MPA design: modelling species distribution with ENFA and MADIFA approaches

Sánchez-Carnero, Noela[1,2], *Rodríguez-Pérez, Daniel*[3], *Couñago, Elena*[2], *Le Barzik, Frank*[2], *Freire, Juan*[2,4]

[1]*Grupo de Oceanografía Física, Facultad de Ciencias del Mar. Universidad de Vigo.*

[2]*Kartenn, Tecnologías para la Gestión Ambiental y Territorial.*

[3]*Departamento de Fisica Matemática y de Fluidos. Facultad de Ciencias, UNED.*

[4]*Teamlabs, Impact Hub Madrid. C. Gobernador 26, 28014 Madrid, Spain (juan.freire@gmail.com)*

Summary: Marine protected areas (MPA) are figures of ecosystem management aimed at regulating the captures of species and protect them from overfishing. In many cases MPAs are a community based strategy, and their geographic delimitation has often been based on traditional ecological knowledge (TEK). New ecological methods based on statistical description of presence-only observations allow the definition of the habitat characteristics most suitable for those species. They define a suitability value for each species at each geographic location that should be maximized within the MPA area chosen for species protection. In this work we use two of these approaches (ENFA and MaDiFA) to–test whether the limits of the Os Miñarzos MPA within the Seno de Corcubión (coast of Galicia, NW of Spain) fulfill these conditions based on catch data recorded by commercial vessels operating in the area. The analysis shows that the MPA includes areas where most of the commercial species analysed bear high suitability values. We conclude that habitat suitability analysis provides an alternative to TEK for the establishment of MPA, but also to continuously monitoring the evolution of species distribution, which could lead to redefinition of these protection areas in the future.

Introduction

Marine protected areas (MPAs) are an effective tool to protect the marine environment (Abdulla et al., 2008). MPAs must include those areas bearing the most suitable conditions for the life and development of key species in the area (especially, those required for critical life stages). Predictive Species Distribution Modelling (SDM) can be used for this purpose (e.g., Guisan and Thuiller, 2005; Sharp et al., 2008). The basic assumption of SDM (Guisan and Zimmermann, 2000) is that individuals select sites with a suitable set of environmental conditions; thus, given a set of sites hosting the focal species, a habitat suitability index (HSI) map can be computed anywhere environmental conditions are given. Traditional Ecological Knowledge (TEK), on the other hand, has been accumulated by local communities whose livelihoods depend on natural resources. TEK is considered reliable, rapid and low cost (Teixeira et al., 2013) for environmental planning and management of MPAs (Ferse et al., 2010).

Here we present an SDM model that allows comparison between HSI of different species and evaluate its predictions within a TEK defined MPA.

Materials and methods

Our study was developed in the Seno de Corcubión, a semi-exposed bay ~133 km^2 located in the westernmost area of Galicia (NW of Spain) where the MPA Os Miñarzos is included.

Fishing records of 12 species (*O. vulgaris* and *S. officinalis*, *M. brachydactyla*, *H. gammarus*, *N. puber* and *Palaemon spp.*, *D. cuneata*, *S. maximus*, *L. bergylta* and *D. sargus*, and *P. pollachius*, *D. labrax)* from local fisheries records, dating back to the MPA design process, were used as observations. 13 ecogeographic variables (EGV) were used for the analysis: bathymetry, slope, orientation, homogeneity, vertical, horizontal and mean curvatures, hypsometric index (derived from a digital terrain model of the sea bottom), bottom type (based on benthic habitat classification), and mean and range of Sea Surface Temperature (SST) and Chlorophyll-a concentration (both determined from time series analysis of satellite imagery).

ENFA (Ecological Niche Factor Analysis, Hirzel et al., 2002) and MaDiFA (Mahalanobis Distance Factor Analysis, Calenge, 2008) were used to estimate distance from each pixel EGV to the species optimal habitat. Then HSI was computed as the probability of finding a less suitable point (further away from that optimal habitat) in the study area. HSI computed with different sets of EGV were tested using Boyce index (BI) to determine what approach rendered the prediction in best accordance with actual observations (similar to Bryan and Metaxas, 2007). Finally, MPA average suitability for a species was compared with its average suitability in the unprotected area. All calculations were done with package adehabitat (Calenge, 2006) for the R statistical software with some minor adaptations.

Results and discussion

The most predictive SDM was ENFA with topography, sea bed classification and oceanographic EGVs, and weighting data with the number of catches (only three species obtained a better BI with MaDiFA). Bathymetry was the most important EGV in marginality axes (or highest specialization in case of MaDiFA) for almost all species (fishes, crustaceans and cephalopods); however second EGV in importance depended on the group of species. All species averaged HSI were over 70% higher within the MPA than outside it, the only exception being *D. labrax*. The species with highest relative suitability was *O. vulgaris*, with HSI nearly 100% above the rest of the study area.
Our analysis shows that Os Miñarzos MPA continuously holds the conditions most often selected by all species. Averaged HSI values inside the MPA were over 1.7 times those in the rest of the study area, to be compared with the optimal value of 2.22, only reachable in ideal conditions. We can conclude that the MPA Os Miñarzos was properly defined using TEK, but also that SDM methods can provide a followup of its boundaries in the years to come.

References

Abdulla, A., Gomei, M., Maison, E., Piante, C., 2008. Status of marine protected areas in the Mediterranean Sea. IUCN, Malaga and WWF, France, pp. 152.
Bryan, T.L., Metaxas, A., 2007. Predicting suitable habitat for deep-water gorgonian corals on the Atlantic and Pacific Continental Margins of North America. Mar. Ecol. Prog. Ser. 330, 113-126.
Calenge, C., 2006. The package "adehabitat" for the R software: A tool for the analysis of space and habitat use by animals. Ecol. Model. 197(3-4), 516-519.
Calenge, C., Darmon, G., Basille, M., Loison, A., Jullien, J-M., 2008. The factorial decomposition of the Mahalanobis distances in habitat selection studies. Ecol. 89(2), 555-566.
Ferse, S.C.A., Máñez Costa, M., Máñez, K.S., Adhuri, D.S., Glaser, M., 2010. Allies, not aliens: increasing the role of local communities in marine protected area implementation. Environ. Conserv. 37, 23-34.

Guisan, A., Thuiller, W., 2005. Predicting species distribution: offering more than simple habitat models. Ecol. Lett., 8(9), 993-1009.
Guisan, A., Zimmermann, N.E., 2000. Predictive habitat distribution models in ecology. Ecol. Model.135(2-3), 147-186.
Hirzel, A.H., Hausser, J., Chessel, D., Perrin, N., 2002. Ecological-niche factor analysis: how to compute habitat-suitability maps without absence data? Ecololgy 83(7), 2027-2036.
Sharp, G., Semple, R., Wilson, M., Vandermuelen, H., Rowland, B., 2008. A Survey of the distribution and abundance of Irish moss (*Chondrus crispus*) on the south shore of Nova Scotia. Port Medway, Shelburne co. to Pennant Point, Halifax. Can. Manuscr. Rep. Fish. Aquat. Sci. Darthmouth. Rept.2856, pp. iii + 34.
Teixeira, J. B., Martins, A. S., Pinheiro, H. T., Secchin, N. A., de Moura, R. L., Bastos, A. C., 2013. Traditional Ecological Knowledge and the mapping of benthic marine habitats. J. Environ. Manag. 115, 241-250.