Biological Conservation 166 (2013) 221–230

Contents lists available at SciVerse ScienceDirect

Biological Conservation

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

Using species distribution modelling to disentangle realised versus potential distributions for rare species conservation

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ARTICLE INFO

Article history:
Received 10 December 2012
Received in revised form 7 June 2013
Accepted 1 July 2013

Keywords:
Species of conservation interest
Rare species
Maxent
Occupancy
Range maps
Western Mediterranean

ABSTRACT

Range maps provide important information in species conservation management, specially in the case of rare species of conservation interest. For the vast majority of cases, this information can only be estimated by means of species distribution modelling. When absence data is unavailable, modelled distribution maps represent the spatial variation of the degree of suitability for the species rather than their realised distribution. Although discerning potentially suitable areas for a given species is an important asset in conservation, it is necessary to estimate current distributions in order to preserve current populations. This work explores the use of species distribution modelling (Maxent) for species of conservation interest when their Extent of Occurrence (EOO) is well-known and there is quality occurrence data. In this case, derived binary maps of potentially suitable areas can be obtained and used to assess the conservation and protection status of a given species in combination with the EOO and existing protected area networks. Seven species, which are rare and endemic to the Western Mediterranean, have been used as an example. Valuable information for conservation assessment such as potentially suitable areas, EOO, Areas of Occupancy (AOO) and degree of protection is provided for this set of species. In addition, the existing informal view that among experts these species have range sizes much smaller than their potentially suitable area is confirmed. This could probably be attributed to important but currently unknown predictor variables and to historical phylogeographic factors.

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1. Introduction

A crucial aspect in the conservation of a species is the knowledge of the area it occupies; *i.e.* its range map and size. This kind of information is needed both to evaluate its risk of extinction (Collar, 1996; IUCN, 2001; Rodrigues et al., 2006) and to assess its degree of protection (Scott et al., 1993; Rodrigues et al., 2004b; Rodrigues et al., 2004a). However, for the vast majority of species such information is either non-existent or very poor at any given scale (Newbold, 2010); this is known as the *Wallacean shortfall* (Lomolino et al., 2004). This problem is aggravated when considering rare species, for which occurrence data tends to be very scarce. Collecting enough data from species surveys to delineate species ranges is an impractical and very expensive task (Niamir et al., 2011). When no planned and systematic surveys exist, the only source of information available is presence-only data coming from opportunistic citations of species, which can be found in the technical and scientific literature or in digital atlases compiled by public or private organizations (Anderson, 2012). Estimating the distribution of species by means of modelling tools becomes the only solution available when performing conservation assessments.

Studies abound that have successfully applied species distribution modelling techniques to existing species occurrence data to predict spatially-explicit species ranges even when data is scarce and presence-only (Elith et al., 2006; Pearson et al., 2007; Phillips and Dudík, 2008; Rebelo and Jones, 2010; Gogol-Prokurat, 2011; Razgour et al., 2011). Species distribution modelling has been shown to be useful when modelling rare species with narrow ranges and available quality data (Sardà-Palomera et al., 2012). Also, in the case of rare species, observations of occurrence normally represent a comprehensive view of their distribution and capture a large part of it (Lomba et al., 2010).

Conservation decision-makers normally prefer binary maps of presence/absence or suitable/unsuitable areas to continuous probability models. Nevertheless, in cases where the latter are validated, they should be provided to decision-makers along with the binary maps in order to convey their inherent uncertainty and to allow the application of different thresholds as needed. In order to convert probability maps into binary maps, a threshold

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0006-3207/$ - see front matter © 2013 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.biocon.2013.07.001

value is needed (Fielding and Bell, 1997; Liu et al., 2005; Jiménez-Valverde and Lobo, 2007). These binary maps can then be used as species distributions and to calculate their range sizes and assess their conservation status and protection. Knowledge of species ranges is necessary to elaborate specific action plans for their conservation and to ensure their inclusion in protected areas, two important conservation actions to ensure species survival (Cuttelod et al., 2008). Extent of Occurrence (EOO) and Area of Occupancy (AOO) are accepted surrogate measures of species ranges used in assessing the extinction risk of species (IUCN, 2001). These are measures that try to reflect the species realised distribution. Yet, when no absence data is available, what we get are distributions close to potential ranges for the species (Jiménez-Valverde et al., 2008; Lobo, 2008). Therefore, when using species distribution modelling techniques in conservation assessment, these differences between realised and potential distributions need to be explicitly accounted for and explained.

Protected areas are one of the main conservation policy tools to address biodiversity protection, *i.e.* preserve species and ecosystems from human impact (Convention on Biological Diversity, 2010; Butchart et al., 2012). Protected area coverage is used as a surrogate indicator or *proxy* of biodiversity conservation status (United Nations Environment Programme, 2009; United Nations Development Programme, 2010; United Nations Environment Programme, 2006; European Environment Agency, 2005; Millenium Ecosystem Assessment, 2005; Chape et al., 2005). Normally, protected areas are designated on the basis of currently known species distributions, not potentially suitable areas. It has been found that protected area systems are highly inefficient since they do not always cover key species (Jackson et al., 2009). Knowledge of the discrepancy between realised and potential distributions can contribute not only to assess conservation and protection status (Attorre et al., 2012) but also to identify possible areas for the translocation of species.

The Mediterranean Basin is a threatened biodiversity hotspot with a high human population density (Cincotta et al., 2000; Myers et al., 2000; Underwood et al., 2009) driving important processes of land use change, habitat fragmentation and habitat loss, especially in coastal areas (Vogiatzakis et al., 2005; Gerard et al., 2010). It is a region of high conservation risk with a great disparity between habitat loss and protection (Hoekstra et al., 2005). It is also one of the world's most diverse regions with respect to plants (Cowling et al., 1996; Médail and Verlaque, 1997; Médail and Quézel, 1999). Its exceptional number of endemic plants (13,000 out of an estimated total of 25,000), representing 4.3% of all plant species globally, make it a *hyper-hot* candidate for conservation support (Mittermeier et al., 1998; Myers et al., 2000; Olson and Dinerstein, 2002) even more so when considering that over 1900 of them are threatened or extinct (Brooks et al., 2002). Endemic species have restricted geographic ranges and are prone to becoming endangered and at risk of extinction, an even higher risk if they are also rare. Knowledge of endemic plant distributions is much needed in the Mediterranean Basin (Kark et al., 2009) and other Mediterranean-climate zones (Loarie et al., 2008; Riordan and Rundel, 2009; Williams et al., 2009). Despite the existence of an extensive protected area network, particularly on the European side, there is little knowledge of the amount of suitable and actual ranges of species of protection interest that fall into protected areas. In addition, endemic species are a specially significant case for which the determination of those ranges is of utmost importance. Conservation actions should ensure that species currently listed as threatened are sufficiently protected (Margules and Pressey, 2000; Underwood et al., 2009).

The purpose of this paper is threefold: (a) to develop a methodology for assessing range sizes and conservation status of rare species, (b) to explore the discrepancy between realised and potential ranges when using species distribution modelling with presence-only data and finally, and (c) to estimate range sizes for seven case-study western Mediterranean endemic species of conservation interest.

2. Methods

2.1. Area of study

The study area is the Western Mediterranean as defined by those areas of Mediterranean climate inside the bounding box with the following coordinates: west = 2,300,000 m, south = 930,000 m, east = 5,100,000 m and north = 2,600,000 m (Lambert Azimuthal Equal Area (LAEA)) (see Fig. 1). We defined Mediterranean climate zones by a broadly drawn polygon comprising categories "csa", "csb" and "csc" in Köppen-Geiger climate classification (Kottek et al., 2006). The study area has been limited to the Western Mediterranean and not the whole basin since none of the study plants has been observed east of Italy. The extent of the study area used when modelling the distribution of species needs careful consideration for it has important consequences for the outcome of the model (Sardà-Palomera et al., 2012), *e.g.* increasing its area increases the AUC values (Jiménez-Valverde et al., 2008). The appropriate extent of analysis should correspond to those areas that have been accessible by the species over relevant periods of time (Barve et al., 2011), *i.e.* region M in a BAM diagram (Soberón and Peterson, 2005; Soberón and Nakamura, 2009). Our study area comprises most of the Iberian peninsula, southern France, western and southern Italy, two thirds of northern Morocco, northern Algeria and northern Tunisia. All data in this study has been projected to LAEA-ETRS89 and used at this coordinate system.

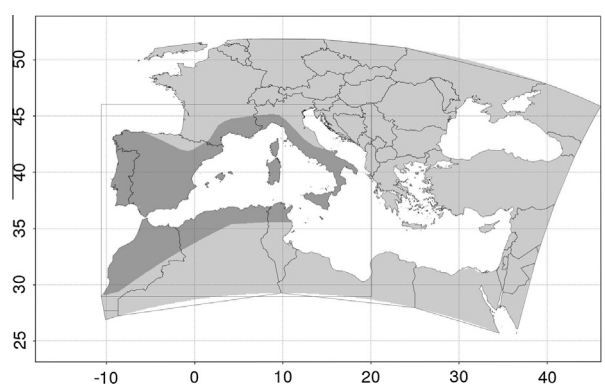

Fig. 1. Study area corresponds to the dark grey area on the map. This area represents the mediterranean climate region within the Western Mediterranean bounding box (west = −10.573961, south = 28.930152, east = 21.237540, north = 51.369878 (WGS 84 – EPSG:4326)). It represents our assumed *M* area, as in (Soberón and Peterson, 2005).

Table 1
Study species. Column: No. occ. is the number of occurrences available per species at 1000 m resolution.

Species	No. occ.
Asplenium majoricum Litard.	19
Carduncellus dianius (Webb) G. López	24
Diplotaxis ibicensis (Pau) Gómez Campo	72
Euphorbia squamigera Loisel.	52
Helianthemum caput-felis Boiss.	50
Medicago citrina (Font Quer) Greuter	10
Silene hifacensis Rouy ex Willk.	25

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