

Balancing complexity and feasibility in Mediterranean coastal food-web models: uncertainty and constraints

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MMMPA



INTRODUCTION

The acceptance of Marine Protected Areas as a useful tool to reduce human impact on marine ecosystems is often mined by knowledge gaps about the effects of the protection on species interactions and system functioning. Ecopath trophic models (Christensen & Pauly, 1992) are an increasingly recognized tool to fill this gap. They allow to quantify biomasses and energy flows, identify keystone species and compute indicators of ecosystem maturity and exploitation state.

The recent EcoTroph plugin (Gascuel, 2005) allows to represent the trophic structure of an ecosystem with its trophic spectrum, the continuous distribution of biomass across trophic levels. It thus increases the potential for cross-ecosystem comparisons and simulations of exploitation effects, and integrates the Ecopath approach.

The main constraint of trophic models is due to the general lack of data for estimating the required input parameters. This obstacle is often overcome by deriving input parameters either from mass-balanced estimations, or from the literature and/or other models for the data-poor functional groups, with a consequent increase in uncertainty and thus reliability of model outputs.

OBJECTIVE

Focusing on uncertainty associated to biomass input data, we performed a sensitivity analysis on a standardized version of a highly-detailed Ecopath model to identify the functional groups to which the model was most sensitive to.

STUDY AREA AND REFERENCE MODEL

The Port Cros MPA (Fig.1) (western Mediterranean) was created in 1963. It covers a surface of 13 km², reaching a maximum depth of 50 m. Biotopes are typical of the Mediterranean with near shore rocky reefs, large Posidonia meadows, and coralligenous habitat, hosting high biodiversity and commercially important fish and decapod crustaceans. 5% of the reserve is a no-take area, outside of which fishing is permitted with severe restrictions.

A comprehensive Ecopath model was built by Valls et al. (2012) representing an average situation for the period 1998 to 2008. Large data availability for this old well studied MPA allowed to build a model including 41 functional groups, comprising 18 groups of fish and 14 groups of invertebrates.

All fish biomass data derived from visual census and scientific trawling in the area. Local biomass data was also available for many invertebrate and primary producer groups.

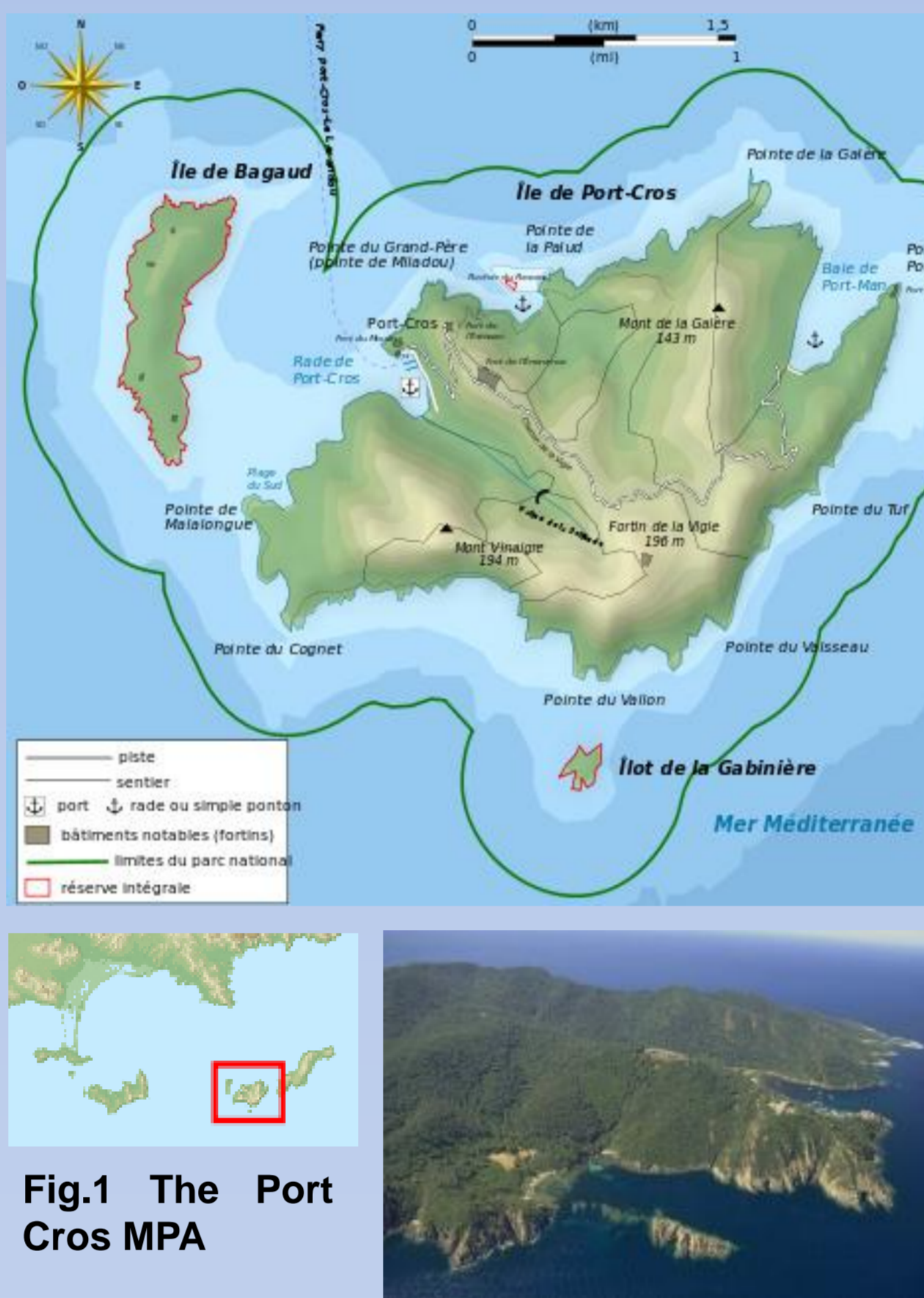


Fig.1 The Port Cros MPA

SENSITIVITY ANALYSIS

The reference Port Cros model was reduced to 32 functional groups without significantly altering model outputs. This standardized version of the model was set as a control to test the consequences of using inaccurate estimates of input biomass for each functional group. 29 new models were built each of them obtained by increasing the biomass of one functional group by 10%. The biomasses of the remaining groups were left to be estimated by the auto-balance procedure of the model.

Differences among each new model and the control were computed for:

- Indexes of ecosystem maturity and complexity (Ecopath): Finn's Cycling Index (FCI), System Omnivory Index (SOI), Relative Ascendancy (A), Trophic Level of the community (TLco), Biomass/Total System Throughput (B/TST), Total Primary Production/Total Respiration (TPP/R)
- Indexes derived from Trophic Spectra (TS) ratios (EcoTroph): number of trophic levels affected by a variation in biomass >1% (Width_TS), maximum level of biomass increase (Peak_TS), overall biomass increase (B_TS).

A Principal Component Analysis was performed to identify the functional groups with the highest impact on trophic spectra and ecosystem maturity indexes.

RESULTS

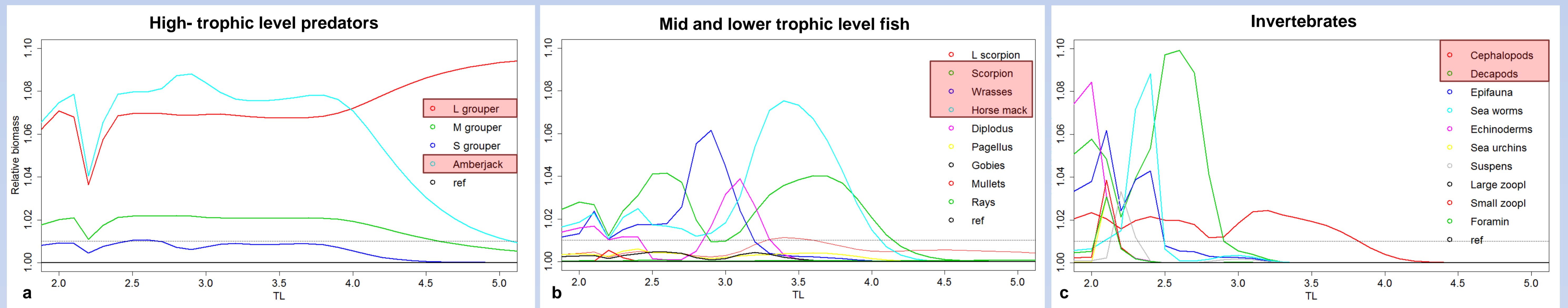


Fig.2 Trophic spectra ratios between each new model and the control. New models were obtained after a 10% increase in the biomass of one functional group. The dotted horizontal line corresponds to the threshold value of a 1% variation in biomass. The solid line at B=1 is the reference condition of the control initial model. Groups with the largest impact on trophic spectra indexes are highlighted in red.

The top predator groups Amberjack+ and Large Dusky Grouper have the largest impact on all trophic spectra derived indexes, i.e. number of trophic levels affected (Width_TS), maximum level of biomass increase (Peak_TS) and overall biomass increase (B_TS) (Fig. 2a highlighted in red and Fig. 3), as well as on ecosystem maturity and flow indexes summarized by PC1 (Fig. 3). Among other fish functional groups, Horse mackerels+ has highest impact in terms of number of trophic levels affected and biomass increment, followed by Scorpionfishes+ and Wrasses+ (Fig. 2b). Among the invertebrates, Cephalopods+ affect the largest number of trophic levels (Fig.2c) followed by Decapods+. Horse mackerels+, Cephalopods+, Decapods+ and Epifauna affect ecosystem complexity by mainly impacting the System Omnivory Index and the TL of the community (Fig.3). The abundant primary producer *Posidonia oceanica* strongly impacts both indexes of energy flow Biomass/Total System Throughput (B/TST) and Total Primary Production/Total Respiration (TPP/R) (Fig.3)

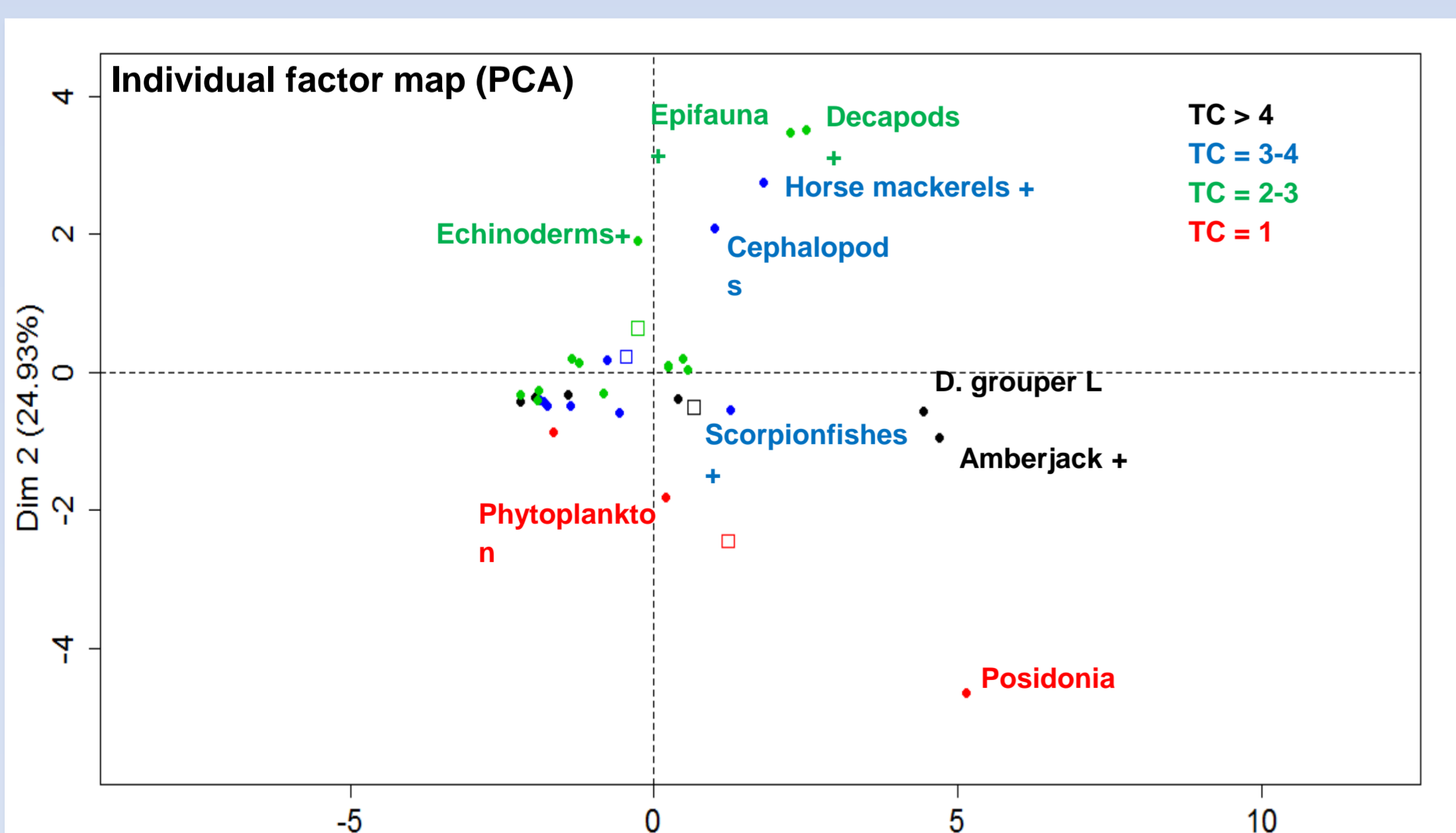


Fig.3 PCA plot representing the first two principal components. In the variables plots, B and TL are the supplementary variables (blue). TC = trophic class.

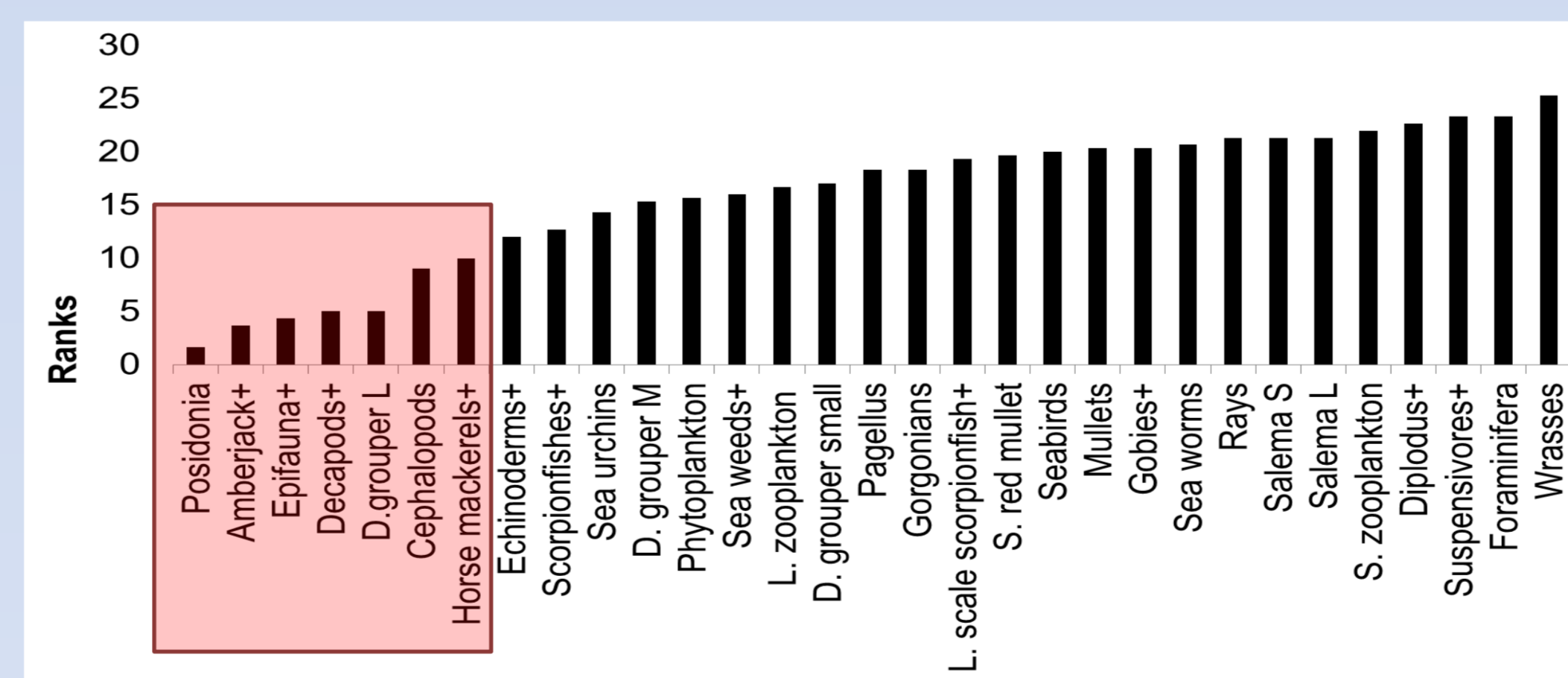


Fig.4 Ranking of the functional groups based on their contributions to the PCA components. The highest ranking groups are highlighted in red.



CONCLUSIONS

The high-trophic level predator groups, the abundant primary producer *Posidonia oceanica*, and some of the fish and invertebrates groups (Fig.4) characterized by a diversified diet (Cephalopods+) and/or a high biomass (Horse mackerels+, Decapods+, Epifauna+) significantly impacted the model outputs, with different relative effects on the trophic structure and the maturity and complexity indices of the ecosystem.

In the view of building a trophic model for a comparable Mediterranean ecosystem, the proposed standardized model structure should be applied, and priority should be given for the collection of local and accurate biomass data for the functional groups we highlighted. This focus will therefore allow to reduce the field sampling without significantly impacting the sensibility of the final model, thus increasing the feasibility of model building for coastal Mediterranean MPAs.

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ACKNOWLEDGEMENTS

MMMPA is an Initial Training Network funded by the European Commission under the Seventh Framework Programme (FP7/2007- 2013).