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# Use of topographic predictors for macrobenthic community mapping in the Marine Reserve of La Palma (Canary Islands, Spain)

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ABSTRACT

Evaluations of the coastal and marine conservation require detailed maps of types of communities that occur in the zone. This paper describes how distribution models are used to develop benthic distribution maps with biological data collected from surveys, and environmental variables derived from a Digital Elevation Model (DEM), including different indices of terrain complexity. We compared the success of two algorithms, Maxent and ENFA, commonly used in the marine environment to identify best suited methods to modelling the distributions of six benthic communities identified in the marine protected area of La Palma (Canary Islands, Spain). The environmental variables depth, slope, type of substrate, Bathymetric Position Index (BPI) and Vector Ruggedness Measure (VRM) were the variables with higher influence on the distribution of communities. The distribution models of both techniques were coincident and congruent, although Maxent produced more constrained predictions than ENFA, highlighting the significantly better performance of the Maxent models for communities with fewer presences, in this study, black coral and brown garden eels. The resulting distribution maps were evaluated and reclassified and they were represented in a unique map that summarises all of the individual maps. Given that the distribution models were made on the same study area and based on presences data collected at the same time, it was possible to make a preliminary analyse of the interactions between the studied communities. In conclusion, distribution models of benthic communities are suitable tools to design reliable and full coverage distribution maps of benthic communities and they provide new information about the behaviour of communities on the range of environmental conditions studied and useful information for management of marine and coastal areas.

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## 1. Introduction

Marine coastal areas play an important role in the socio-economic development of many territories, such as the Canary Islands, where a significant proportion of the economic activities and human population inhabit coastal areas. Therefore, the relevance and recognition of research on ecological studies related to the management of marine and coastal areas has increased, and distribution maps of species and communities are a fundamental tool in this field. In this context, Geographic Information Systems (GIS) have facilitated important advances in marine mapping at different scales (Dolan et al., 2008; Kostylev et al., 2001).

There is a wide variety of GIS methods and techniques used for the creation of distribution maps, in both the data collection and the processing. The selection of the best methods depends on the project objectives, scale, seabed characteristics and the spatial resolution of the resulting map (Diaz et al., 2004; Kenny et al., 2003; Solan et al., 2003). For the collection of data, direct submarine observations, such as diving or video surveys, have been utilised mostly in small-scale areas, and littoral and sublittoral regions (Earll, 1992; Jordan et al., 2005; Norris et al., 1997). The application of remote sensing techniques, such as aerial photographs and satellite images, have enabled the large-scale mapping (Urbanski and Szymelfenig, 2003) but in general these techniques are directed to geophysical exploration (Diaz et al., 2004; Sinclair et al., 1999;

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Vrbanich et al., 2001) or to study communities of shallow water and clear waters with optimum conditions of wind, clarity and sun position (Marchanda and Cazoulat, 2003; West and Williams, 2008). The different strategies in the design of distribution maps from the collected information can be classified in (1) the interpretation of the data by the author (mainly in reports), (2) spatial interpolation (e.g. Jerosch et al., 2006) and (3) the development of predictive distribution models (Guisan and Zimmermann, 2000). The latter technique has been described and applied for species distributions in terrestrial environment (Guisan and Zimmermann, 2000; Hernández et al., 2008b; Segurado and Araújo, 2004), and it has also been applied in marine species in the last years (Degraer et al., 2008; Dolan et al., 2008; Galparsoro et al., 2009; Guinan et al., 2009; Hermosilla et al., 2011; Jones et al., 2012; Leverette and Metaxas, 2005; Skov et al., 2008). These techniques are aimed at distribution of species, but they also have been used in studies on the distribution of benthic communities of certain areas in which the entities or groups of species to modelling are well defined and classified (Degraer et al., 2008; Maggini et al., 2006) or, as an alternative, the dominant species are selected to classify their superimposed distributions, in order to generate simulated community maps (Bandelj et al., 2009; Guisan and Zimmermann, 2000; Ierodiaconou et al., 2011).

Currently, there are numerous methods for modelling the distribution of species. These models have been developed to respond to different ecological and statistical aspects of the distribution (Elith et al., 2006; Guisan and Zimmermann, 2000). The application of different techniques may provide different results, which must be studied and compared to determine the best choice considering that the selection of an appropriate method should not depend solely on statistical considerations. One of these prediction approaches is Ecological Niche Factor Analysis (ENFA), developed by Hirzel et al. (2004). Until now, ENFA has been applied mainly on a regional and global scale to model benthic species distribution (Bryan and Metaxas, 2007; Clark et al., 2006; Galparsoro et al., 2009; Leverette and Metaxas, 2005; Wilson et al., 2007), even in regional studies of cetacean distribution (Compton, 2004; Mandleberg, 2004), although ENFA can be useful for local analyses of marine species (Dolan et al., 2008). The Maximum Entropy Model (Maxent) is a technique developed by Phillips et al. (2006) that is one of the most commonly used tools for modelling the distribution of terrestrial (Elith et al., 2006; Rupprecht et al., 2011) and marine species (Anderson and González, 2011; Hermosilla et al., 2011; Howell et al., 2011; Jones et al., 2012; Ready et al., 2010). The Maxent software package was designed to assess the geographic distribution of species in relation to environmental variables with limited presence-only data (Pearson et al., 2007; Phillips et al., 2006; Phillips and Dudík, 2008), and various studies have proved that Maxent tends to present the best results when ranked against other methods (Elith et al., 2006; Hermosilla et al., 2011; Hernández et al., 2008b; Jones et al., 2012; Rupprecht et al., 2011).

Whatever the modelling technique used in species and communities, topographic variables created from DEMs are the main information used in both terrestrial and marine habitat (Guisan and Zimmermann, 2000). Despite of the numerous and demonstrated applications of DEM and derived parameters in terrestrial habitats, until recently, no detailed terrain data were available for the marine environment. Marine studies focus on ecology, biodiversity and biogeography, only used a basic knowledge of seafloor bathymetry without precise position information for biological samples, and any explicit link to the seabed terrain (Wilson et al., 2007). With the advent of multibeam technology and geospatial technology (GIS, GPS) mapping of marine benthic habitats entered a new era (Kenny et al., 2003). Multibeam surveys provided spectacular detail of sea terrain revealing numerous previously unrecognised features and the detailed bathymetry data necessary for the production of submarine DEMs and terrain analysis (Wilson et al., 2007). The strong relationship between topographic data and the presence of benthic communities and species have proven their value for habitat mapping (Kostylev et al., 2001; Parnum et al., 2004; Wilson et al., 2007) and studies of the distribution of benthic flora and fauna (Galparsoro et al., 2009; Kostylev et al., 2003; Wilson et al., 2007). DEMs represent the most accurate information available about marine environments and in most cases they determine the spatial resolution of the resulting model. Thus, a DEM and its basic derivatives have become the main environmental information used for marine spatial modelling of benthic entities.

Infralittoral benthic flora and fauna of the Canaries are well known and have been amply studied (Afonso-Carrillo and Sansón, 1999; Barquín-Diez et al., 2005; Bianchi et al., 2000; Brito et al., 1984; Brito and Ocaña, 2004; Espino et al., 2006; Haroun et al., 2003). Over the last ten years, the Spanish Ministry of Environment and local government has financed individual projects for each island of the Canary Archipelago to create a database on geophysical data and distribution maps of the main benthic assemblages and habitats from a depth of 0 to 50 m. Although the objective of every project of each island was the same, the projects were developed by different private companies using different methods and in different periods from 2000 to 2006. Consequently, the habitat and community charts and distributions greatly different, reflecting the lack of unified criteria in the methodology. Due to the absence of updated data, the inaccessibility of information and the many mistakes found in the distribution of habitats and communities, these maps lead to erroneous and harmful decision-making for marine management.

The aim of this paper is to establish distribution maps of the main macrobenthic communities of La Palma marine protected area by means of two presence-only analyses, Maxent and ENFA. Only the topographic information derived from the DEM is used as an environmental predictor, and direct observations from underwater video surveys are used for registering the presence of benthic communities. The same training and evaluation datasets were used to compare the accuracies of these two techniques. We examined the relationship of different environmental variables to the benthic communities in the study area, and we determined which ruggedness indices are more relevant. Moreover, this analysis defines the seafloor feature conditions that determine the presence of the different communities and the capacity of bottoms to accommodate different entities.

## 2. Materials and methods

### 2.1. Study area

La Palma is a volcanic island located at the northwest of the Canaries, a subtropical archipelago situate in the north of the Eastern Central Atlantic Ocean. The seafloor of the Island is characterised by high slopes of rocky and sandy bottoms that can reach high depths at only a few metres from the coast line. The Marine Reserve of La Palma is located at the western margin of the Island (Fig. 1), and it was established in 2001 to protect fish stocks, highly depleted due to high levels of exploitation. This side of the island also has the status of Special Area of Conservation (SAC) by the Habitats Directive 92/43/EEC to conserve the marine mammals *Tursiops truncatus*, the turtle *Caretta caretta* and *the submerged or partially submerged sea caves* habitat. The marine reserve is about 3455 ha extension and reaches to 1000 m depth but the study area is a water depth from 0 to 50 m, and we included in the analysis adjacent zones to the marine reserve, therefore, the final study extension is about 1574 ha, 597 ha inside the marine reserve and 977 ha outside. This protected study zone is only 18.7% of the marine reserve, but

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