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SCUOLA DI INGEGNERIA

Interplay of Climate, Fishing, and Biodiversity: Risk Assessment in the Mediterranean Sea

PhD Student: **Laura Pavirani**
Tutors: Prof. Mario Giovanni Cosimo Antonio Cimino
Dr. Gianpaolo Coro

ABSTRACT

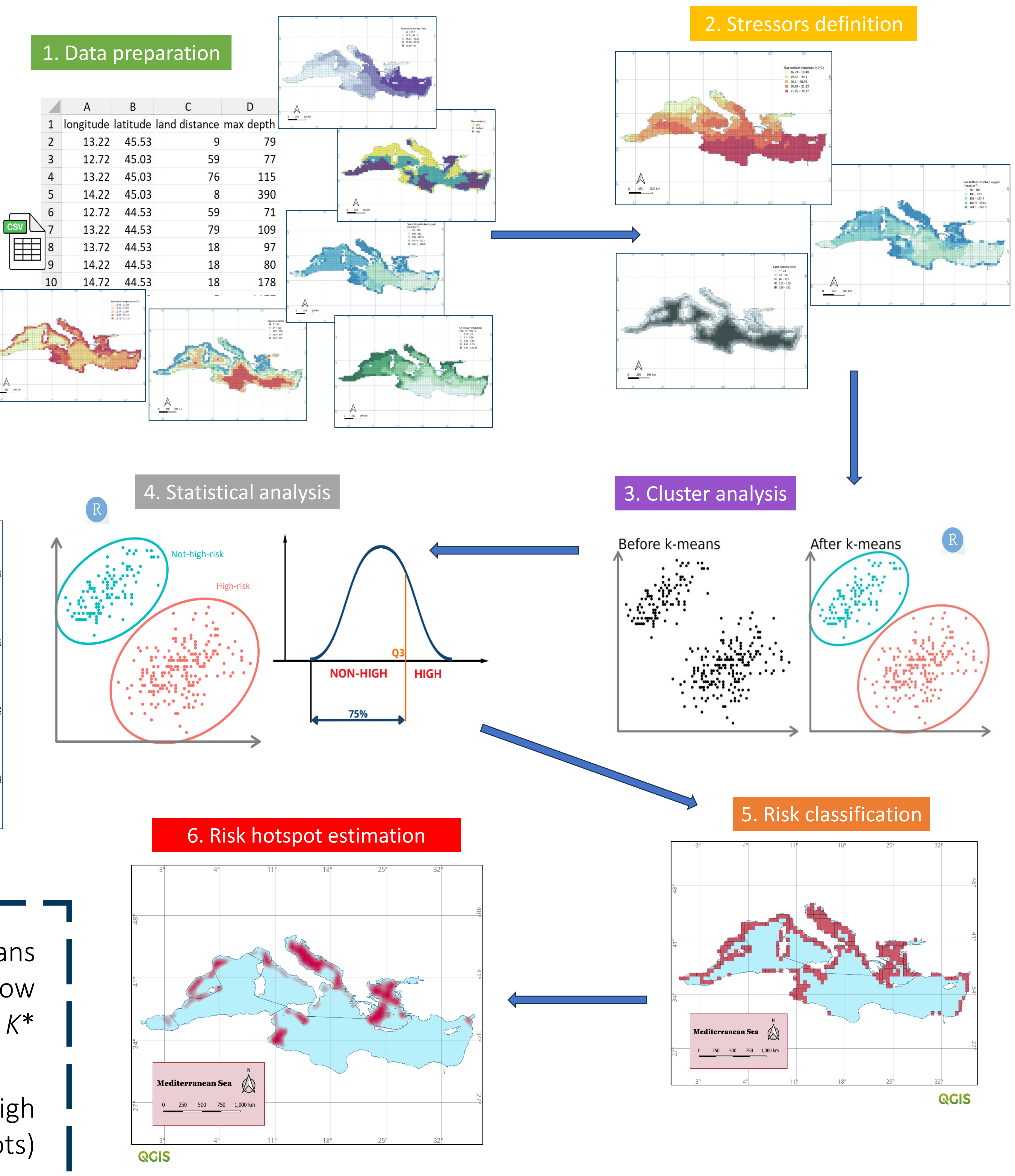
In Marine Science, risk assessment is a set of methodologies that estimate the potential impact of natural and anthropogenic pressures (*stressors*) on the ecosystem[1]. The workflow I developed presents an approach that automatically identifies high-risk hotspots in the study area, where environmental, fishing activity (manifest and hidden[2]), and species richness stressors overlap creating an area at high risk of degradation and overexploitation. It is a valid support tool for the models used in risk assessment. As a case study, I applied the workflow to the Mediterranean Sea, using open geospatial data from 2017 to 2021 and projections to 2050 under a business as usual (RCP8.5) future scenario.

PROBLEM AND MOTIVATION

Traditional Ecosystem Models are widely used in risk assessment, but they have limitations:

- They typically consider one stressor at a time,
- They often follow a qualitative approach,
- They require long implementation times by experts.

In contrast, my approach introduces a reusable, semi-automated workflow designed for big data applications. It enables the flexible and simultaneous analysis of multiple stressors impacting the ecosystem, delivering results quickly. This makes it a highly efficient support tool for ecosystem management.

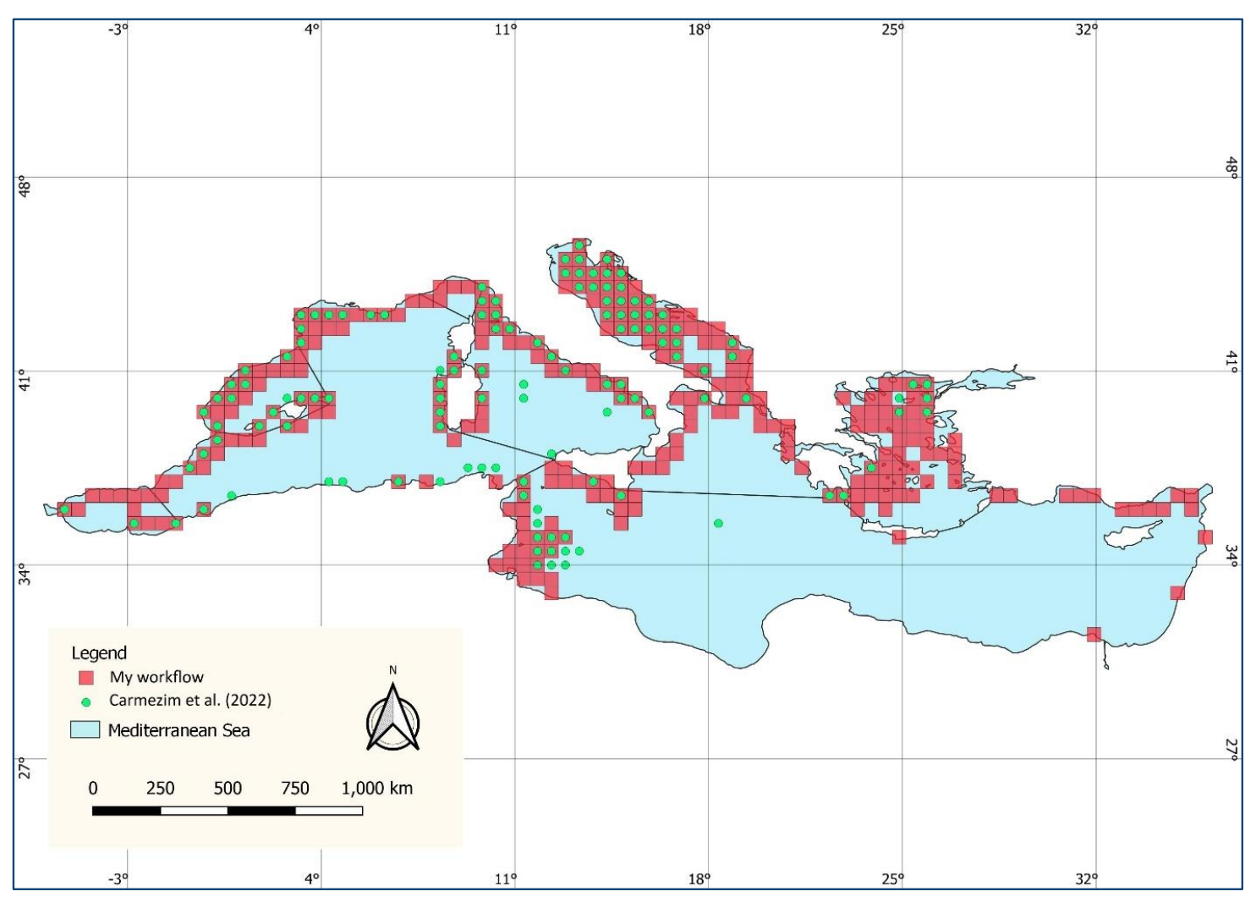


	A	B	C	D
1	longitude	latitude	land distance	max depth
2	13.22	45.53	9	79
3	12.72	45.03	59	77
4	13.22	45.03	76	115
5	14.22	45.03	8	390
6	12.72	44.53	59	71
7	13.22	44.53	79	109
8	13.72	44.53	18	97
9	14.22	44.53	18	80
10	14.72	44.53	18	178

Variable name	Sub-specifications	Unit of measure	Time range	Original time resolution	Original spatial resolution
Fishing activity	Hidden, total	Hours	2017-2022	Annual	0.01°
Depth	Mean	m	-	-	0.0042°
Land distance	Water column	km	-	-	0.5°
Temperature	Sea-surface, sea-bottom	°C	2017-2021, 2050	Annual	0.5°
Salinity	Sea-surface, sea-bottom	PSS	2017-2021, 2050	Annual	0.5°
Dissolved oxygen	Sea-bottom	mmol m^{-3}	2017-2021, 2050	Annual	0.5°
Net primary production	Sea-surface	mgC m^{-3} day^{-1}	2017-2021, 2050	Annual	0.5°
Species richness	Water column	No.	2017-2021, 2050	Annual	0.5°
Stock richness	Water column	No.	2017-2021, 2050	Annual	0.5°

Datasets of environmental, anthropic, biodiversity, stock, and climatic variables I used in this study

Quantitative comparison with another risk assessment study in the literature[3]



APPROACH

My methodology combines unsupervised learning with statistical analysis, using a multi-K-means algorithm as its core[4]. An index function (UNIF()) evaluates cluster quality by penalizing low uniformity and outliers, ensuring more robust clustering. The optimal clusterization *K** corresponds to $K^* = \arg\min_{3 \le k \le N/2} \mathrm{UNIF}(k)$.

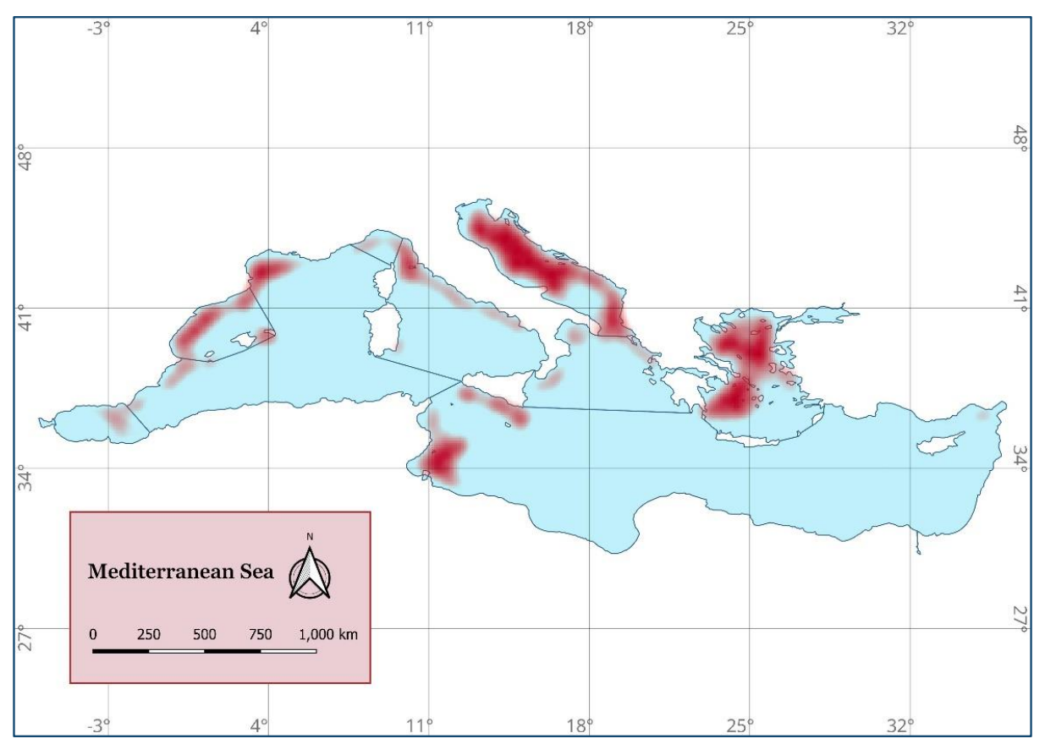
Stressor values above the 75th percentile are marked as "high," and centroids with mostly high values are labeled as *high risk*. The workflow produces a "heatmap" of high-risk areas (hotspots) based on the distribution of high-risk values.

RESULTS

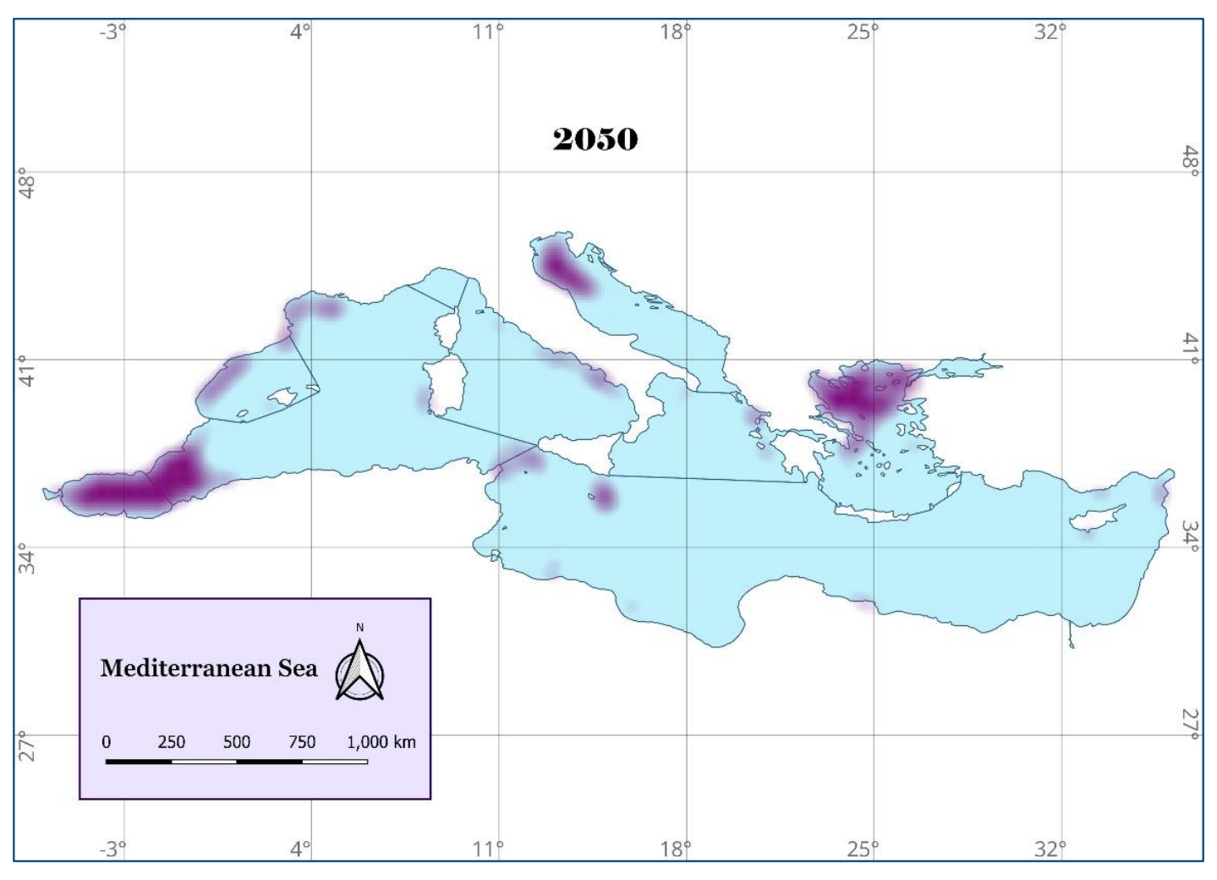
The results revealed "high risk" hotspots (colored areas). In these areas, a combination of stressors such as overexploitation of fisheries resources, excessive fishing hours, climate change, geographical factors, and environmental conditions create particularly high-risk conditions for biodiversity and, consequently, for stock richness.

Heatmaps highlight common high-risk areas across the years studied.

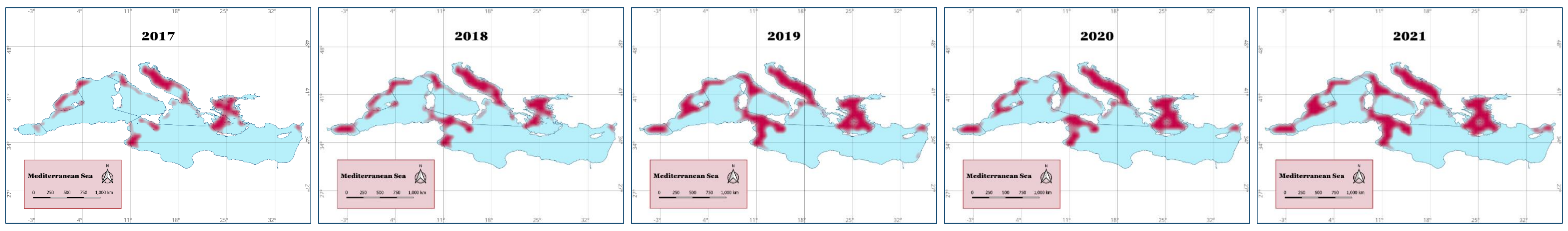
Time-averaged total fishing activity pressure on species and stock richness in peculiar environmental conditions



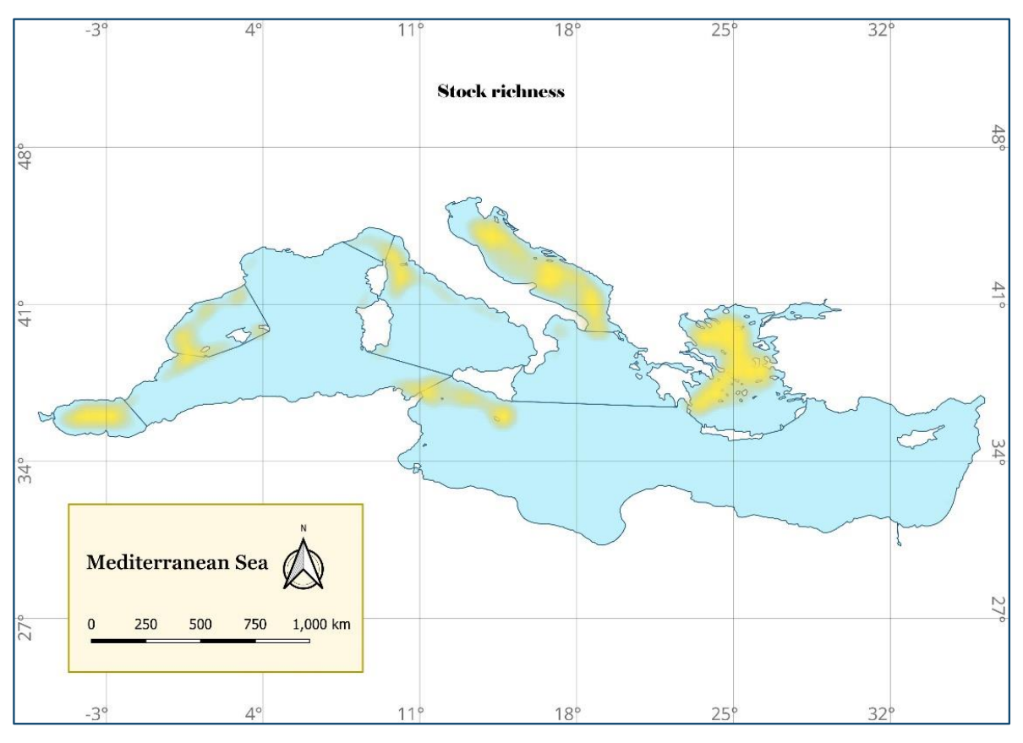
Hotspots of climate change



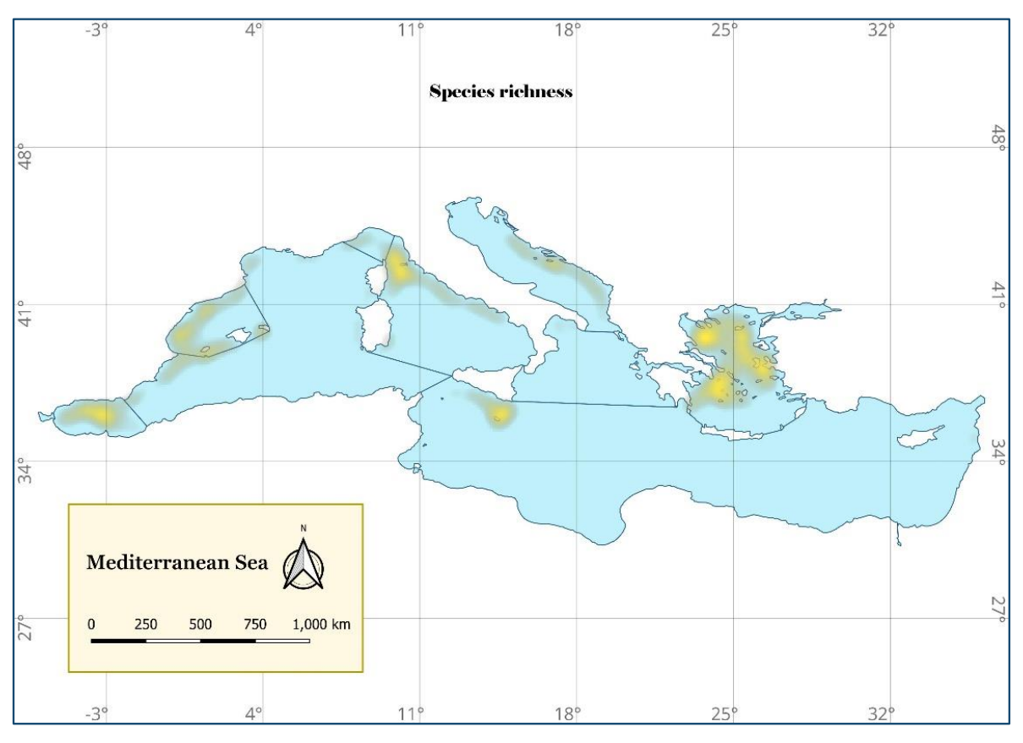
Fishing activity pressure on species and stock richness in peculiar environmental conditions from 2017 to 2021



Stock richness change due to climate change



Species richness change due to climate change

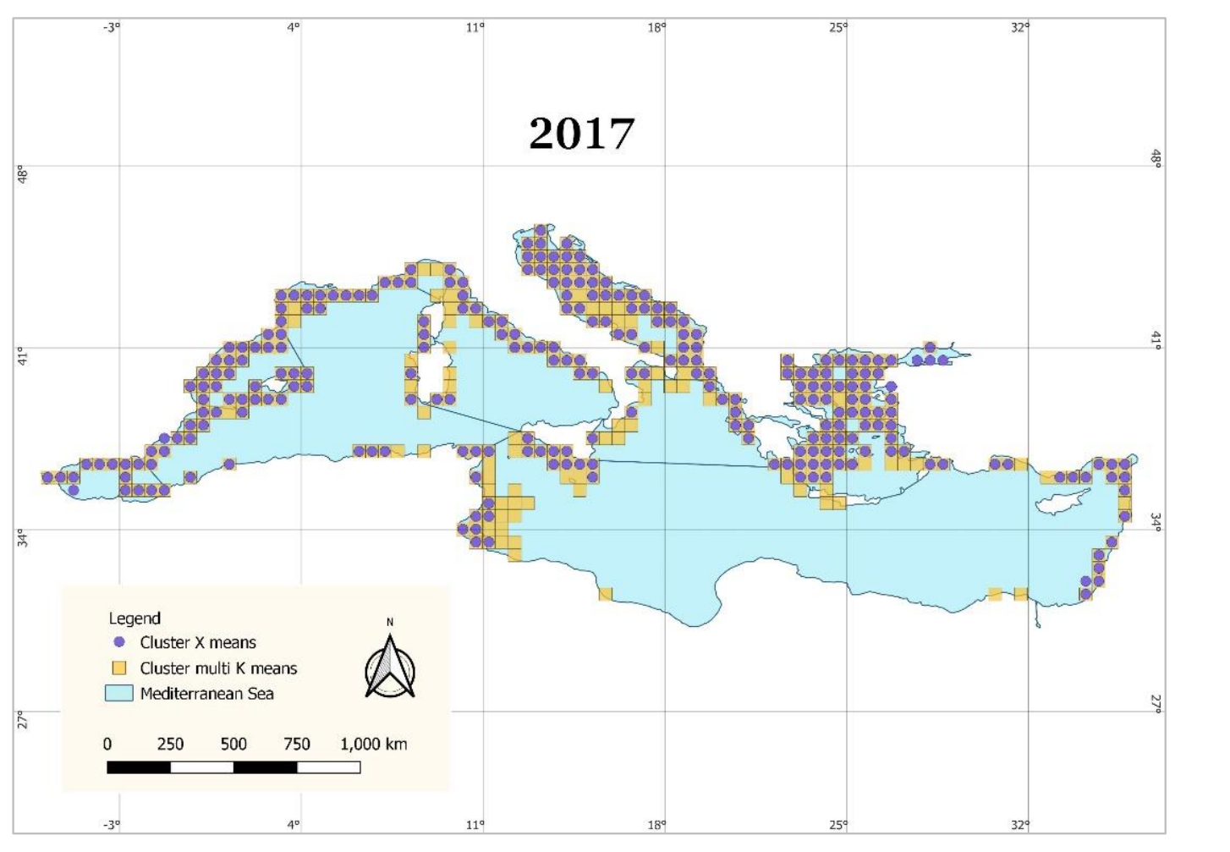


CONCLUSIONS & FUTURE WORKS

Understanding the interplay of environmental, human, social, and economic factors, and how they will evolve with climate change, is crucial for prioritizing management interventions. The maps produced can provide prior information to Bayesian models for ecosystem modelling and spatial planning.

Next steps:

- Compare my methodology (multi-K-means) with other clustering algorithms to determine the method that produces optimal results in identifying patterns and interactions between stressors.
- Apply my workflow to other areas (e.g. the basin of Lake Massaciuccoli in Tuscany) to test its flexibility and scalability.



Example of comparison between multi-K-means algorithm and other methodologies (X-means) on the estimation of high-risk locations due to fishing activity pressure on species and stock richness in peculiar environmental conditions (2017)

REFERENCES

1. K. Holsman, J. Samhouri, G. Cook, E. Hazen, E. Olsen, M. Dillard, S. Kasperski, S. Gaichas, C. R. Kelble, M. Fogarty, et al., An ecosystem-based approach to marine risk assessment, Ecosystem Health and Sustainability 3 (1) (2017)
2. G. Coro, L. Pavirani, A. Ellenbroek, Extracting Mediterranean Hidden Fishing Hotspots Through Big Data Mining. IEEE Access, 12, 85465-85483 (2024).
3. J. Carmezim, M. G. Pennino, J. Martìnez-Minaya, D. Conesa, M. Coll, A mesoscale analysis of relations between fish species richness and environmental and anthropogenic pressures in the mediterranean sea, Marine Environmental Research 180 (2022)
4. G. Coro, L. Pavirani, A. Ellenbroek, Computing Ecosystem Risk Hotspots: A Mediterranean Case Study. Submitted to Ecological Informatics (August 2024).

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