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Research article

Protected area effectiveness against land development in Spain

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A B S T R A C T

Land use-land cover (LULC) changes towards artificial covers are one of the main global threats to biodiversity conservation. In this comprehensive study, we tested a number of methodological and research hypotheses, and a new covariate control technique in order to address common protected area (PA) assessment issues and accurately assess whether different PA networks have had an effect at preventing development of artificial LULCs in Spain, a highly biodiverse country that has experienced massive socioeconomic transformations in the past two decades. We used digital census data for four PA networks designated between 1990 and 2000: Nature Reserves (NRs), Nature Parks (NPs), Sites of Community Importance (SCIs) and Special Protection Areas (SPAs). We analysed the effect of explanatory variables on the ecological effectiveness of protected polygons (PPs): Legislation stringency, cummulative legal designations, management, size, age and bio-physical characteristics. A multiple Before-After-Control-Impact (BACI) semi-experimental research design was used whereby artificial land cover increase (ALCI) and proportional artificial land cover increase (PALCI) results were compared inside and outside PAs, using 1 km and 5 km buffer areas surrounding PAs as controls. LULC data were retrieved from Corine Land Cover (CLC) 1990 and 2006 data. Results from three spatial-statistical models using progressively restrictive criteria to select control areas increasingly more accurate and similar to the assessed PPs were compared. PAs were a generally effective territorial policy to prevent land development in Spain. NRs were the most effective PA category, with no new artificial land covers in the assessed period, although exact causality could not be attributed due to legal overlaps. SPAs were the least effective category, with worse ALCI data than their control areas. Legal protection was effective against land development, which was influenced by most bio-physical variables. However, cumulative legal designations and PA management did not seem to influence land development. The spatial-statistical technique used to make cases and control environmentally similar did not produce consistent outcomes and should be refined.

1. Introduction

Habitat destruction and degradation are the primary causes of biodiversity loss in terrestrial and freshwater ecosystems (Joppa et al., 2008; Piekielek and Hansen, 2012; WWF, 2016). They result from increasingly intensive LULC changes to meet rising food, commodity, energy, transport and housing demands (Smith et al., 2016). Among all LULC changes towards intensive uses, land development can arguably be considered the most concerning one from an environmental sustainability perspective because it can (and often does) cause permanent and irreversible destruction or degradation of natural and semi-natural habitats through impacts such as vegetation clearing, soil sealing, fragmentation or isolation (McKinney, 2002; Jiménez et al., 2005; EEA, 2011; Martínez-Fernández et al., 2015).

PAs are the main global policy for the long-term conservation of biodiversity and associated ecosystem services (Dudley, 2008; Gaston et al., 2008; Venter et al., 2014). Thus, preserving natural or semi-natural LULCs of high biodiversity value should be considered a paramount factor when assessing PA effectiveness (Gaston et al., 2008; Joppa et al., 2008; Nagendra, 2008). Some studies on the effectiveness of PA sets or networks to prevent conversion of

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natural LULCs have been conducted in tropical areas (Joppa et al., 2008; Andam et al., 2008; Pfeifer et al., 2012; Carranza et al., 2014; Spracklen et al., 2015; López-Rodríguez and Rosado, 2017) and in data-richer, temperate areas (Gaston et al., 2006; Araújo et al., 2007; Mallinis et al., 2014; Martínez-Fernández et al., 2015; Fiorini et al., 2017). Although some of these studies have used sound semi-experimental designs to ascertain causality (Addison, 2011), few of them have discriminated the effect of legal protection and management effort in PA effectiveness related to LULC change.

Accurate attribution of PA effects faces a number of challenges (Schreckenberg et al., 2010; Addison, 2011; Ferraro and Hanauer, 2015). Firstly, partial or total overlap between different designation categories is common and makes it difficult to discriminate legal protection effects on official PA boundaries (Iojă et al., 2010; Foster et al., 2014; Stortini et al., 2015). (Rodríguez-Rodríguez et al., 2016a) proposed a spatial 'protected polygon' (PP) approach that differentiates overlapping and non-overlapping PPs within official PA boundaries for more accurate analysis of legal effects. Secondly, PA boundaries are not static in time and, as conservation theory, resources and practice evolve, so is expected PA design in terms of shape, size or connectivity (Pressey et al., 2007; Araújo et al., 2011). Assigning PA effects with changing boundaries has therefore clear implications regarding result precision. Thirdly, selecting adequate control sites for pre-defined samples such as PAs remains an active research subject (Mas, 2005; Andam et al., 2008; Spracklen et al., 2015). Overlaps with other PAs or other types of sectoral protection measures outside targeted PAs are also a common issue affecting control, 'unprotected' areas (Spracklen et al., 2015). Some authors have tried to reduce control-case overlap problems by restricting buffer distances from PA boundaries, thus reducing the probability of overlap with neighbouring PAs (Pfeifer et al., 2012) or by extracting some other protected zones from the analysis (Andam et al., 2008; Spracklen et al., 2015). Additionally, PA effectiveness studies comparing LULC changes inside PAs and in *ad hoc* adjacent buffers outside PAs are not considered accurate enough, as buffers can have environmental or socioeconomic characteristics that are very different from those inside PAs so as to affect LULC changes, making comparisons inappropriate and results, biased (Mas, 2005; Andam et al., 2008). Different methods to mimic experimental studies by creating environmentally similar control sites to cases have been proposed: buffer areas with the same proportion of some categorical, uncorrelated variables (Mas, 2005); selection of adjacent, equal-area inner and outer zones (Spracklen et al., 2015); or more complex covariate matching methods (Andam et al., 2008). Although all these techniques control for the most common confounding factors affecting LULC, none of these studies claims to avoid all overt or hidden bias, as diverse unconsidered environmental and socioeconomic variables at different scales may influence multi-factorial dependent variables such as LULC changes (Andam et al., 2008).

In densely populated places like Europe, human competition with biodiversity for land is intense (EEA, 2011). Artificial land cover increase is the dominant LULC change (EEA, 2015a), which seriously threatens European biodiversity (Davis et al., 2014). By the year 2000, the Mediterranean Basin was among the two global biodiversity hotspots with the greatest urban area and that area was forecasted to increase by 160% by 2030 (Seto et al., 2012). In Spain, a Euro-Mediterranean country affected by both regional trends, massive transport, residential and tourist infrastructure development in the past two decades has caused huge LULC changes towards artificial covers across the country, especially along the coast and in peri-urban areas (Jiménez, 2012; Alfonso et al., 2016). As a result of such trends, 99% of Spanish land is located within 7.6 km, 6.4 km and 5.2 km from a built-up area, transport corridor and impervious surface, respectively (Torres et al., 2016). Those changes peaked around 2007, as soon after that year the housing bubble burst and subsequent economic and financial crisis markedly reduced new infrastructure, industrial or residential developments in the country (García, 2010; Fernández-Tabales and Cruz, 2013). Spain is also a highly biodiverse country (Médail and Quézel, 1999; Williams et al., 2000; Araújo et al., 2007) which makes it especially important to assess and control the effects of land development on Spanish biodiversity. To respond to such sustainability challenge, substantial legislative effort has been made to designate PAs under different categories, which currently cover nearly 28% of the Spanish terrestrial territory (Múgica et al., 2014), although management effort, including monitoring and assessment, still needs considerable improvement in many PAs (Rodríguez-Rodríguez et al., 2015).

In this study, we used complete digital census PA data in Spain to: a) verify some methodological hypotheses to enhance accuracy of PA effectiveness assessments; b) test a number of research hypotheses related to the effectiveness of PAs as a public policy to prevent land development in Spain; and c) test a simple spatial-statistical technique for selecting adequate control areas and making more valid comparisons in PA effectiveness assessments.

2. Materials and methods

2.1. Study area

Spain covers most of the Iberian Peninsula, in south-western Europe, plus two archipelagos: Balearic Islands and Canary Islands. The five PA categories assessed here were selected because they have clear legal, nominal and managerial characteristics across the whole country. Administrative competencies for PA designation and management correspond to the 19 regional governments, except for the overall coordination of the network of National Parks which is a national government's competency (Spanish Government, 2007, 2014). Fig. 1 shows the spatial coverage of the PA categories assessed in this study according to their selection criteria.

2.2. Data collection and pre-processing

Official digital boundaries of five PA networks representing most terrestrial protected area in Spain as well as a continuum in terms of legislation stringency were retrieved from the Spanish Ministry of Environment's digital repository, updated by December 2014 (MAGRAMA, 2015): Nature Reserves (N = 141), National Parks (N = 10), Nature Parks (N = 141), Special Areas of Conservation (SACs)/Sites of Community Importance (SCIs; N = 1451) and Special Protection Areas (SPAs; N = 636). Only PAs that had not been, to our knowledge, reclassified or enlarged since their original designation dates were selected in order to provide precise results in time. We added national parks' peripheral protection zones to their respective national park area, as they confer legal protection against LULC changes (Spanish Government, 2014) and would thus make inadequate controls.

All GIS layers except SCIs' and SPAs' included each PA's designation date. For SCIs and SPAs, we joined the "Natura 2000 Access Database" including each site's proposal, confirmation (for SCIs) and designation dates (EEA, 2015b) to the original SCI and SPA layers. We considered SCIs' proposal dates as designation dates, as legal restrictions regarding LULC changes generally apply since the site is proposed for inclusion in national SCI proposal lists prior to submission for approval by the European Commission (European Communities, 2000). Only terrestrial PAs equal to or bigger than 100ha were selected (N = 1874 PAs) due to the coarse resolution of