Ecological Indicators 45 (2014) 139–147

Contents lists available at ScienceDirect

Ecological Indicators

journal homepage: www.elsevier.com/locate/ecolind

Landscape metrics as indicators of coastal morphology: A multi-scale approach

Rosa M. Chefaoui*

Centre of Marine Sciences (CCMAR), University of Algarve, Campus of Gambelas, P-8005-139 Faro, Portugal

ARTICLE INFO

Article history:
Received 2 January 2014
Received in revised form 21 February 2014
Accepted 3 April 2014

Keywords:
Coastal morphology
Generalized linear models
Landscape metrics
Moving-window
Scales

ABSTRACT

In this study, the aim was to assess how commonly used landscape metrics perform as predictors of coastal shape. I examined nine metrics computed in FRAGSTATS to model the distribution of three coastal features of the Iberian Peninsula: beaches, capes and gulfs. A multi-scale approach was used combining three extents, three resolutions and five moving-window sizes to implement generalized linear models (GLMs). This study has found that three landscape metrics (edge density, mean perimeter-area ratio and percentage of landscape) were good indicators for the three coastal features, while mean shape index was only for beaches and gulfs. Differences in performance were found among the coastal features and scales studied. GLMs revealed that the smallest extent (Levante coast) and resolutions (250 m^2 and 1 km^2) achieved better validation results, suggesting a higher suitability of these scales for detecting changes in vectorial shorelines. Differences in sensitivity and specificity were also found among models estimated from different moving-window sizes. The present study confirms previous findings on the high multicollinearity of landscape metrics, and the convenience of testing correlations in advance. Raster-based metrics computed from vectorial coastlines were effectively incorporated in spatial modeling. This research provides new insight into the use of coastal shape to predict species distributions and other coastal processes, serving as a base for future studies.

1. Introduction

Dependence of species on landscape structure has been extensively studied in the last decades (see Turner, 2005; Wu, 2013). A considerable amount of literature has been published on the relationships at multiple scales between landscape structure and species diversity or richness (e.g. Atauri and de Lucio, 2001; Steffan-Dewenter et al., 2002; Schindler et al., 2013), species assemblages (e.g. Gaucherel et al., 2007), and connectivity between populations (e.g. Ferreras, 2001). Therefore, terrestrial-based landscape metrics used as predictors in species distribution models (SDMs) have achieved favorable results (e.g. Mladenoff et al., 1995; Westphal et al., 2003; Foltête et al., 2012). Research in marine ecosystems also provides evidence for community-related characteristic spatial patterns (e.g. Garrabou et al., 1998), the influence of seascape on reef fish communities (e.g. Grober-Dunsmore et al., 2008; Belmaker et al., 2011), seascape heterogeneity and the efficacy of marine reserves (Huntington et al., 2010), among other relationships (see Wedding et al. (2011) for review). In addition, an increasing number of studies have been published on SDMs of marine species over recent years (see Robinson et al., 2011). So far, however, little progress has been made in the integration of landscape/seascape metrics in marine SDMs, with the exception of the use of surface morphology metrics derived from bathymetry (Pittman and Brown, 2011).

Coastlines play an important role in landscape ecology, constituting an edge between terrestrial and marine environments. Coastal morphology is relevant since can be used as a geoindicator of susceptibility to erosion (Marcomini et al., 2007), thus its analysis could improve the prediction of damage caused by severe weather events. Moreover, some coastal features may be good indicators of species associated with particular habitats (e.g. beaches, sheltered habitats) to be considered in SDMs, or management of marine protected areas (MAPs). However, the availability of detailed GIS layers on coastal habitats is limited to funded projects in a small number of countries (e.g. McBreen et al., 2011). Thus, metrics to evaluate coastal morphology over wider areas are needed. Previous research has consistently shown the difficulties to determine the most suitable metrics for a specific landscape; these metrics are highly redundant (Riitters et al., 1995; Cushman et al., 2008) and susceptible to changes in scale and landscape (e.g. Turner et al., 1989; Wu et al., 2002; Uuemaa et al., 2005). Therefore, examining

* Tel.: +351 289 800 900x7355; fax: +351 289 818 353.
E-mail addresses: rmdiaz@ualg.pt, rosa.chef@gmail.com

http://dx.doi.org/10.1016/j.ecolind.2014.04.004
1470-160X/

how landscape metrics change with scale in real landscapes is recommended (Wu et al., 2002) and previous studies have noted the importance of using moving window algorithm at multiple scales (e.g. Zurlini et al., 2006; Zaccarelli et al., 2008). On the other hand, several approaches have been proposed to measure coastlines. Mandelbrot (1967) suggested that coasts are statistically self-similar and could be characterized by a fractal dimension (D). A different view on this topic was presented by Andrle (1994), who criticized the dependency of D on scale of measurement and introduced the angle measure technique (AMT), which does not require that any assumption be made concerning the form of the relation between complexity and scale. The first study of coastal habitat selection by landscape metrics was reported by Albeke et al. (2010) who used the boundary convexity tool (BCT; Albeke et al., 2009) to predict otter latrine locations at a relatively local scale.

The aim of this research was to assess the suitability of commonly used landscape metrics to predict coastal features at multiple scales, and estimate its potential incorporation to marine SDMs and other coastal studies. Here, I used a procedure using FRAGSTATS (McGarigal et al., 2012) to calculate mapped distributions of landscape metrics using a moving-window approach. I tested in advance multiple landscape metrics over a range of moving-window sizes to avoid multicollinearity. The metrics so obtained were used as predictors to develop regression models of coastal features at multiple scales representative of those commonly used in SDMs and environmental studies. The scales were defined by the combination of extent, cell resolution and moving-window size used. This approach is innovative in using coastal geomorphological features themselves from a real landscape (Iberian Coast), instead of presences of species linked to coastal habitats. Thus, avoiding other parameters affecting species distributions such as abiotic and biotic factors, dispersal or evolutionary capacity (Soberón and Peterson, 2005), and multiple types of biases and uncertainties (see e.g. Kadmon et al., 2004; Rocchini et al., 2011). The study attempts to show the prospects of the application of landscape metrics to predict coastal species and other ecological processes linked to the morphology of the coasts.

2. Methods

2.1. Coastal features on multiple scales

Capes, gulfs and beaches distribution data of the coast of the Iberian Peninsula were compiled from databases offered by Spanish public institutions (Guía de Playas, 2013; NGCE v1.0), and Portuguese raster cartography (IGEOE) visualized and digitized using Google Earth. Gulfs, bays, inlets, estuaries and harbors from these databases, were grouped into the category “Gulfs”, on the basis of being sheltered habitats. “Capes” comprises capes, promontories, and other major headlands. Because of continuous distribution of the beaches along the Iberian coast, a predictive model of all them would not be feasible; thus, only those of over 2 km in length were considered under “Beaches”. To simplify the approach, records on islands and inland river beaches were discarded. Data sizes vary according to each scale (Fig. 1).

I designed a multiscale analysis defined by: (a) a nested set of spatial extents: Iberian Coast, Mediterranean Coast, and Levante Coast (Fig. 1); (b) three resolutions for grid mapping: 250 m × 250 m, 1 km × 1 km, and 10 km × 10 km (Table 1); and (c) five moving-window sizes to compute landscape metrics. Scales were selected to be representative of most ecological studies carried out with SDM while allowing discrimination of changes in coastal morphology. Coastlines at all extents were rasterized from high resolution world vector shoreline (GSHHG v. 2.2.2) using GEODAS desktop software (GEODAS-NG v. 1.1.1.1) to select and extract subsets. Given the differences between the collected data in terms of their format as well as their projections, I reprojected all vectorial and grid data to WGS 84/UTM zone 30 N using the “rgdal” package in R (R Core Team, 2013), assuming the distortion would be minor as this is the central zone from the three extant in the study area (huses 29–31). Data points incorrectly located were checked to fit the set of rasterized shorelines.

2.2. Selection of landscape metrics and moving-window sizes

I estimated the most appropriate landscape metrics and moving-window sizes to use in subsequent generalized linear

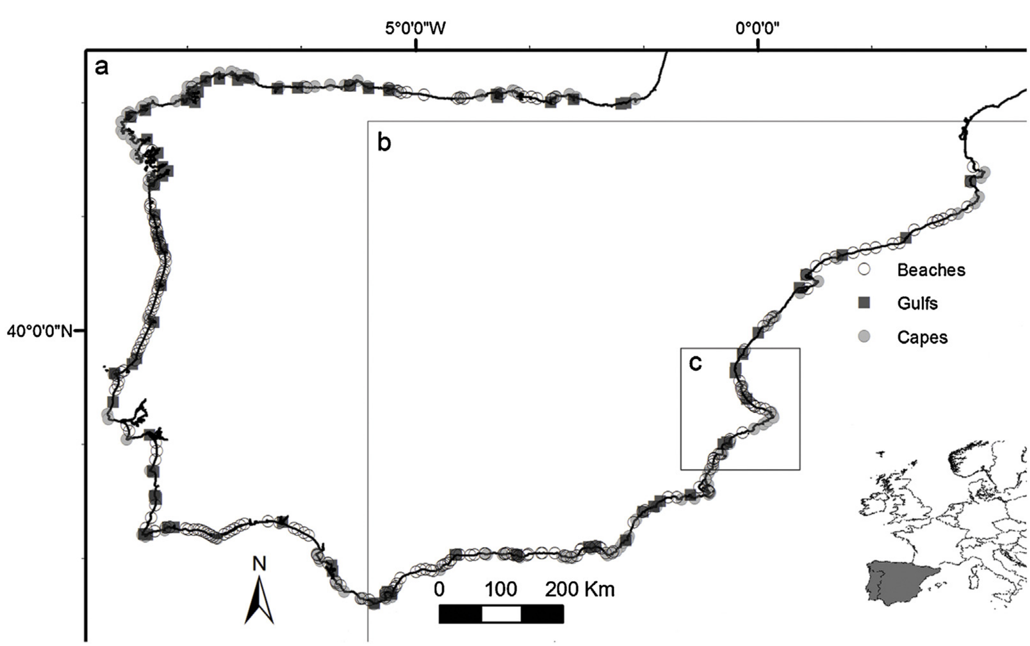

Fig. 1. Location of the coastal features within the three extents used in the study. Extents: (a) coast of the Iberian Peninsula; (b) Mediterranean coast and (c) Levante coast.