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PROCEEDINGS OF 2nd MEDITERRANEAN SYMPOSIUM ON THE CONSERVATION OF CORALLIGENOUS AND OTHER CALCAREOUS BIO-CONCRETIONS

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USING MAXENT TO UNDERSTAND AND PREDICT THE DISTRIBUTION OF CORALLIGENOUS ENVIRONMENTS

Abstract

The Marine Strategy Framework Directive (MSFD) defines monitoring goals for coralligenous environments as well as their good environmental status assessment within the Mediterranean by 2016. Developing methods to monitor and evaluate challenging ecosystems at multiple scales is a necessity and advance to achieve these goals. Habitat distribution modelling and remote sensing techniques are important tools for ecosystem based management, conservation planning and impact assessments. Therefore, we aimed to analyse the performance of the Maximum Entropy approach (MaxEnt freeware) for modelling the distribution of coralligenous habitats. We built the habitat suitability models using i) presence data collected in the Portofino Marine Protected Area (Ligurian sea) and, ii) geophysical substrate properties extracted from multibeam sonar measures (depth, slope, aspect, rugosity, and geomorphic zones) to allocate known coralligenous communities in the MPA and to forecast new undescribed areas. We conclude that predictions based on combined model results provide more realistic estimates of the core area suitable for coralligenous environments and should be the modelling approach implemented in conservation planning, monitoring activities and management.

Key-words: MSFD, Habitat distribution modelling, MaxEnt, Ligurian Sea

Introduction

Coralligenous habitats are considered an important bioconstruction that confers great structural and functional complexity hosting more than 20% of the Mediterranean species. Besides their importance, little is known of their ecological needs to achieve adequate management. The Marine Strategy Framework Directive (MSFD) defines monitoring goals for coralligenous environments as well as their good environmental status (GES) assessment in the Mediterranean Sea by 2016. Effective implementation of these policies requires a sound understanding of the extent and distribution of benthic biological assemblages as a starting point. In addition, developing low cost methods to monitor and evaluate challenging ecosystems at multiple scales is a necessity and advance to achieve these goals. Remotely sensed data have the potential to provide a broad-scale synoptic view of benthic environments and provide temporal data that may be used to assess events in community dynamics (Zapata-Ramirez *et al*., 2013). Recent developments in marine habitat mapping using remote sensing tools (*e.g*. multibeam sonars and georeferenced photo or-underwater video) and the integration with distribution modelling techniques have resulted in an increased availability of environmental data (Brown *et al*., 2011; Reiss *et al*., 2014). MaxEnt, in particular, is now a common distribution modelling (DM) tool used by conservation practitioners for predicting the distribution from a set of records and environmental predictors (Phillips & Dudik, 2008; Elith *et al*., 2011; Fourcade *et al*., 2014). These models estimate the fundamental ecological niche in the environmental space (*i.e.* species response to abiotic environmental variables gathered by remote sensing techniques) and project it onto the geographical space to derive the probability of presence for any given area or, depending on the method, the likelihood that specific environmental conditions are suitable for the target species (Mellin *et al*., 2010; Fourcade *et al*., 2014). Effective modelling allows us to visualise spatial patterns and identify natural or anthropogenic processes as well as environmental variables governing species distribution and abundance (Mellin *et al*., 2010; Fourcade *et al*., 2014). In this context, predictive modelling based on species/environment relationships provides a potentially useful way to synthesise information from scattered samples into coherent maps of distributions of species and habitats, ecological goods, and services (Reiss *et al*., 2014). More specifically these tools can be applied (i) to explore the possible effects of climate change on benthic species distribution patterns (Elith *et al*., 2011; Reiss *et al*., 2014), (ii) to assess habitat distributions in areas that, due to their complexity, are difficult to study and therefore have limited data availability (Fourcade *et al*., 2014), and (iii) to estimate the most suitable areas for a species and infer probability of presence in regions where no systematic surveys are available (Martin *et al*., 2014). Only a limited number of coralligenous environments sites have been mapped to a certain extent, including interpretations of the different associated habitats using MaxEnt (Martin *et al*., 2014). Modelling techniques can contribute to solve this gap using the available information of species presence and environmental data from Multibeam Echosounder (MBES) records, producing Habitat Suitability (HS) maps, which describe, in high resolution, the predicted spatial distribution of the vulnerable habitats, threatened sessile species and essential fish habitats (EFH). Therefore, we aimed to analyse the performance of the Maximum Entropy approach (MaxEnt freeware) for modelling the distribution of coralligenous habitats located at Portofino Marine Protected Area (MPA) and to identify how environmental variables based on high resolution bathymetry influence their distribution.

Materials and methods

Data sources

Portofino MPA (http://www.portofinoamp.it) has a surface of 3.74 km^2. The coast is characterized by a narrow continental shelf with a very steep slope reaching a maximum of 80-90m depth. Multibeam bathymetry data was collected using a Multibeam system SONIC 2024 (Selectable Frequencies 200-400kHz) during 2010 and were provided by the Ligurian Region (Dipartimento Ambiente, Regione Liguria). Bathymetric and backscatter data were exported as 32-bit rasters with a cell size of 1m. With these data a wider area in the circalittoral zone was selected, where coralligenous formations occurred. In the study area depth ranged from -20m to -90m (total surface area considered for the model 5.287 Km^2, of which 2.57K^2 m fall inside of the MPA). We combined a suite of techniques that segment the acquired MBES data in terms of seabed morphology and composition. To determine sea-bed morphology, we applied standard layers using the Benthic Terrain Model (BTM) extension on ArcGis 10.2 platform (ESRI, Redlands, CA, USA). Geomorphometric attributes (*e.g*. slope, aspect, curvatures) were measured for each bathymetric datasets, with a particular emphasis given to attributes expressing the complexity of the seafloor, such as Bathymetric Position Index (BPI) and Vector Ruggedness Measure (VRM). In order to determine the seabed composition of the study area, we carried out a combination of morphometric and textural analyses of both bathymetric and backscatter data performing a an unsupervised Iterative Self-Organizing Data Analysis Technique (ISODATA) classification using ENVI 5.1 software (EXELIS VIS, Boulder, CO, USA) (see Zapata-Ramírez *et al*. 2013) with which we finally obtained 7 morphosedimentary classes (Mid slope, Lower bank shelf, Upper slope, Cliffs, Caves and Overhangs, Shallow slope and Bank shelf). Since coralligenous environments occur on a variety of geomorphologies, including near vertical walls and terraced slopes, we assessed multiple sites within the MPA locations to assess variation in the structural groups relative to this factor. Using these data, the importance of seafloor morphology in structuring coralligenous habitats was studied across the MPA.

During 2013-2014 field trips were designed using a random-stratified approach identifying the checkpoints (300 points) within the GIS and correlated with the GPS locations and taking in account several parameters such as: MPA Zonation, Complexity (rugosity/slope), the 7 morphosedimentary classes and the accessibility from land that could help to guaranty future monitoring activities. From each of these checkpoints, a diver or VideoRay Pro 4 ROV system for areas deeper than 40m were used together with two calibrated Go-pro Hero (3D system) to collect images, - One Go-pro Hero 2 to gather video, lasers and strobes for the divers or ROV. The diver or ROV swam over the bottom recording benthos composition with video and still photographs for ∼15 minutes (as proposed in Zapata *et al*., 2013). The video was pointed directly at the seabed and held between 1.0 and 1.5 m from the substratum. In addition we used an Underwater acoustic positioning system (USBL) to record the position of the diver and the ROV and related with the boat position. All sample data were stored using ArcGIS software, in order to facilitate the habitat distribution modelling

Habitat suitability models using Maximum entropy model (MaxEnt)

We built the habitat suitability models using i) presence data with the checkpoints collected in the study area and, ii) environmental variables (EVs) extracted from multibeam sonar measures of geophysical substrate properties (depth, slope, aspect, rugosity, and morphosedimentary classes). These bio-physical variables were then modelled using the machine-learning method (MaxEnt) to predict the distribution of coralligenous formation at the MPA. The default model parameters were used as they have performed well in other studies (Phillips & Dudık, 2008; Fourcade *et al*., 2014). The importance of each variable in the model was assessed using a jack-knifing procedure that compared the contribution of each variable (when absent from the model) with a second model that included the variable. The final habitat suitability maps were produced by applying the calculated models to all cells of the total surface area (5.286405 km^2) in the study region, using a logistic link function to yield a habitat suitability index (HSI) between zero and one (Phillips and Dudık, 2008). Model accuracy between the test data and the predicted suitability models was assessed using a threshold-independent procedure that used a receiver operating characteristic (ROC) curve with area under curve (AUC) for the test localities and a threshold-dependent procedure that assessed misclassification rate following the methodology proposed by Phillips & Dudık, (2008).

Results

To model the distribution of coralligenous habitat at Portofino MPA, a total of 88 presence records were used for training, 29 for testing and 10088 points to determine the MaxEnt distribution (background points and presence points). MaxEnt model was successful in predicting the distribution of Coralligenous habitats, with AUC score 0.984 for the training data set and 0.964 for the test data (Fig. 1) and were significantly different from that of a random prediction of AUC= 0.5 (Wilcoxon rank-sum test, p,0.01). This indicates that EVs chosen are relevant to distinguish the distribution of coralligenous in the study area. Slope (39%), Morphosedimentary classes (24.1%) and Rugosity (17.3%) were the three main contributors to the model, followed by Bathymetric Position Index (13.2%);

Depth (5.9%) and Curvature (0.4%). The interpretation of the Jackknife tests shows that Morphosedimentary classes was the most influential EV in determining HS as well as the one that had most useful information not contained in other EVs and was most effective in the contribution to the HS. By intersecting the known distribution of coralligenous habitats with the environmental layers, it was possible to gain insight into the species niches. (Fig.1). According to the models, in Portofino MPA, coralligenous habitats are most likely to be found on the steep rough walls (cliffs) where facies of octocorals in particular *Paramuricea clavata* is well represented, in caves and overhangs where *facies* of semi dark communities and associations of *Corallium rubrum, Parazoanthus axinellae* and *Leptopsammia pruvoti* occurs and, in less proportion, in upper slope where *facies* of scattered octocorals such as *Eunicella singularis* are characterized. The majority of records were found in areas where slopes were well represented as it is highlighted in the percentage of the contributors in the model. Figure 2 shows a representative area of steep slopes located at Isuela, a stack formation along the cliff and where *facies* of *P. clavata* is well distributed.

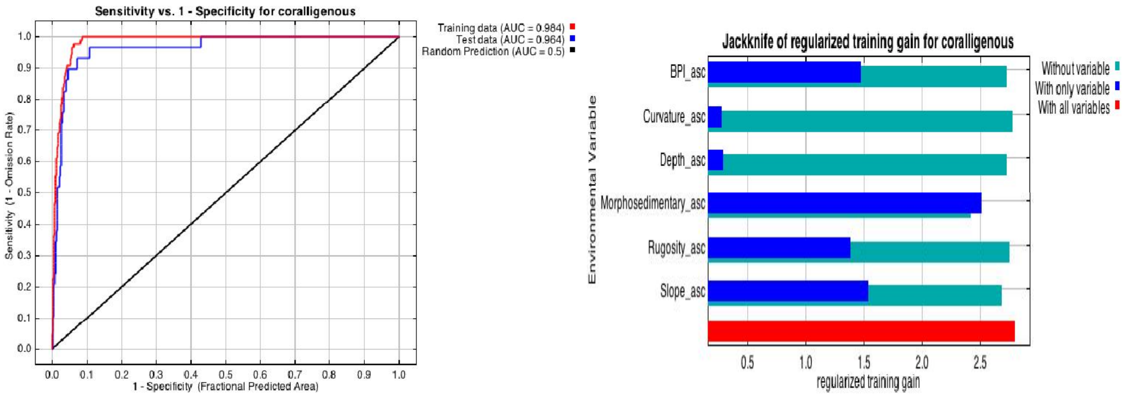

Fig.1: On the left ROC curves for the training (red) and test (blue) sets of coralligenous occurrence. The AUC index can take values between 0 and 1, where 0.5 represents a distribution indistinguishable from random; a lower value indicates performance worse than random and 1 indicates perfect discrimination. On the right result of the jackknife test of variable importance of coralligenous training data.

Conclusions

The results show that the MaxEnt model is a useful technique to characterize and give a better understanding of the distribution patterns of coralligenous habitats in relation with environmental factors extracted from multibeam sonar measures. The approach provides both high-resolution, full coverage surveys of selected areas that can be precisely revisited during monitoring activities as well as broader scale features of the terrain, such as slope, surface roughness and aspects that provide notion of the habitat structure and regarding sea floor integrity. In addition, optical information help us examining the correlations between populations and underlying bathymetric processes that determine their distribution that also provides the foundation to monitor future changes. The results presented here fits in the regional spatial mapping of coralligenous environments (MSFD: 2008/56/EC), allowing the production of high quality bathymetric and habitat maps as one of the first requirement for a sustainable management. Therefore, providing measures to achieve or maintain Good Environmental Status (GES) by 2020.

The presented methods are simple and cost-effective becoming an optimal solution for extended monitoring by the combination of innovative and new tech tools.

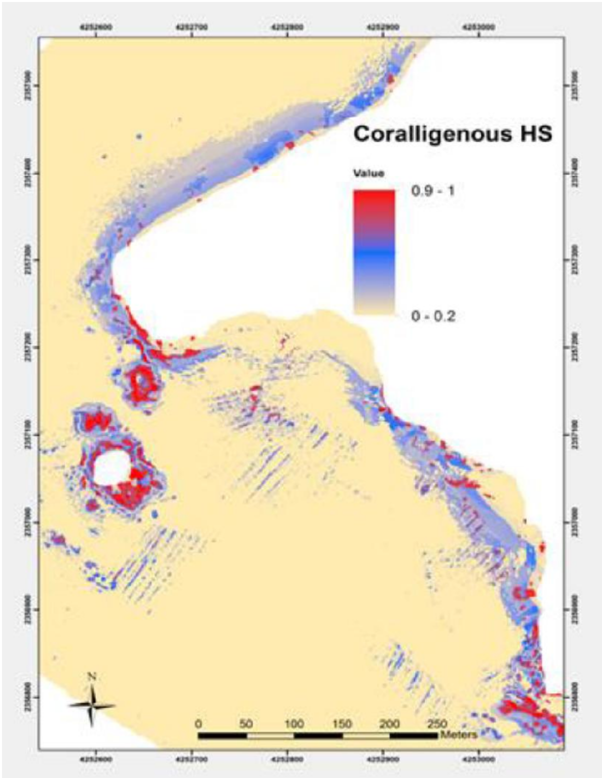

Fig. 2: Predicted occurrence probability for coralligenous formations at Portofino MPA. Yellow background indicates that coralligenous is not present, blue indicates low probability and red high probability of presence. The map shows a close up of the study area known as a Isuela, a stack formation along the cliff.

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