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Structural connectivity as an indicator of species richness and landscape diversity in Castilla y León (Spain)

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ABSTRACT

Connectivity loss has been identified as one of the greatest threats to biodiversity, at both the species and ecosystem levels. This study aims to find possible correlations between structural connectivity and faunal richness and landscape diversity in Spain's largest region, Castilla y León. Based on data provided by the National Biodiversity Inventory and the CORINE Land Cover land-use mapping for 2000 and 2006, species richness was characterized by the number of species occurring in a grid overlaid on the 10 × 10-km-territory. The Shannon Index for land uses was also calculated in each one of the grid cells, providing information on landscape diversity. Structural connectivity was studied using the Morphological Spatial Pattern Analysis, thus providing information on landscape diversity for different edge widths in two different habitat types. Lastly, the analyses showed that there is a slight relationship between structural connectivity and landscape diversity, but not between structural connectivity and faunal richness.

1. Introduction

The movement of organisms and materials across landscapes is commonly called connectivity and is important for maintaining ecological processes (Olds et al., 2012). Connectivity is a vital element in landscape structure because of its importance in species-landscape interactions (Tian et al., 2017). Hundreds of habitat network initiatives are underway around the world (Bennett and Mulongoy, 2006) as a means of implementing the 21st-century paradigm of connectivity conservation (Crooks and Sanjayan, 2006; Worboys et al., 2010). Landscape connectivity is important for the ecology and genetics of populations threatened by climate change and habitat fragmentation (Rayfield et al., 2016). Broadly speaking, connectivity is a function of habitat area, quality and arrangement, and the dispersal capabilities of individual species (Hodgson et al., 2009).

Today, one of the main nature conservation strategies is to define and apply connectivity criteria. In this sense, connectivity models are useful tools that improve the ability of researchers and managers to plan land use for conservation and preservation (Pelletier et al., 2014). Structural connectivity can be defined as "*the land's ability of the land to allow the movement of organisms among patches with resources*" (Taylor et al., 1993; Gurrutxaga and Lozano, 2007). This connectivity is achieved through ecological corridors that are of great importance for biological conservation and evaluation of biodiversity (Vogt et al., 2007). Moreover, it improves the performance of a wildlife reserve (Olds et al., 2011). Related with this, the ability to identify regions of high functional connectivity for multiple wildlife species is essential for habitat conservation and management and for corridor planning (Koen et al., 2014). Although it is becoming increasingly common for corridors to be included in biodiversity conservation programmes, their practical conservation value has nevertheless been the subject of fierce debate (Dawson, 1994; Rosenberg et al., 1997; Beier and Noss, 1998). Bienen (2002) draws attention to conservation corridors and the spread of infectious disease.

Population viability may depend on habitat area, habitat quality, the spatial arrangement of habitats (aggregations and connections) and the properties of the intervening non-breeding (matrix) land (Hodgson et al., 2011). Previous studies have shown that the width, shape and dimension of connectivity in the habitat affect diversity and abundance of species due to the effect of the special structure of the dispersion distribution and persistence of the species (Galanes and Thomlinson, 2008).

On the other hand, many of the methods used to identify wildlife linkages depend on the identification of focal or umbrella species (Beier et al., 2006; Cushman and Landguth, 2012). However, this can pose a challenge because a favourable dispersal habitat for one species might

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be impermeable for others. Indeed, several studies have found that corridors identified for one species are not necessarily used by other species (Beier et al., 2009; Cushman and Landguth, 2012; Cushman et al., 2013; LaPoint et al., 2013). Thus, the development of an approach that can accommodate functional connectivity requirements for multiple species would be a valuable contribution to conservation research.

The habitats of many species have been extensively reduced, degraded, and fragmented to the point that their survival, and the functionality of these ecological systems is often seriously threatened (Sala et al., 2000). Connectivity loss in the natural ecosystem is considered as one of the main threats to wildlife dispersal and survival and to biodiversity conservation in general (Triviño et al., 2007; Gurrutxaga and Lozano, 2009). This has caused growing interest in the consideration of connectivity in landscape management and conservation planning (Pascual-Hortal and Saura, 2006).

Human impact on natural ecosystems is the most important driver of the current mass extinction of species (Millennium Ecosystem Assessment, 2005) and one of the greatest concerns for biodiversity conservation. The reduction of the ecosystems due to human pressure, as well as the substitution of habitats with other kinds of land uses, result in the permanent loss of these habitats (Lele et al., 2008). For example, areas of land abandonment and agriculture expansion usually affect biodiversity conservation (Nanni and Grau, 2017). With these problems in mind, a series of concepts such as wildlife corridors, landscape links, and ecoducts has been developed within the theoretical framework of landscape ecology (Turner, 2005; Turner et al., 2011).

The establishment of ecological networks (ENs) has been proposed as an ideal way to counteract the increasing fragmentation of natural ecosystems and as a necessary complement to the establishment of protected areas for biodiversity conservation (Boitani et al., 2007). Since the 1980s the idea of ENs has attracted increasing attention, particularly in Europe (Jongman and Kristiansen, 2001). One strategy to mitigate the serious effects of this fragmentation is to maintain or increase connectivity between the different ecosystems that make up the habitat (Saura et al., 2011). Works such as DellaSala et al. (2015) stress the importance of maintaining or increasing landscape connectivity as a fundamental principle of ecosystem management. Modern forest managers must understand how forest landscape structure also helps maintain biodiversity in harvested landscapes (Lindenmayer, 2016), including those who seek to implement forest conservation initiatives on multiple spatial scales (Gustafsson and Perhans, 2010) and achieve sustainable forest management that balances the social, economic, and environmental values of forest ecosystems (De Groot et al., 2010; Wood et al., 2017).

Morphological Spatial Pattern Analysis (MSPA) is an innovative method for evaluating structural connectivity, classifying the area occupied by an ecosystem into different structural categories such as core elements, connecting elements, edge elements, and isolated elements (Soille and Vogt, 2008). MSPA makes it possible to analyse the functional connectivity of the pattern under consideration using the Probability of Connectivity Index (PC) (Saura and Pascual-Hortal, 2007).

There is a need to develop actions for the conservation and sustainable use of biodiversity to preserve natural heritage. Species richness is a common method used to evaluate biological diversity (Ribeiro et al., 2011). In addition, landscape diversity is one of the main correlates with species richness, showing positive correlations between habitat heterogeneity and species diversity (Tews et al., 2004). Study of landscape diversity has increased and improved in the recent years thanks to the development of new technologies for geographical information, and remote sensing, as well as the consolidation of the theoretical and methodological framework in relation to the influences of this land diversity on species diversity (Moreira, 2001; Hernando et al., 2017). A number of indices have been proposed to estimate the diversity of landscapes, habitats and ecosystems, in order to quantify the landscape, its composition and its configuration. One of these is the Shannon Index, which makes it possible to measure landscape structure (Ramezani and Holm, 2009), establishing a clear relationship between landscape diversity, species richness and structural connectivity (Velázquez et al., 2018).

We studied possible correlations between structural connectivity and faunal richness and structural connectivity and landscape diversity in Castilla y León. If these correlations are high, structural connectivity could be used as an indicator of landscape and fauna diversity and thus help in decision-making in the management of the natural environment.

Other specific objectives of this study are: (1) to study the structural connectivity of forest and natural areas in Castilla y León; (2) to determine the influence of edge width on the structural connectivity of the forest and natural spaces of Castilla y León; (3) to characterize animal richness based on the presence of vertebrates; (4) to characterize the landscape diversity; and (5) to study the evolution of landscape diversity in Castilla y León over time.

2. Material

2.1. Area of study

Castilla y León is the largest region in Spain, with an area of 94,225 km^2, which accounts for 18.6% of the total area of the country, and is one of the least populated regions. It is a broad plateau surrounded by mountains, with marked contrasts in elevation that vary between 200 and 2600 m. This results in large differences in rainfall, which is around 1500 mm a year in the mountains and about 400 mm in the centre of the region.

There are three climate zones in the Castilla y León region:

- Atlantic climate, which affects the mountains in the north. It is characterized by mild temperatures, resulting in associated vegetation consisting of meadows and deciduous tree forests (beech, oak and chestnut woods).
- Continental Mediterranean climate, with extreme temperatures, present in the centre and south of Castilla y León. The predominant vegetation consists of Holm oak and cork oak; zones of steppe and shrub-like vegetation can also be found.
- High-mountain climate, which is cold and moist, presenting the vegetation in bioclimatic levels: Mediterranean forest in the lower zone, Atlantic forest in the middle section, and mountain meadows in the higher upper levels.

2.2. Material

The information about Castilla y León region required to carry out this study was obtained through the CORINE Land Cover cartography project (European Environment Agency, 2006; 2012) and the Vertebrate database of the National Inventory of Biodiversity (Ministerio de Medio Ambiente y Medio Rural y Marino, 2007), explained in detail below:

2.2.1. CORINE land cover cartography (CLC)

The cartography database used in this work was drawn from the CORINE Land Cover project, whose fundamental aim was the establishment of a multi-temporal database of the covered area and uses of the territory in Europeat a scale of 1:100,000.

The different land uses are divided in 44 categories, 36 of which are located in our study zone. The minimum surface mapping unit is 25 ha and 5 ha in the case of changes in land occupation.

There are currently 4 CLC versions based on data from the years 1990, 2000, 2006 and 2012. In our case, we decided to start from the cartographic information from 2006 and 2012 to analyse the evolution of landscape diversity in recent years (See Fig. 1).