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ECOREGIONALISATION OF THE MEDITERRANEAN SEA

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SUMMARY

The discipline of biogeography aims to study the spatial distribution of species in relation with environmental and geographical gradients. More recently, this approach has been used to ***partition*** geographical areas according to biological, physical and chemical features. This novel geographical framework is helpful for ecological ***monitoring*** or ***conservation*** purposes as it outlines ecological discontinuities. Nonetheless, in a context where an ***ecosystem-based*** approach is advised for almost all ecological management, no geographical framework was proposed based on all ecosystem components (from environmental conditions to the spatial distributions of species).

In this study, based on the ***most comprehensive*** dataset gathered on the Mediterranean sea and on newly developed ***mathematical tools***, we propose an objective 3D mapping of biogeochemical regions (based on more than 10 environmental variables) and ecoregions (based on more than 1200 species modelled distributions, from phytoplankton to top predators) in that basin. In addition, we evaluate the weights of various anthropogenic pressures on each ecoregion, along three categories: climate change pressure, fisheries pressure and direct anthropogenic pressure (such as pollution, oil spills, etc.).

DATA

Environment

22 variables : T°, salinity, chlorophyll but also depth of the euphotic layer, strength of the thermocline, …

Spatialised on a 0.2° grid and 25 vertical levels.

Grouped in epi, meso, bathypelagic layers and bottom.

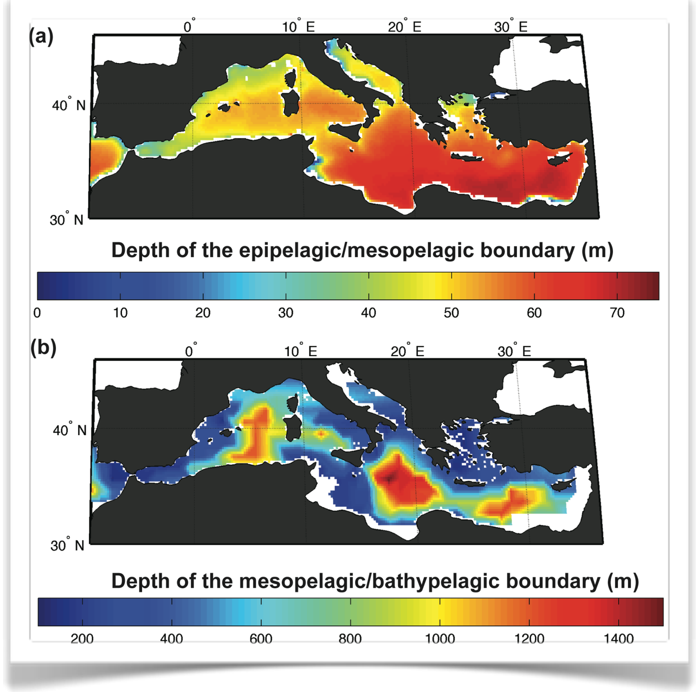
Sources : MedAtlas, QuickSCAT, GEBCO, and various papers.

Species

Occurrence record of *1281* species in 4 groups: phytoplankton, zooplankton, fish, others (mammals, sharks, turtle)

Sources : Copepod, IOBIS, GBIF, Pangea, FishBase, SeSame, Alvain et al 2008, Albouy et al 2012

Anthropogenic impact 18 variables from Halpern et al 2008



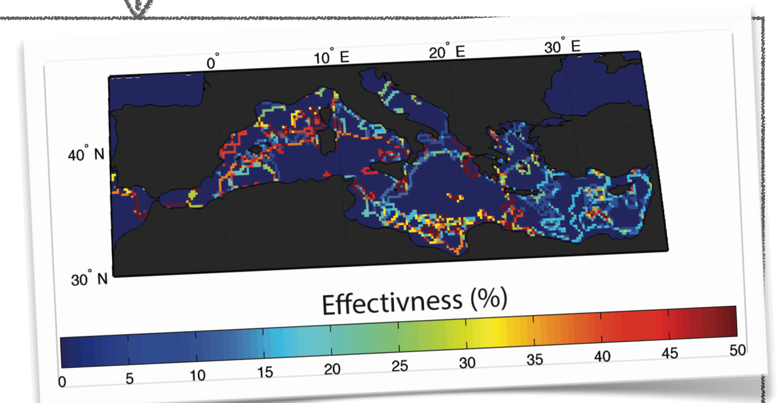
CLUSTERING

k-means | c-means | hclust complete | hclust Ward

Estimation of the optimal number of clusters

Superposition of cluster boundaries

(Reflect physical features in the flow)



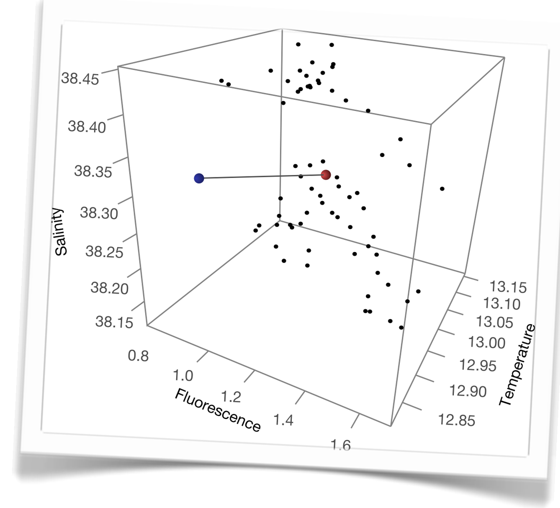
Watershed algorithm and definition of ***spatially coherent*** clusters = regions

ENVELOPE MODELLING

Used in two ways:

- Environmental envelopes of each ***cluster*** and computation, for each point of the map, of the probability of belonging to that cluster;
- Environmental envelope of the occurrences of each ***species*** and computation of the probability of presence at any location.

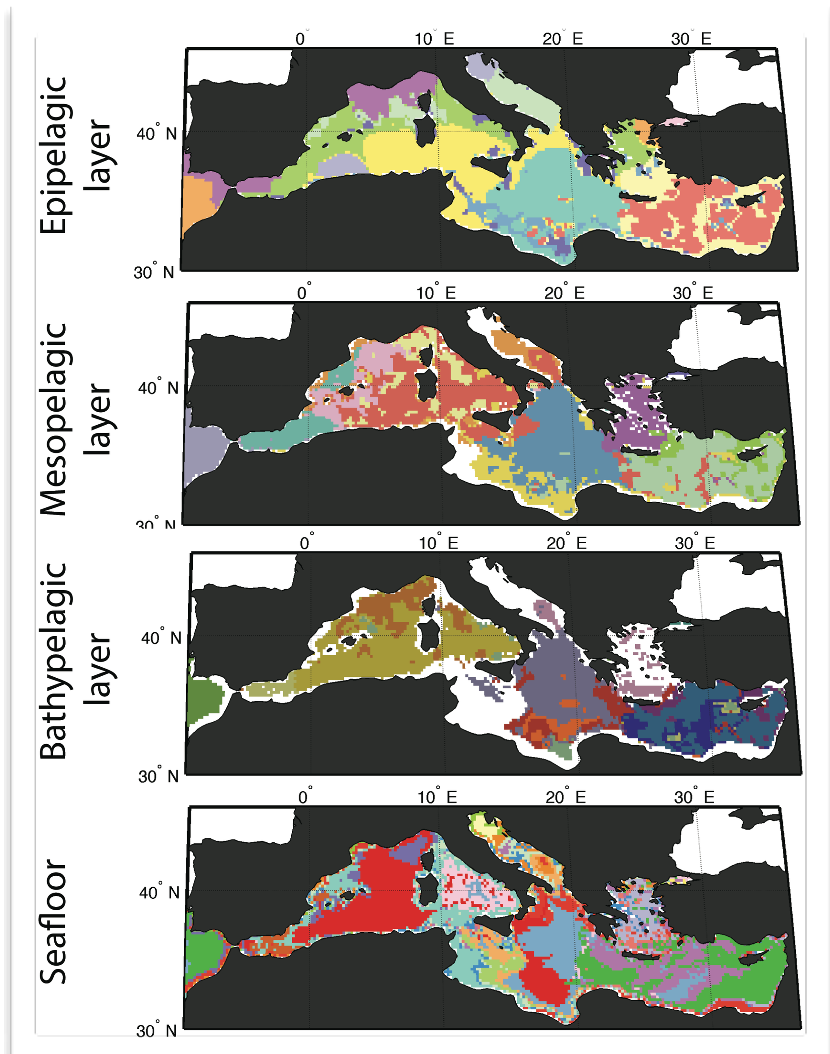
The definition of the envelope is based on the Mahalanobis distance from the point of interest (blue) to the cloud of points defining the region/species (black and red). Therefore it takes the ***covariance structure*** into account (shape of the cloud).



The probabilities are estimated through permutations, following the Non-Parametric Probabilistic Ecological Niche (***NPPEN***) algorithm (Beaugrand et al 2011).

BIOGEOCHEMICAL REGIONS

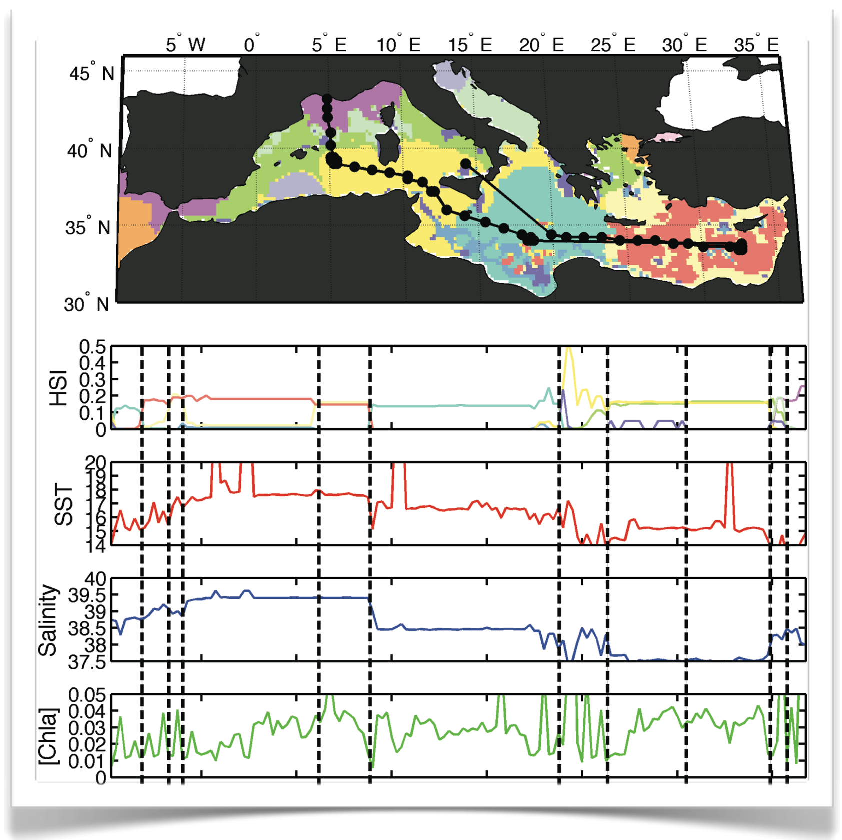
Variables relevant for each layer (epi, meso, bathypelagic and bottom) are fed to the clustering algorithm. This results in biogeochemical ***regions*** which present distinct ***environmental profiles***. They cannot be simply considered as water masses (identified by T/S diagram) but are *biotopes* defined by multivariate environmental intervals. Once such clusters are defined, their environmental envelopes can be extracted and reprojected on the full-size dataset (0.2°, 25 layers) giving a 3D map of the region.

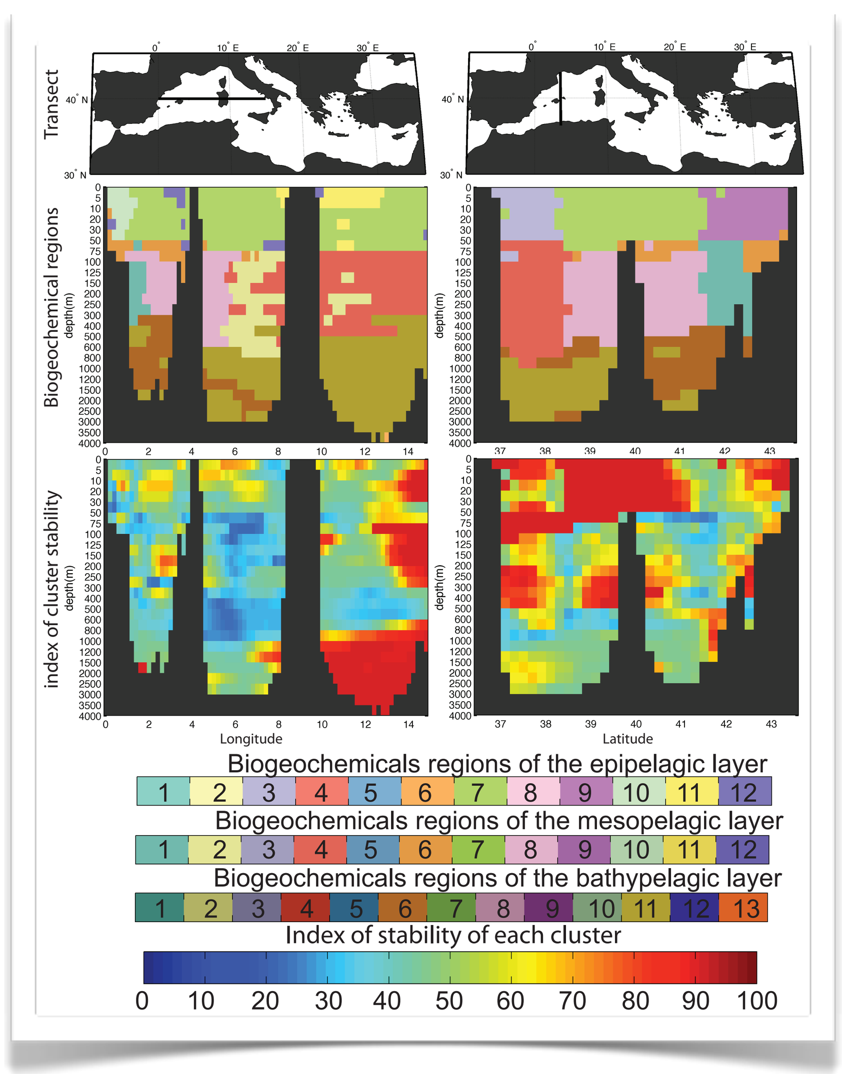


Clusters built from database data can be checked against real-world cruise data at the surface (BOUM cruise - bottom left) and show ***good agreement*** in the boundaries between regions.

This map highlights that the features are stronger and better defined near the ***surface***. The main ***frontal*** structures are highlighted by the analysis (Ligurian, Alboran…).

Cluster stability is low in those dynamic frontal regions, as well as in the strong ***vertical convection*** regions (Gulf of Lion, 42° to 44°N from 0 to 700 m).

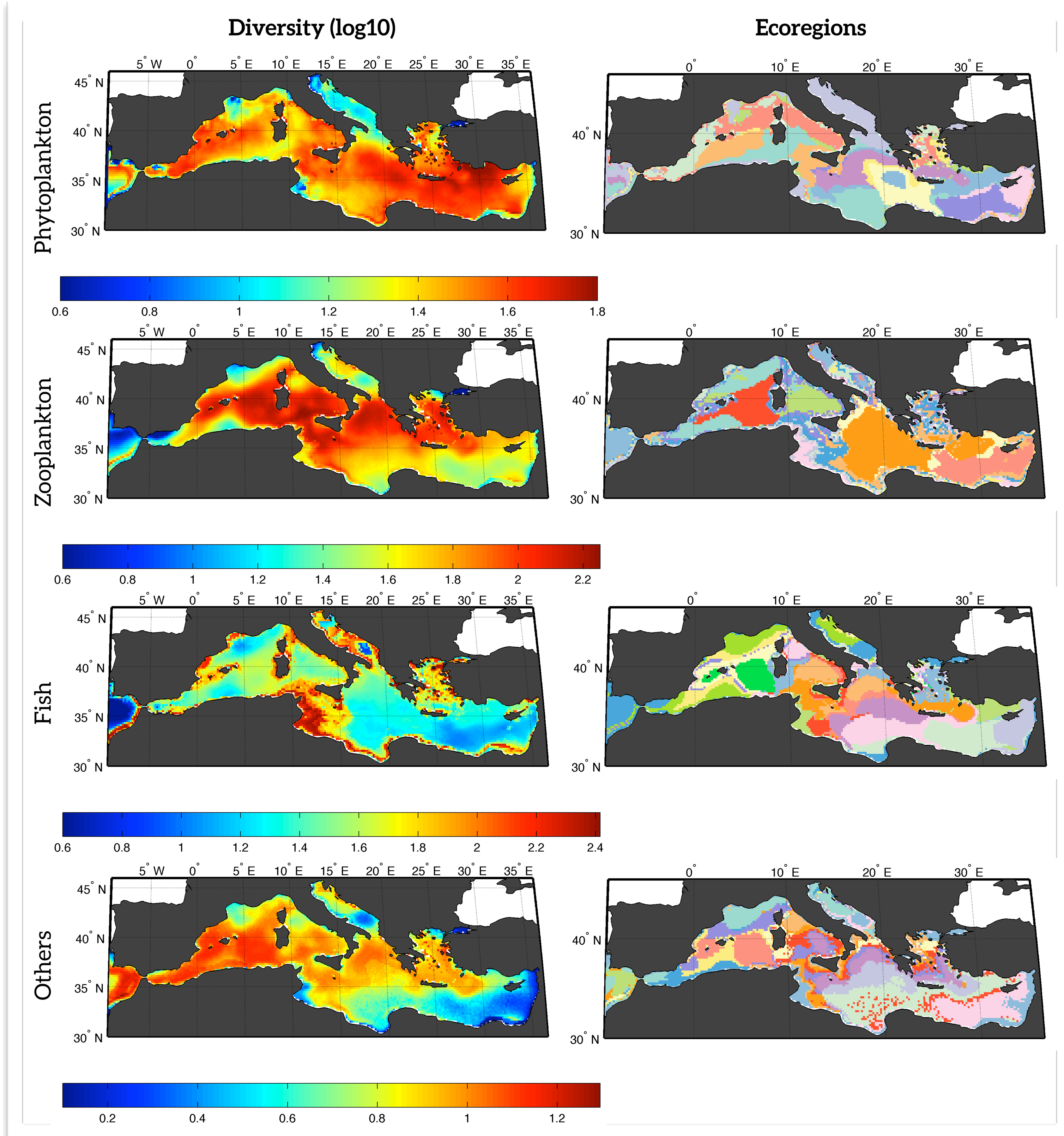




ECOREGIONS

The probability of occurrence of each species is mapped through envelope (niche) modelling. Diversity is estimated as the sum of the probabilities of occurrence. Finally, those probabilities are used as the data for clustering, which delineates ecoregions per taxonomic group.

Lower trophic level patterns are explained by ***temperature*** (high temp, high diversity) and ***food*** availability (high Chla, low diversity). Fish diversity is mostly ***demersal***. Diversity and regionalisation of other, larger species, reflects their ***behaviour*** (migration through Gibraltar).

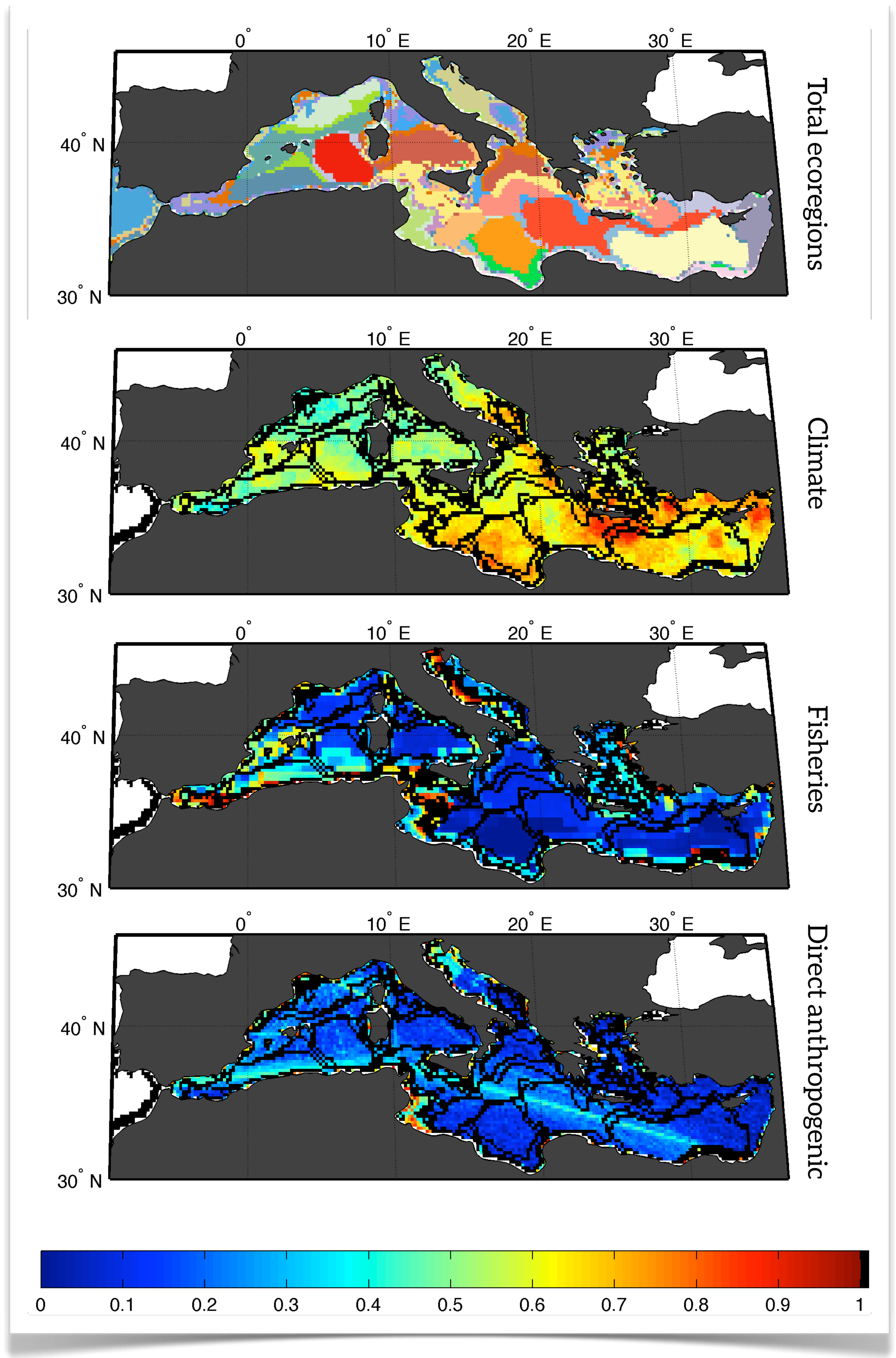


ANTHROPOGENIC IMPACTS

Ecosystem level regions are defined by combining per-group ecoregions boundaries. Within those regions, potential threats are mapped and quantified along 3 groups: climate related (T°, pH, …), fisheries related (total catch, bycatch, …) and direct pressures (pollution, …).

Coastal ecosystems are most affected, notably Tunisia and Northern Adriatic. ***Climate change*** threats are the only ones concentrated in the open sea. They will affect regions of ***high planktonic diversity***.

The worst prognosis for combined effects is for the regions offshore of Egypt, Lebanon and Greece.



TAKE HOME

- 12-15 distinct regions
- strong vertical differentiation
- biochemical regions well defined by fronts
- ecology refines biochemical regions
- differences in distribution/diversity between "trophic" groups
- anthropogenic impact uneven, affects high diversity regions

NEXT

- Better, more ecological, grouping of species
- Multiple niche models
- Creation of a total environmental impact index

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