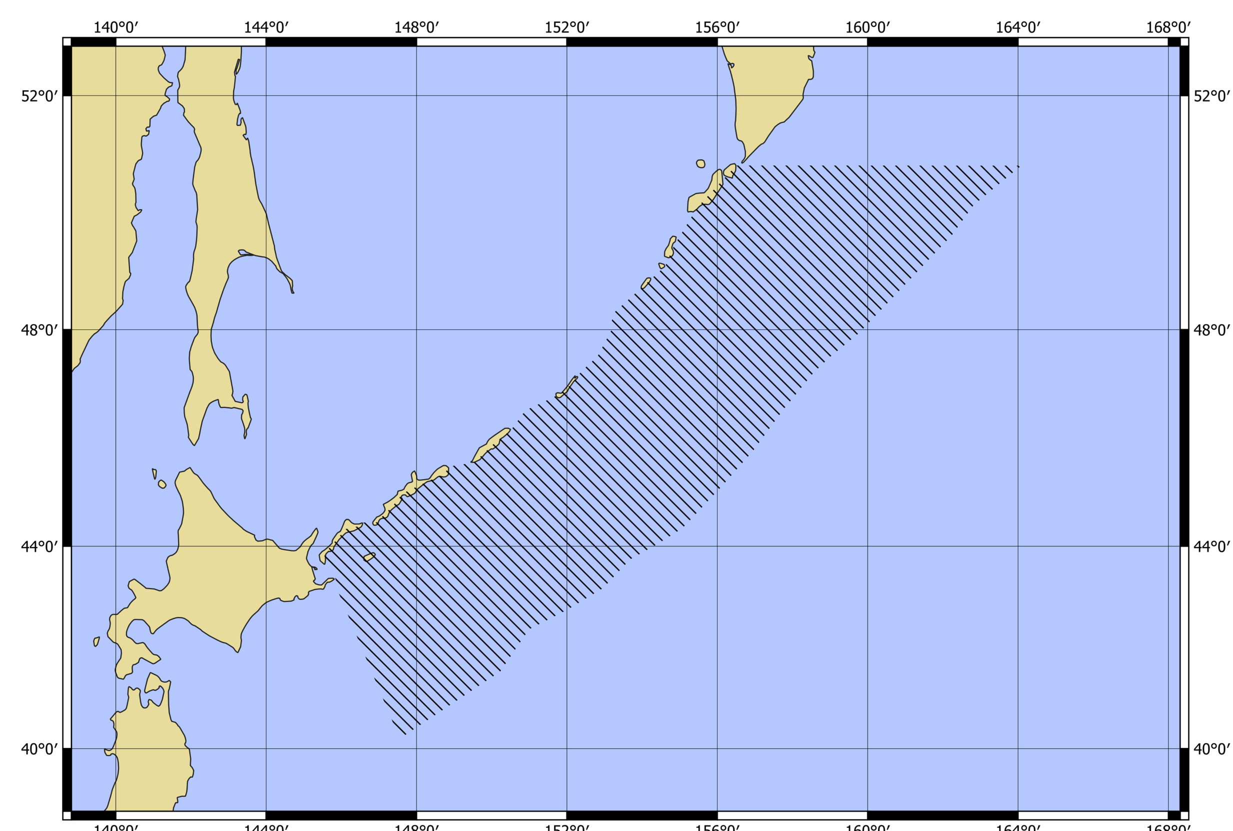

Fig.1 The chub mackerel fish area in Russian EEZ

The chub mackerel (Scomber japonicus) is one of the most significant commercial fish species in the Northwest Pacific Ocean (FAO Statistical Area 61). Chub mackerel is a transboundary stock, harvested by Japan, Russia, and China. Until recently, Russia did not conduct a specialized mackerel fishery in the Northwest Pacific. The Russian fishery resumed its catch in 2015. In recent years, a consistent decline in Russian catches has been observed. While the Russian catch was 98,812 tonnes in 2018, it dropped to 7,200 tonnes in 2024. Throughout its range, chub mackerel is characterized by extensive migrations, which allow the population to occupy a vast area in different seasons by utilizing favorable habitats (primarily feeding grounds), thereby defining its transboundary status.

For pelagic species characterized by high spatio-temporal variability in distribution, traditional methods for calculating abundance indices, based on simple averaging of catch per unit effort (CPUE), can yield biased estimates. Modern approaches involve standardizing CPUE by accounting for the influence of environmental factors, fishery characteristics, and spatio-temporal autocorrelation in the data.

The initial data consisted of daily catch per unit effort, expressed in tonnes per vessel-day, for chub mackerel over a nine-year period (2016–2024). These data were interpreted as abundance indices. For the analysis, a computational grid corresponding to the spatial distribution of fishing effort was constructed.
Statistical analysis was performed in the R environment using the sdmTMB package, designed for fitting Generalized Additive Mixed Models (GAMMs) with Gaussian Markov Random Fields (GMRFs). This approach allows for the explicit accounting of spatial and temporal dependence in observations, which is critical for the correct processing of fisheries data.
The following variables were included in the model as covariates:
Cyclic day-of-the-year components:

$$d_{\sin} = \sin\frac{2\pi d}{N_y}$$

$$d_{\cos} = \cos\frac{2\pi d}{N_y}$$

where d_{sin} and d_{cos} are the cyclic components, d is the day of the year, and N_Y is the number of days in year Y (365 or 366).
Fishing vessel engine power: This parameter was used as a proxy for vessel type and fishing power, allowing for the standardization of the "effort" itself.
Sea surface temperature (SST): An important oceanographic factor directly influencing the distribution of pelagic fish.

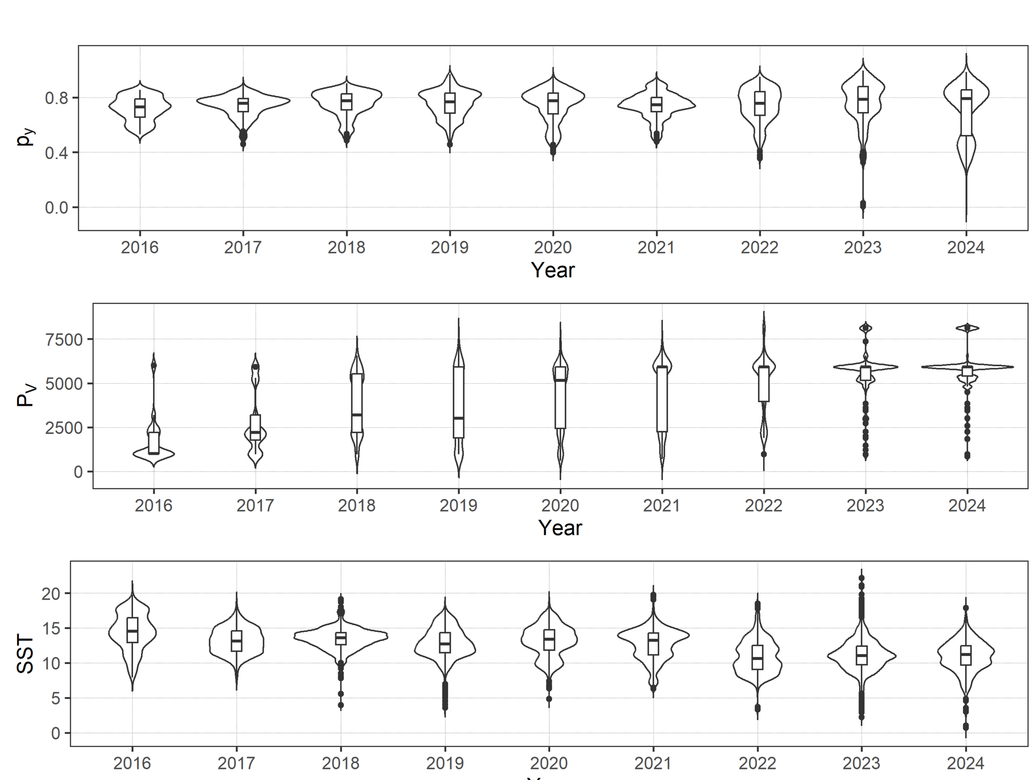

Fig.2 The distribution of covariates vslues by the year

To determine the optimal temporal dependency structure, three different model specifications were tested and compared:
IID (Independent and Identically Distributed effects): A model assuming no temporal autocorrelation between years.
RW (Random Walk): A model in which temporal effects follow a random walk process, where the state in the current year depends on the state in the previous year plus a random error.
AR1 (First-Order Autoregression): A model similar to RW but including a damping parameter, which allows for a more flexible temporal dependency structure.
Model selection was based on the Akaike Information Criterion (AIC) and the Bayesian Information Criterion (BIC).
A comparison of the information criteria for the three competing models revealed a clear distinction in their quality. The IID model showed values of AIC = 73744.11 and BIC = 73854.23. The RW model demonstrated the worst performance (AIC = 74005.38, BIC = 74106.13), indicating its inadequacy for describing this particular time series. The lowest values for the information criteria were obtained for the AR1 model: AIC = 73743.66 and BIC = 73846.41. Consequently, the AR1 model was statistically justified and selected as the final model for subsequent analysis.
Standardized abundance indices for chub mackerel were calculated based on this selected model.

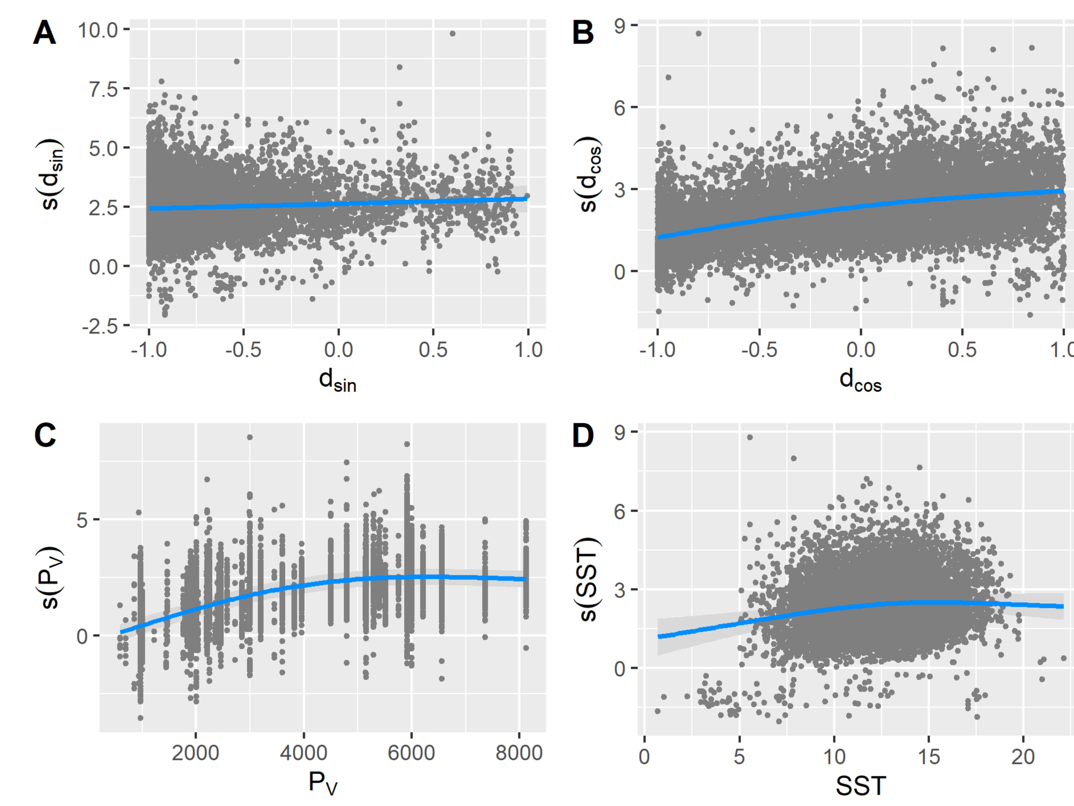

Fig.3 The covariates partial effects

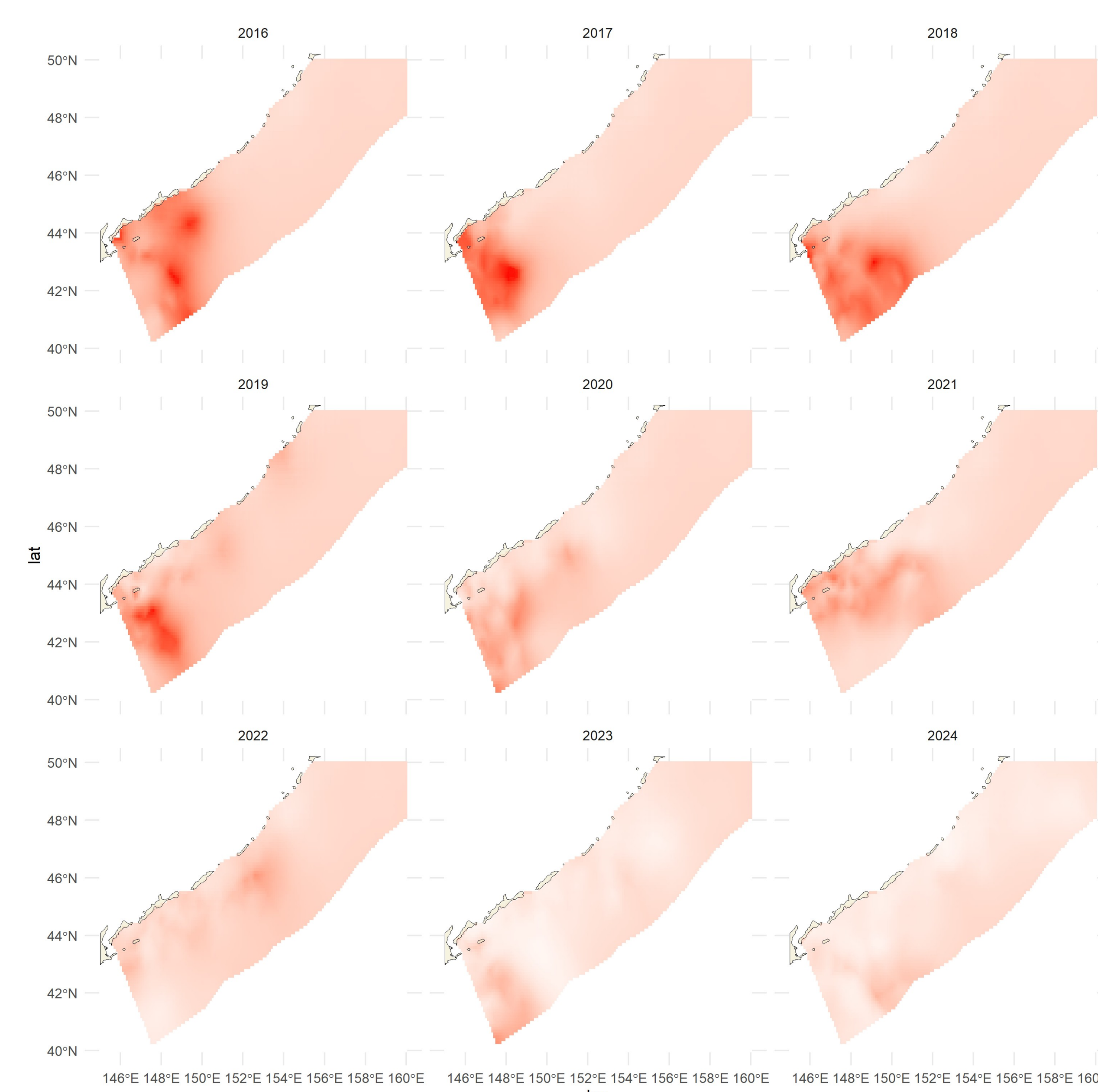

Fig.4 The index distribution in the Russian chub mackerel fishing area

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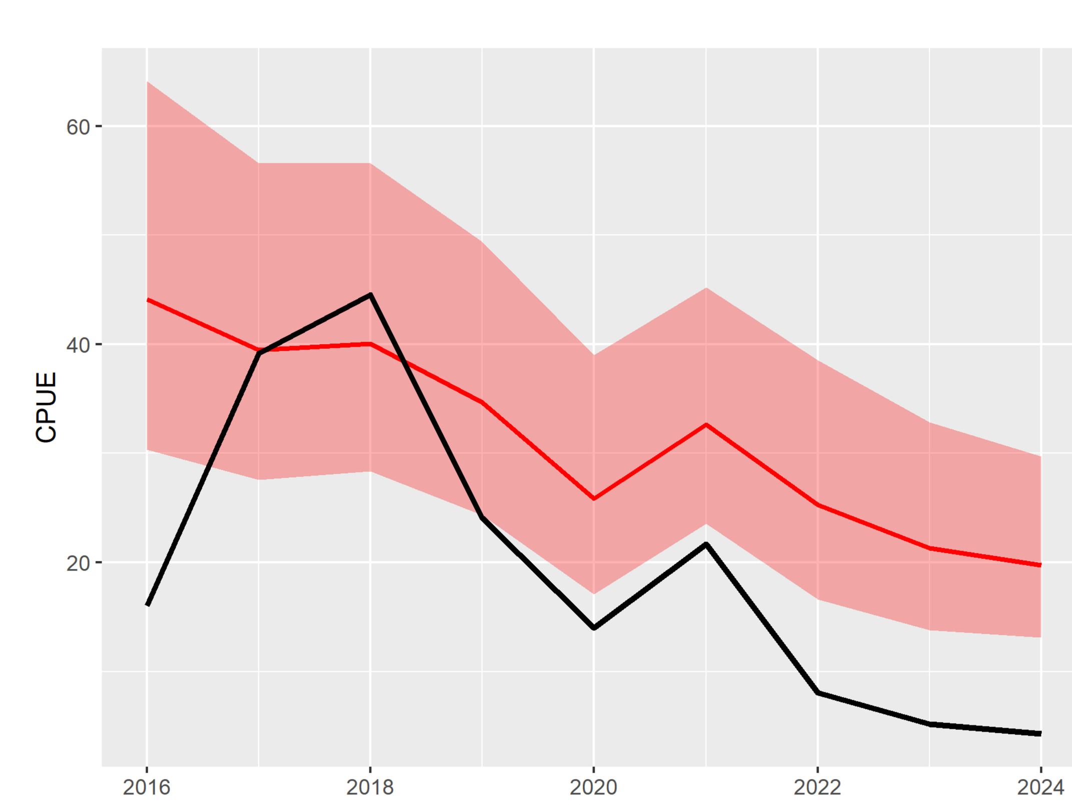

Fig.5 The index dynamic in the Russian chub mackerel fishing area

A deeper understanding of the reasons behind the observed decline requires further research, including analyses of oceanographic conditions, trophic interactions, and fisheries mortality data.