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Plantation or natural recovery? Relative contribution of planted and natural pine forests to the maintenance of regional bird diversity along ecological gradients in Southern Europe

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ABSTRACT

Forest plantations are increasingly used as tools to restore local biodiversity. Measures aimed at making plantations more complex and similar to natural forests to preserve biodiversity are still under debate. In this paper, we compare the role of natural and planted *Pinus* spp. for the maintenance of regional forest bird diversity along large-scale ecological gradients in Southern Europe. We modelled the relative contribution of the extent of either natural or planted pine forests to explain the richness of pine-dwelling forest birds in 3950 sample units (10 km × 10 km cells) in peninsular Spain after controlling for the potential effects of geographical variables, environmental factors, surrounding land-uses, forest cover and vegetation structure within pine forests. Planted pine forests maintained less pine-dwelling forest bird species than did natural pine forests after controlling for confounding variables and structural differences. Such differences may be due to the time lags involved in forest bird community assembly. Regional and local drivers explaining the regional bird species richness varied among pine species, either natural or planted. Management recommendations to increase bird diversity should not be based on just mimicking natural pine forest structure as quickly as possible. Rather, specific practices should be developed locally together with the maintenance of unexploited natural stands for both reference and conservation of the results of the temporal component of community assembly.

1. Introduction

Tree plantations for production, protective and/or recreational purposes occupy an extensive part of the forested territory (FAO, 2015). In general, plantations show a more homogeneous composition and structure than natural forests because they tend to have fewer woody species, the trees are often even-aged and regularly spaced, they are commonly planted in high densities, and management is based on shorter rotations than natural stands (Gómez-Aparicio et al., 2009; Ruiz-Benito et al., 2012; Calladine et al., 2016). Furthermore, the species planted are usually different from the local natural vegetation, as fast-growing, early successional species are preferred because of their higher short-term productivity. In extreme but rather common cases, even exotic or genetically improved species are planted (Calladine et al., 2016).

Numerous studies have addressed the negative consequences of the simplified structure and composition of tree plantations for the maintenance of local and regional diversity (Stephens and Wagner, 2007; Pawson et al., 2008; du Bus de Warnaffe and Deconchat, 2008; Paillet et al., 2010; Riffell et al., 2011; Calviño-Cancela, 2013; Calladine et al., 2016). In general, plantations used for timber production maintain lower biodiversity levels than natural forests, especially when the species composition and vegetation structure of the plantation are homogenized and exotics or species expanding outside their regional range replace local tree communities. Nevertheless, most studies involve within-plantation comparisons or comparisons among plantations of exotic species or species expanding outside their regional range and the natural forest vegetation, whereas few studies compare plantations with their natural counterparts (Díaz et al., 1998; Díaz, 2006; Santos et al. 2006; Gómez-Aparicio et al., 2009; Ruiz-Benito et al., 2012; Bergner et al., 2015; Calladine et al., 2016). This knowledge gap questions

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the management practices of making plantations just as complex and naturalized as possible to preserve biodiversity, as limitations and alternatives to this naïve assumption have rarely been tested (Betts et al., 2005; Brockerhoff et al., 2008; Bremer and Farley, 2010; Pawson et al., 2013).

Currently, society is demanding that forests, including plantations, should provide a wider range of ecosystem services in addition to timber production or fuel wood (Bateman et al., 2013; Martín-Lopez et al., 2012), and it is aware that management aimed at maximizing one service can decrease the provision of other services due to their conflicting relationships (e.g., Caparrós and Jaquemont, 2003). Biodiversity contributes directly and indirectly to the maintenance of a wide range of ecosystem services (Rey-Benayas et al., 2009; Cardinale et al., 2012); hence, forest management aimed at counteracting the negative effects of productive uses and climate change on forest biodiversity should be increasingly demanded (Gil-Tena et al., 2009; Díaz et al., 2015; Calladine et al., 2016). Therefore, in this changing context, plantations have increasing value as a conservation tool, and the idea of plantations mimicking natural forests to include biodiversity conservation among their goals is gaining relevance (European Commission, 2013; FAO, 2010; Brockerhoff et al., 2008; Fady et al., 2016).

Birds are widely used in the scientific literature as biodiversity indicators due to its general sensibility to environmental change (Stephens and Wagner, 2007). Nevertheless, little is known about the differences in the bird biodiversity maintained by plantations compared with natural forests of the same species. Graham et al. (2014) demonstrated that mature plantation forests of oak can support bird communities comparable to natural oak woodlands but in an area where forest specialists are lacking. Sweeney et al. (2010) compared the breeding bird communities of first- and second-rotation plantations and found that no differences in bird richness between rotations but higher bird density in the second rotation for a given age. To the best of our knowledge, none of the previous studies have analysed the role of pine forest plantations for biodiversity maintenance in relation to their natural counterpart at a large scale. This point contrasts with the large-scale afforestation programs based on pines that have occurred in the Mediterranean region during the last century (Serrada et al., 2008; FAO, 2015), especially the most recent ones developed under the Common Agricultural Policy measures of reforestation in former arable land (Díaz et al., 1998; Santos et al., 2006). These plantations had from their very beginnings an explicit conservation purpose as they aimed to provide environmental benefits, such as watershed protection, reduced erosion, carbon fixation and biodiversity protection, in addition to economic and social benefits in terms of employment, rural development or recreation.

The main objective of this study is to compare explicitly how planted and natural pine forests contribute to the maintenance of regional communities of forest birds along wide geographical and environmental gradients. However, there are multiple paths via which environmental and habitat variation can impact bird species richness; therefore, the identification of the drivers is challenging. There may, in fact, be no a priori reason to expect the drivers that contribute to bird species richness in different pine forests (in terms of tree species and natural versus planted forests) to respond in the same way to topography, climate, land use, forest cover and forest structure drivers because their populations may experience different limiting factors among forests. Therefore, we also examine whether the same environmental and geographical drivers influence bird species richness in different pine forests in Southern Europe. If this is the case, differences among pine species are to be expected, and specific forest management recommendations for different pine species would be needed to increase the biodiversity conservation function of planted versus natural pine forests.

2. Material and methods

2.1. Study area

Within the Mediterranean basin hotspot (Myers et al., 2000), the Iberian Peninsula harbours especially rich plant and animal communities due to its large size, topography, and geographic position between Europe and Africa (Blondel et al., 2010). For these reasons, Mediterranean, Alpine and Atlantic regions are found in this peninsula, with their characteristic and distinct animal and plant communities. Six native pine species are found in the Spanish Iberian Peninsula; they are, in the order of the area they occupy, *Pinus halepensis* Mill., *Pinus pinaster* Ait., *Pinus sylvestris* L., *Pinus nigra* Am., *Pinus pinea* L., and *Pinus uncinata* Mill. (Supplementary Table S1). These *Pinus* spp. have played a very important role in the large-scale reforestations that have occurred since 1940 (more than 3.5 million ha of planted forest; Serrada et al., 2008). In this study, data on the extent and location of natural and planted pine stands in the Spanish Iberian Peninsula were taken from the Spanish Forest Map and from the Spanish Regions of Provenance maps. These sources integrate historical information on the origin of pine stands (either planted or coming from natural regeneration) with genetic data. Following Alía et al., 2009 we considered as natural pine forests the pine stands matching an identified provenance region, and as planted forests the stands known to be planted or whose provenance region do not match their regional context (Fig. 1; Supplementary Table S1; see also Ruiz-Benito et al., 2012).

2.2. Bird species richness

Presence-absence data of bird species was obtained from the Spanish Breeding Bird Atlas (Martí and del Moral, 2003), which collected data systematically gathered by SEO-Birdlife for the 1998–2001 breeding period. Data collection consisted of sampling all habitats found in 10 km $\times$ 10 km UTM squares recording all bird species detected, with any evidence of reproduction within the square such as territorial songs, nests, or fledglings. The presence-absence data refer to the 10 km $\times$ 10 km UTM grid throughout Spain and not to specific vegetation types or patches within grid cells. To analyse the relationships between the bird species richness and the composition, structure, and typology of pine forests within cells, we followed a two-stage approach (Araújo et al., 2005). First, we did not consider the full list of species breeding in each cell but rather the subset of species most likely linked to pine forests (Supplementary Table S2). We determined the breeding bird species present in cells where *Pinus* spp. occupied more than 50% of the cell using ARCGIS software to overlay the bird maps with the map of pine forests obtained from the Spanish Forest Map (scale 1:50,000, Vallejo, 2005; MAAM, 1997–2006). This list included 223 species in 584 cells, both forest-dwelling and those linked to other land uses. The list was thus further reduced to the 44 species most likely to occupy pine forests according to their dependence on this type of vegetation (hereafter called 'pine-dwelling forest birds'). Dependence or avoidance of pine stands, and preference for other vegetation types was established after Díaz et al. (1996, 1998), Tellería et al. (1999), Martí and del Moral (2003), Gil-Tena et al. (2007) (see Díaz et al., 2015 for a similar approach). We then determined the number of species belonging to this reduced list that were present in each UTM cell.

The reduced list included not only bird species exclusive to pine forests but also species that occupy broadleaved forests and even shrublands. In fact, most species that occupy Mediterranean forests are typically generalists rather than forest specialists (Brotons et al., 2016). To account for the potential effects of these vegetation