Effect of legal protection and management of protected areas at preventing land development: a Spanish case study

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Abstract

Protected areas are entrusted long-term biodiversity conservation, but measures of their effectiveness are limited, methodologically diverse and, sometimes, of improvable accuracy. Using a semi-experimental BACI research design, this study assesses the environmental effectiveness of two highly related multiple-use protected area (PA) categories of European relevance at preventing land development: Sites of Community Importance (SCIs) and Special Areas of Conservation (SACs). The non-overlapping SCI and SAC polygon networks of a northern Spanish region (Navarra) were used as the best possible case studies in the country because their main difference is implementation of active management (in the case of SACs). One kilometre outer buffer areas were created to serve as controls for each of the two PA networks. Three spatial-statistical models that progressively consider exclusion areas according to additional land protection legislation and biophysical covariates were tested to maximise their accurateness. Percentual increases of land development were compared for each of the four groups: SCIs, SCI-Buffers, SACs and SAC-Buffers, using Corine Land Cover (CLC) data from 2006 and 2012. Results show that SACs have been fully effective at preventing land development in the Navarra region whereas some exceptional development occurred in SCIs, even though their biophysical characteristics made them less prone to development than their buffer areas. Additional legislation seems to slightly add to protection inside PAs and provides clear protection to surrounding buffer areas. Residential uses were minor among the new artificial uses around Navarra's PAs.

Keywords Natura 2000 site · Effectiveness · Legislation · Land use-land cover · BACI design

Introduction

Land development resulting from urban, industrial and infrastructural expansion is a phenomenon of global concern due to

its serious effects on biodiversity conservation through natural habitat destruction, degradation and fragmentation, and soil sealing (Irwin and Bockstael 2007; McDonald et al. 2008; McKinney 2002). Actually, habitat destruction and degradation are the primary causes of biodiversity loss in terrestrial and freshwater ecosystems (WWF 2016). To counter habitat loss and species decline, PAs have been designated across the globe (Bhola et al. 2016; Nagendra 2008). However, measurements of PA effectiveness are diverse, use different techniques, focus on different indicators and differ in accuracy and precision (Gaston et al. 2008; Nagendra 2008). In tropical areas, avoided deforestation is often used as an indicator of PA effectiveness (Andam et al. 2008; Mas 2005; Pfeifer et al. 2012; Spracklen et al. 2015). In Europe, development of natural and semi-natural habitats is the dominant land use-land cover (LULC) change (EEA 2015a), and seriously threatens European biodiversity (Davis et al. 2014). Thus, other PA effectiveness indicators, such as housing growth, have been suggested for use in non-forested ecosystems and developed nations (Radeloff et al. 2010).

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LULC changes can be monitored on a consistent, regular and quantitative basis through remote sensing techniques, which make them a suitable and comparable indicator of PA effectiveness (Nagendra 2008). LULC changes from natural or semi-natural LULCs to artificial ones can be considered largely permanent and irreversible (Jiménez et al. 2005). Thus, we focused on these LULC changes as the primary metric of PA effectiveness (Nagendra 2008) for having the greatest direct, negative and permanent impact on biodiversity conservation (McKinney 2002). Other LULC changes, such as cropland expansion, may also have important effects on biodiversity (Davis et al. 2014; Martinuzzi et al. 2015), although it is assumed that those changes can be reversed much more easily, sometimes through natural succession, than changes from natural or semi-natural LULCs to artificial LULCs (McKinney 2002).

Differences in protection may entail differences in the intensity and direction of LULC changes in PAs (Martínez-Fernández et al. 2015). SCIs and SACs can be considered multiple-use PAs in which a wide range of socioeconomic activities are permitted, if they are not considered harmful to protected features (European Commission 2016a; Rodríguez-Rodríguez et al. 2015a). Both PA categories can also be classified under the IUCN PA management category IV: Habitats/Species Management Areas (Atauri et al. 2006; Dudley 2008). Given that SACs are only different from SCIs in the sense that active management is being implemented in them, they make exceptionally good cases and controls, respectively, for accurately assessing and clearly discriminating the effects of legal protection of PAs from those of PA management, which remains a pending research task (Ferraro and Hanauer 2015; Juffe-Bignoli et al. 2014; Rodríguez-Rodríguez et al. 2016a). Some authors claim that accurate PA effectiveness assessments should compare only environmentally similar cases and controls and that not doing so systematically results in overestimating the *protection effect* of PAs (Andam et al. 2008; Joppa and Pfaff 2011; Mas 2005; Nagendra 2008; Spracklen et al. 2015), as PAs have been historically designated in areas with some biophysical characteristics that make them of little human use and economic interest (Gaston et al. 2008; Joppa and Pfaff 2009). Previous studies that have considered covariates to create buffer areas (controls) that were biophysically similar to PAs (cases) have reported a reduced effect of *protection* on deforestation when compared to unrestricted controls (Andam et al. 2008; Joppa and Pfaff 2011; Mas 2005). Nevertheless, the effect of additional sectoral legislation that forbids or restricts land development inside and outside PAs has rarely been considered as influencing PA effectiveness.

Land development inside PAs in developed nations with strong policies and institutions can be deemed exceptional, although substantial LULC changes towards residential uses in the immediate surroundings of PAs compared to national

averages have been reported (Radeloff et al. 2010) and are forecasted to expand (Martinuzzi et al. 2015). Encroachment of natural ecosystems in PAs by artificial LULCs hampers PA effectiveness and jeopardises conservation of protected biodiversity in terms of isolation of wild populations and increased risks associated to human-nature interactions, such as wildfires, leading to inner habitat destruction or degradation (Radeloff et al. 2010). Land development was the main LULC change in Spain during the 1990–2000 decade. In this period, Spain increased its artificial areas by 26%, nearly doubling the EU-15 average in the same period at 14%, chiefly at the expense of natural grasslands, moors and heathland and sclerophyllous vegetation (Jiménez et al. 2005). This process of land development was especially intense in regions like Navarra, which increased its artificial areas by more than 50% in that decade (Jiménez et al. 2005) and by as much as 95% in the 1987–2006 period (Jiménez 2012). Massive residential and infrastructural construction still continued across Spain until the burst of the housing bubble in 2008 (Alfonso et al. 2016; Jiménez 2010). Attraction of local populations to natural amenities and PAs has been reported for some Spanish regions like Madrid (Barrado 1999), and many coastal regions (Alfonso et al. 2016), so much so that residential development was perceived as the main threat to the conservation of their PAs (Rodríguez-Rodríguez 2008).

This study has two main aims: (1) Discriminating the effect of legal protection and management of multiple-use PAs on land development; and (2) Testing the differences in *protection* among different spatial-statistical models that progressively refine control areas and cases to make them more accurate and similar by considering additional territorial protective legislation and biophysical covariates.

Materials and methods

The designation of SACs follows a stepwise process (European Commission 2016b) according to the Habitats Directive (EEC 1992), with even more steps in decentralised countries like Spain. Firstly, each autonomous region identifies candidate SCIs according to the existence of Species and/or Habitats of Community Interest. Then, regions submit that proposal to the Spanish Government, which compiles all proposals and submits them to the European Commission for approval. Once regionally proposed sites are included in the national SCI proposal list, Member States are advised not to allow such sites to deteriorate before their official designation as SCIs, when preventive protection provisions under article 6 of the Habitats Directive start to apply (European Communities 2000). This recommendation *de facto* applies a preventive protection regimen implementing the Habitats Directive's provisions on nationally proposed SCIs. When the proposed sites are approved by the European

Commission, they become formally SCIs and Member States (the Autonomous Regions, in Spain) have up to 6 years to designate them as SACs, produce a management plan for them and initiate active management of the sites.

Study area

The Autonomous Region of Navarra is a small region of approximately 10,400 km² in northern Spain (Fig. 1). Its population in 2015 was 640,154 people, 55% of which concentrates around the municipality of Pamplona (Government of Navarra 2015), in the central-northern part of the region. Geomorphologically, and bioclimatically, the region is highly diverse. It spreads across three biogeographical regions: Alpine (to the north-east, in the Pyrenees), Atlantic (to the north-west) and Mediterranean (the rest). According to the competencies of the Autonomous Regions in Spain to designate and manage PAs, Navarra was the first Spanish region to designate SACs in the mid-2000s and thus to initiate management of SCIs.

Study hypotheses

We wanted to test nine methodological and research hypotheses (Table 1).

Materials

We used the SCI/SAC digital layer from the Spanish Ministry of Environment updated by December 2014 (MAGRAMA 2015) as the basic PA source for this analysis. We joined additional PA data, such as the PA proposal and designation dates from the EU's Natura 2000 Database (EEA 2015b). Then we clipped all SCIs and SACs against the territory of the Navarra region (IGN 2011) to select just SCIs and SACs from this region. We used the region of Navarra because it is the Spanish region that first designated SACs from SCIs, so comparison could be made using the two latest CLC data: 2006 and 2012 (Copernicus 2016a, b).

Methods

We followed a semi-experimental, BACI research design (Smith 2002), whereby land development data inside PAs (cases) and in their control areas *Before* and *After* PA designation (the *Impact*), were compared. BACI designs are found appropriate to gauge causality in PA effectiveness assessments (Addison 2011; Nagendra 2008). The SCIs and SACs used here were restricted to a relatively small inland area and scattered across Navarra's biogeographic regions. They belonged to the same administrative network, were located at a similar distance from the region's main city, Pamplona,

Fig. 1 Location of the Region of Navarra, its capital city (Pamplona) and its non-overlapping Site of Community Importance (SCI) and Special Area of Conservation (SAC) networks

Table 1 Hypotheses tested

Hypothesis type	Hypothesis	References
MH1	Proximal buffers can be considered environmentally similar to their PAs	Oudin et al. 2008
MH2	Applying a spatial-statistical covariate control technique will make cases and controls more environmentally similar	Andam et al. 2008; Mas 2005
RH1	Multiple-use PAs are effective to prevent land development	Martínez-Fernández et al. 2015
RH2	Legal protection of PAs prevents land development	Martínez-Fernández et al. 2015; Rodríguez-Rodríguez and Martínez-Vega 2018
RH3	Additional sectoral legislation further prevents land development in PAs	Andam et al. 2008; Spracklen et al. 2015
RH4	Additional sectoral legislation confers protection to <i>unprotected</i> controls against land development	Andam et al. 2008; Spracklen et al. 2015
RH5	PA management adds to legal protection to prevent land development	Dudley 2008; Hockings et al. 2006
RH6	The main new artificial LULCs inside or in the vicinity of Navarran PAs are residential	Radeloff et al. 2010; Rodríguez-Rodríguez 2008
RH7	Biophysical factors contribute to PA protection against land development	Andam et al. 2008; Gaston et al. 2008; Mas 2005; Joppa and Pfaff 2009; Spracklen et al. 2015

MH, methodological hypothesis; RH, research hypothesis

and were originally proposed as SCIs, and thus given initial preventive protection, on the same date (01/03/1999). All these characteristics made the two PA groups, in principle, good candidates for comparison, the main difference being the existence of management, in the case of SACs. Care was taken to select only SACs that had been designated after the acquisition dates of the satellite scenes that were used to create CLC-2006 in this region (*Before*-designation land development data) and at least 3 years before the date of the satellite scenes used to create CLC-2012 (*After*-designation land development data) for allowing enough time for land development to show an effect after the designation dates of SACs (Fig. 2).

We converted all initial SCIs ($N=10$) and SACs ($N=5$) into spatially unconnected protected polygons by creating single part polygons, and selected all protected polygons that were larger than 100 ha and did not overlap with any other PA designation category. That way, we could be sure that the effect

of protection in those polygons came either from individual legal protection (SCIs) or from legal and managerial protection (SACs). Protected polygon census data including 19 *purely* SCI polygons covering 48% of the original SCI (whole PA) area and 7 *purely* SAC polygons containing 73% of the original SAC area were thus selected (Fig. 1). Protected polygons are considered a more realistic and ecologically meaningful approach to assess PA effectiveness than the conventional *administrative* approach and have been used in a number of PA assessments (Foster et al. 2014; Rodríguez-Rodríguez et al. 2015a, 2016a, b; Rodríguez-Rodríguez and Martínez-Vega 2018). The main characteristics of each PA and protected polygon used are shown in Appendix 1.

We compared CLC class 1 LULCs (artificial areas) between 2006 (Copernicus 2016a) and 2012 (Copernicus 2016b) for four polygon groups: SACs, SCIs and 1-km buffer unprotected areas surrounding each protected polygon from both designation categories. These groups represent a clear theoretical protection

Fig. 2 Research design outline

gradient, from legal protection and managerial protection (SACs), through legal protection but no management (SCIs), to no protection or management (buffer areas). In the PA network pair-wise comparisons, SCIs acted as controls of SACs for assessing the effect of management on land development, whereas in the jointly comparisons, buffer areas acted as controls for each of the two PA types.

We used Proportional Artificial Land Cover Increase (PALCI) as an indicator of PA effectiveness. PALCI measures the increase in artificial LULCs related to the total area of a given network between two time points (2006 and 2012). We compared PALCI for each of the four groups: SACs, SAC-buffers, SCIs and SCI-buffers:

$$PALCI_x = PALC_{x_{t2}} - PALC_{x_{t1}},$$

where $PALC_{x_{t_n}}$ is the proportion of artificial LULCs at time n in case or control network x . The closer PALCI is to zero, the more effective the PA has been. Subtraction was preferred to division for PALCI calculation due to the very high proportions of null artificial LULCs at t_1 in both PA networks: 74% for SCIs and 88% for SACs. All calculations were made using Arc-GIS v. 10.3 (ESRI 2014) in the ETRS-89 LAEA projection and Microsoft Excel.

Tested models

We compared the results between PA networks and between each PA network and their control areas using a new spatial-statistical approach with three different models of increasing accurateness (Appendix 2) considering (a) surrounding buffer areas not overlapping with other PAs (model 0); (b) additional sectoral legislation prohibiting or restricting land development (model 1); and (c) biophysical variables likely affecting land development (model 2; Fig. 3).

A post hoc similarity analysis was made between cases and controls to ascertain their degree of initial (model 1) and *improved* environmental similarity (model 2) according to the assessed covariates to ascertain whether model 2 increased environmental similarity between cases and control. We used the normalised Manhattan Similarity Coefficient (Cha 2007), according to the following formula:

$$D(X, X') = 1 - \frac{\sum_{i=1}^k |X_i - X'_i| / \text{Range}(X_i)}{K}$$

Where, X_i is the median value of group X for variable i ; Range is the amplitude of measurement X_i in the study area; and K is the number of variables used to assess groups X and X' . The Manhattan Similarity Coefficient ranges between 0

Fig. 3 Methodological outline of the study

(complete difference between compared group values) and 1 (complete similarity). Then, a Global Similarity Index (GSI) was computed for each model by calculating the mean *D* value for the six covariates.

Results

Preliminary biophysical analysis of cases and controls

Methodological hypothesis 1: proximal PA buffers can be considered environmentally similar to their PAs

This hypothesis is largely supported by evidence. In model 1, SCIs and SCI-buffers, on the one hand, and SACs and SACs buffers on the other were very similar in all covariates except in 'degree of initial treeless cover' (Appendix 3).

Methodological hypothesis 2: the covariate control technique used makes cases and controls more environmentally similar

This hypothesis is not supported by evidence. Similarity between cases and controls was greater in model 1 than in model 2 in most cases (Appendix 3).

PA effectiveness on land development

Table 2 shows the main descriptive statistics on land development for each model.

Research hypothesis 1: multiple-use PAs are effective to prevent land development

This hypothesis is largely supported by evidence. SACs were more effective at preventing land development than their

buffer areas in models 0 and 1, and equally effective (completely effective) in model 2. SCIs prevented land development substantially more than their surroundings in models 0 and 1, but experienced more development than their controls in model 2.

Research hypothesis 2: legal protection of PAs prevents land development

Evidence to support this hypothesis is contradictory depending on the model used. On the one hand, SCI area prevented conversion to artificial LULCs by around eightfold in models 0 and 1. In contrast, model 2 shows that SCIs experienced more land development than their control areas, even if just a 0.09% increase in the 6-year period assessed. SCIs increased their artificial area in 31 ha between 2006 and 2012. However, this increase in artificial area affected just one of the 19 protected SCI polygons (resulting in a 0.45% artificial LULC increase in that polygon). Development in the remainder 18 SCI polygons representing 95% in total and nearly 93% of the whole SCI network area remained equal. Thus, although SCI development in Navarra can be deemed exceptional, legal protection affecting SCIs, by itself, cannot be considered fully effective at preventing land development in this region.

Research hypothesis 3: additional sectoral legislation further prevents land development in PAs

This hypothesis is slightly supported by evidence. Excluding areas affected by additional land protection legislation slightly increased PALCI in the SCI network (by 1.02 times).

Research hypothesis 4: additional sectoral legislation confers protection to unprotected controls against land development

This hypothesis is supported by evidence. PALCI in buffer areas was noticeably affected by additional territorial legislation. Buffer areas without additional legal protection (model 1) increased their PALCI by 0.02 and 0.05% for SCI-buffers and SAC-buffers, respectively, when compared to the same areas including additional legal protection (model 0).

Research hypothesis 5: PA management adds to legal protection to prevent land development

This hypothesis is largely supported by evidence. SACs experienced no development, in contrast to SCIs that showed, depending on the model, between 0.03 and 0.09% increases in artificial land uses (although only affecting a small part of just one SCI polygon, as previously mentioned).

Table 2 Artificial land cover increase (PALCI) values (in percentage) and main descriptive statistics for each polygon network and model

	Model 0	Model 1	Model 2
PALCI _{SCI}	0.03	0.03	0.09
<i>n</i>	19	19	8
Area (ha)	95,309	93,366	35,664
PALCI _{SCI-Control}	0.23	0.25	0.00
<i>n</i>	1	1	2
Area (ha)	103,752	86,767	13,108
PALCI _{SAC}	0.00	0.00	0.00
<i>n</i>	7	7	5
Area (ha)	22,480	22,240	17,836
PALCI _{SAC-Control}	0.08	0.13	0.00
<i>n</i>	1	7 (1)	1
Area (ha)	22,480	16,293	1041

Research hypothesis 6: the main uses of new artificial LULCs inside or in the vicinity of PAs are residential

This hypothesis is not supported by evidence. The only SCI polygon that experienced land development between 2006 and 2012 changed from natural LULCs to *industrial or commercial* LULCs (CLC sub-class 121), whereas the main new artificial uses in SCI and SAC buffer areas were *construction sites*, *mineral extraction sites* and *industrial or commercial sites*, respectively. New residential uses were residual, affecting just 7.5 ha of SCI buffer areas (Table 3).

Research hypothesis 7: biophysical factors contribute to PA protection against land development

This hypothesis is supported by evidence. The effectiveness of the SCI network decreased threefold (i.e. PALCI was three times greater) when environmental covariates are considered. Similarly, PALCI decreased in buffer areas to become neutral for both SCIs and SACs.

Discussion

Effectiveness of legal and managerial protection against land development

An effectiveness gradient at preventing land development was apparent between the four groups, depending on the model used: Legal protection and managerial protection (SACs) > Legal protection (SCIs) ≠ No protection (buffers). Legal and managerial protection was fully effective at preventing land development in multiple-use PAs in the Navarra Region for the analysed period. Legislation enforcement through active management affects potential offenders' perceptions of probability of detection, penalty assignment and severity of punishment. These mechanisms of PA effectiveness are more likely to deter offences against PAs than if they are absent (Ferraro

and Hanauer 2015). Legal protection in isolation was highly but not fully effective to prevent land development. However, if the only SCI polygon that underwent inner development was excluded from the analysis, then no difference between SACs and SCIs had been found (null PALCI in either network). The fact that only one in 19 legally protected polygons experienced slight inner development in the 6-year assessment period seems thus more the exception than the rule, making the case for the sustainability of multiple-use PAs, even in absence of management. These results for SCIs are generally more positive than those by Rodríguez-Rodríguez et al. (2018), who found moderately good performance of SCIs at reducing land development in all Spain in the 1987–2006 period. Similar moderate effectiveness of Natura 2000 sites (SCIs and SPAs together) was found by Martínez-Fernández et al. (2015). Differences with our results are likely due to the different studied periods, scales and settings between those studies and ours.

Although delayed management of Natura 2000 sites was suggested to affect LULC changes negatively in Spain (Martínez-Fernández et al. 2015), this seems not to be the case here. The only new artificial area inside SCIs was a 31-ha solar power plant at the southern border of the SCI coded ES2200037 (Bárdenas Reales) that was built following favourable EIA authorisation by the regional government, as foreseen in the SCI/SAC-related legislation (EEC 1992). Therefore, the *protection flaw* comes from legislation *lightness*, not from lack of management, as administrative authorisation to build the plant may have been equally awarded in a SAC (European Communities 2000), whose main objective is to maintain or restore natural habitats and species' habitats at a favourable conservation status, not to avoid construction per se (EEC 1992). Actually, the official approach used in Natura 2000 sites is a flexible sustainable development approach allowing a wide range of human activities in the territory, rather than a highly restrictive approach excluding all human activities which may impede legitimate local socioeconomic development (EC 2014). It should be

Table 3 New artificial land uses in SCI-buffer areas and SAC-buffer areas between 2006 and 2012

Artificial land uses (CLC sub-classes)	Area SCI buffers 2006 (ha)	Area SCI buffers 2012 (ha)	Increase 2006–2012 (%)	Area SAC buffers 2006 (ha)	Area SAC buffers 2012 (ha)	Increase 2006–2012 (%)
Continuous urban fabric	404.42	411.94	1.86	0.00	0.00	0.00
Discontinuous urban fabric	1086.93	1090.72	0.35	157.88	157.88	0.00
Industrial or commercial units	476.99	608.90	27.66	115.75	115.75	0.00
Mineral extraction sites	78.35	38.91	−50.34	68.96	89.41	29.66
Dump sites	92.71	65.86	−28.96	0.00	0.00	0.00
Construction sites	126.67	264.60	108.90	0.00	0.00	0.00
Sport and leisure facilities	49.30	49.30	0.00	0.00	0.00	0.00
Total	2315.36	2530.23	9.28	342.58	363.03	5.97

noted that, in contrast with other more permanent artificial LULCs such as residential, transport infrastructural or industrial, solar power plants do not generally entail complete soil sealing and can be decommissioned (and the occupied land, reclaimed) after their useful lifespan (EC 2014; TEEIC 2017).

Our results add to evidence from previous studies comparing national PAs and Natura 2000 sites across all Spain that also found that the proportion of the Natura 2000 site total area (of SCIs and SPAs) that became artificial between 1987 and 2006 was smaller than in surrounding unprotected areas (Martínez-Fernández et al. 2015; Rodríguez-Rodríguez and Martínez-Vega 2018). Rodríguez-Rodríguez and Martínez-Vega (2018) found stark differences in land development figures according to legal stringency of PA networks in Spain, with multiple-use PAs being much less effective than reserves, although legal overlaps of the latter introduced some confusion. Other studies, mostly across tropical areas, have found contrasting results on LULC changes by legally stringent PAs, ranging from better performance with regard to multiple-use PAs (Linardi et al. 2013; Sims 2014) to poorer effectiveness of reserves (Nelson and Chomitz 2011), or no difference (Nagendra 2008), so further research seems to be needed.

Model 2 results for SCIs were unexpected. However, the previously mentioned study found that around 14% of the analysed PAs (of different categories) had greater land clearing rates than their surrounding areas, although most of those cases were attributed to uncontrolled extraction of vegetation by local communities (Nagendra 2008). Despite land and freshwater PA coverage at 21%, European-wide official data confirm that regional environmental policies have not been effective enough at preventing natural and semi-natural habitat destruction and foresee negative future trends (EEA 2015a). A recent review on the ecological performance of the Natura 2000 Network also found that LULC changes, including increased development, posed a major threat for protected habitats and a larger one for protected species in Europe than climate change (Davis et al. 2014). All these findings make a case for the strengthening of the LULC change aspects of environmental legislation affecting Natura 2000 sites, and Special Protection Areas in particular (Rodríguez-Rodríguez and Martínez-Vega 2018). Effectiveness of Natura 2000 sites at preventing natural and semi-natural habitat destruction and degradation within their borders is especially relevant for two reasons. Firstly, they are among the most ecologically driven PA categories, specifically designated for the conservation of especially valuable biodiversity including threatened, rare, endemic or representative species and habitats (EEC 1992). Secondly, Natura 2000 sites cover the largest proportion of protected area in Spain (over 27% of its terrestrial area, more than doubling the area covered by national PAs by 2013; Múgica et al. 2014), and in most European countries (EEA 2015a). In other important aspects of environmental effectiveness, such as species conservation,

European legislation including the Birds and Habitats Directives does seem to have been effective (Epstein et al. 2016; Sanderson et al. 2016).

Some biophysical variables seem to have naturally increased protection of SCIs in Navarra. Regarding SCI-SAC comparison, SCIs had a much larger area than SACs (from more than fourfold to twofold, depending on the model), and higher degrees of initial treeless cover. Both variables may have favoured land development probability compared to SACs (Spracklen et al. 2015). Regarding SCI-buffers, SCIs were at higher altitudes, had steeper slopes and less degree of initial artificial and treeless covers. According to Spracklen et al. (2015), strong environmental gradients between PAs and contiguous buffer areas are possible even at small distances, providing PAs with protection unrelated to PA regulations. Those biophysical differences may have added to SCI legal protection and explain the differences in PALCI between SCIs and their controls partly. Buffer areas were similar in size to their PA networks in all models except in model 2, where SCIs covered nearly three times more area than their controls, and where SACs covered more than 17 times more area than their controls. This may probabilistically and partially explain why SCIs experienced more development than their buffer areas in model 2, as suggested at other spatial scales (McDonald et al. 2008). However, the legally approved development of the only affected SCI can be considered exceptional, and, if not considered, then PALCI would have been the same (null) between SCIs and their controls in model 2, as commented previously. This result would also underpin the effectiveness of legal and managerial protection, as SACs experienced the same degree of development (no development) than their controls with 17 times more area in model 2. In model 1, SACs were bio-physically similar to their controls and also experienced less PALCI, as expected.

The *additional protection* effect of further territorial legislation restricting land development in PAs, although likely, cannot be clearly confirmed from this analysis. The PA area affected by the sectoral legislation considered in this study and excluded from cases and controls is small (around 2% of the SCI network area and 0.5% of the SAC network area) and seems to have affected artificial and non-artificial areas proportionally, thus scarcely affecting PALCI. It is likely that a more complete sectoral *exclusion layer* that also included widespread territorial protection against land development afforded by public utility forests (covering approximately 14% of the Spanish territory) and cattle paths had rendered more stark differences, but this hypothesis remains to be tested. However, even if of limited extent, sectoral territorial legislation reduced land development in buffer areas, as expected, and should thus be considered when selecting adequate control areas for PAs (Rodríguez-Rodríguez and Martínez-Vega 2018).

Residential development was not a major pressure to SCI and SAC polygons or their surroundings in Navarra between 2006 and 2012, in contrast to previous studies in other

countries (Radeloff et al. 2010) and Spanish regions (Jiménez 2012; Rodríguez-Rodríguez 2008). Between the late 1990s and 2008, Spain experienced massive residential and infrastructural expansion mostly at the expense of natural and semi-natural habitats (Jiménez 2012; Martínez-Fernández et al. 2015). In Navarran PAs and their surroundings, residential uses were predominant among artificial LULCs. However, they scarcely increased in the analysed period, in contrast to large increases of other artificial land uses, chiefly construction sites, mining sites, and industrial and commercial sites. The absence of big cities and coastal areas in the Region of Navarra, the arid, rural nature of large central and southern parts of the region, and the high altitudes and harsh weather conditions in the north-east possibly reduced the residential appeal of many regional areas. Artificial LULCs showed the greatest persistency in areas surrounding PAs in Spain in the 1987–2006 period (Martínez-Fernández et al. 2015). Accordingly, although some artificial LULCs decreased in the vicinity of SCIs, they reconverted to other artificial uses: from *mineral extraction sites* to *industrial or commercial sites* (1 site) and from *dump sites* to *construction sites* (1 site).

Methodological findings and remarks

Our spatial-statistical covariate analysis just moderately underpins previous claims that *uncontrolled* control areas should not be compared to cases in PA effectiveness assessments (Andam et al. 2008; Ferraro and Hanauer 2015; Mas 2005), as initial environmental similarity between cases and controls was remarkably high.

The spatial-statistical covariate control technique used in model 2 did not make controls substantially and consistently more similar to cases. Accordingly, model 2 did not reduce the PA *protection effect*, which was greater than in more environmentally similar model 1, as expected (Andam et al. 2008). The technique greatly reduces the number of cases and controls in model 2, and thus the area under assessment. Thus, the spatial-statistical approach for selecting environmentally similar case and control areas used here showed of limited use to improve case-control similarity and accurateness of PA effectiveness assessments in a simple manner without the need of complex statistical or modelling techniques, as it was conceived. Complex statistical (Andam et al. 2008) and/or multiple causal modelling (Ferraro and Hanauer 2015) are suggested techniques to produce accurate outcomes on PA effectiveness. However, even these complex techniques cannot guarantee total absence of bias (Andam et al. 2008) or complete identification and assignment of direct and indirect causal mechanisms in complex, multivariate socio-ecological systems such as PAs (Ferraro and Hanauer 2015). Thus, consideration should be paid to whether such substantial effort is always worthy according to available resources and the degree

of accurateness needed. In any case, evidence from this and other studies points to at least preliminarily checking biophysical characteristics of cases and controls to decide whether to use some covariate control technique or not. In cases where cases and controls are originally environmentally similar, covariate control techniques may not be needed.

Improvements to the covariate control approach used here can include preliminary statistical analyses to include only the most relevant, lowly correlated covariates (among them and with conservation outcomes) in the analysis (Mas 2005); ordered covariate analysis for stepwise unrepresentative data deletion, by firstly addressing covariates that entail discarding entire biophysically unrepresentative polygons (discrete covariates with unique values for entire polygons; e.g. distance to major cities), followed by analysis of covariates that determine discarding just some unrepresentative area from polygons (discrete covariates with multiple values for each polygon (e.g. slope); refining the case-control exclusion rules so no entire buffers and a substantial portion of the total area under analysis are discarded, especially in limited sample studies such as this one; including exclusion thresholds for each of the covariates based on actual data (e.g. development influence limit of cities/coast/infrastructures). In cases with limited number of cases or controls (such as ours), avoiding excluding sample based on meaningful thresholds for each covariate could save valuable numbers of cases and controls without affecting accurateness. Other methodological issues such as the broad resolution of CLC data, incomplete validation of existing CLC 2012 data or inherent geometric and thematic errors using spatial data techniques may have omitted some fine scale changes and influenced our results to some extent (Martínez-Fernández et al. 2015).

The *protected polygon* approach used here is a useful way of overcoming the common problem of multiple and irregular PA designation category overlaps over the same areas, especially in mature and well-developed PA networks (Foster et al. 2014). It allows, for instance, delimitating the ecological boundaries of PAs (Rodríguez-Rodríguez et al. 2016b), assessing cumulative legal protection afforded to them (Rodríguez-Rodríguez et al. 2015b), or discriminating the effects of individual legal designation categories, as in this case. It is, however, a less useful approach than the conventional *administrative* approach from a managerial point of view, especially when different planning and managerial administrations are involved in the PA sample (Rodríguez-Rodríguez et al. 2016b).

Conclusions

The multiple-use PAs assessed here were generally useful to prevent land development, although some exceptional development occurred in PAs with just legal protection (SCIs).

Additional territorial legislation did not add substantial protection to PAs but it provided relevant protection to buffer areas, even if additional territorial protection data were incomplete. Legally protected PAs (SCIs) also seem to have benefited in protection from their environmental characteristics: they had higher altitudes, steeper slopes and less initial artificial and treeless covers than their control areas, which likely made them less prone to development regardless of legal protection (Spracklen et al. 2015). Legally designated and managed PAs (SACs) completely prevented land development in every model, making a strong case for the effective combination of legal and managerial protection of biodiversity by PAs in contexts of reasonably sound institutional functioning, like Spain.

Model comparison allows selecting the most accurate model according to environmental similarity between cases and controls. Pair-wise, all tested models are valid, as they treat cases and controls equally. However, the technique to create model 2 did not manage to make cases and controls more environmentally similar, and should be refined.

Broader empirical evidence from different environmental, socioeconomic and institutional contexts than the limited PA sample assessed here should be accumulated to definitely state whether legal protection is enough to prevent land development, and for which kinds of regulations and contexts. It should also help to confirm whether managed PAs under flexible, multiple-use regulations are always a fully effective way of preventing this crucial global threat to biodiversity conservation.

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