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ORIGINAL ARTICLE

Rural abandoned landscapes and bird assemblages: winners and losers in the rewilding of a marginal mountain area (NW Spain)

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Abstract In many regions of Europe, large-scale socio-economic changes have led to the abandonment of rural activities and a gradual takeover of natural vegetation. It is important to assess the relative positive and negative effects of land abandonment on particular areas where the low-intensity farming is no longer socially or economically viable in order to quantify the potential conservation costs and benefits of a rewilding as a land-use management policy. During the period 2000–2010, we studied the land-use/land-cover changes in an abandoned mountain landscape (Galicia, NW Spain) and evaluated the effects on breeding bird occurrence and distribution. For this purpose, we analysed remotely sensed data-derived maps in combination with data obtained from bird censuses carried out in 2000 and 2010 at both landscape and census plot scale. The results revealed a gradient of change from bare ground and open shrubland to closed shrubland and woodland. Thirteen shrubland and forest bird species showed a significant increase (including species of conservation concern such as Turtle Dove, Dartford Warbler and Western Bonelli's Warbler), while four ecotone and open-habitat species (e.g. Red-backed Shrike) showed a significant negative trend. In conclusion, rewilding appears to have overall positive effects on biodiversity and should be considered by policy makers as alternative land-use strategy in marginal mountain areas, particularly if they have been historically affected by wildfires. Fire management aimed at favouring the creation of small burned areas in progressively closed landscapes derived from rewilding may be a complementary alternative to maintain open habitats in these areas.

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Introduction

Land-use change is a large component of global change (Vitousek et al. 1997) and the effects on biodiversity and ecosystem services currently represent a major challenge for ecologists and conservationists (Pereira et al. 2005; Figueiredo and Pereira 2011; Queiroz et al. 2014). The intensity of land-use change varies greatly and the situation is context-specific; thus, although semi-natural areas are modified and intensive agriculture increases in some locations, agro-pastoral activities are abandoned in others (Hobbs et al. 2006; Stoate et al. 2009; Tryjanowski et al. 2011).

In north-western Iberia, semi-natural grasslands and remote mountain areas with poor soil quality are particularly susceptible to a decline in agro-pastoral use (Rounsevell et al. 2006; Corbelle and Crecente 2008; Gracia et al. 2010; Navarro and Pereira 2012). These areas have been maintained for centuries by traditional agricultural practices and livestock grazing and are currently the focus of European conservation policies targeted at reversing farmland depopulation (Dax 2005; Stoate et al. 2009). However, despite the huge economical resources invested during the last few decades to prevent rural exodus and maintain these traditional and cultural landscapes, forests and shrubland have expanded because of land abandonment (Moreira et al. 2001; Falcucci et al. 2006; Stellmes et al. 2013).

Several authors have recently suggested that rewilding[1] may be an appealing conservation response to farmland abandonment in areas of Europe and the rest of the world where the social structure of farming communities has been eroded and low-intensity farming is no longer socially or economically viable (Navarro and Pereira 2012; Guilherme and Pereira 2013; Queiroz et al. 2014). These authors propose rewilding as a potential alternative approach to conservation, in which the maintenance costs are much lower than the current target-driven, intensively managed approaches (Gillson et al. 2011; Navarro and Pereira 2012; Queiroz et al. 2014). However, there is some ongoing discussion about the consequences of land abandonment-driven rewilding on biodiversity and ecosystem services (Tryjanowski et al. 2011; Navarro and Pereira 2012). Queiroz et al. (2014) reviewed 276 published studies describing various effects of farmland abandonment on biodiversity and found that study's geographic region, selected metrics, assessed taxa, and conservation focus significantly affected how those impacts were reported. On the one hand, the widespread abandonment of agricultural practices in some areas increases landscape homogenization, leading to biodiversity declines. On the other hand, abandonment can also provide a unique opportunity for the regeneration of native ecosystems with high nature values, such as native forest, of restoration of natural grasslands (for a detailed discussion and examples, see Queiroz et al. 2014). As a land management policy, rewilding involves several challenges, such as the need to maintain open areas, increased fire risk in intermediate successional stages, and human-wildlife conflicts.

Fire is a major disturbance in ecosystems in Mediterranean Europe (Moreira et al. 2011; Keeley et al. 2012). For millennia, fire has been a key self-regulating process influenced by natural factors such as climate and vegetation characteristics. Nevertheless, the ongoing trend towards landscape homogenization that has taken place over recent decades as a result of rural land abandonment and subsequent shrub encroachment and afforestation has lead to an increase in fuel continuity (Debussche et al. 1999; Loepfe et al. 2010; Moreira et al. 2011), and, therefore, fire occurrence and fire severity (Vega-García and Chuvieco 2006; Loepfe et al. 2010; Pausas and Fernández-Muñoz 2011). Large fires are becoming more frequent, and this is favouring the appearance of homogeneous landscapes covered by fire-prone shrubland (Moreira et al. 2011). The main factors underlying the recent changes in fire regime in these fire-prone ecosystems are rural land abandonment, together with a higher number of ignitions derived from human-caused fires associated with land-use change and ownership conflicts (Chas-Amil et al. 2010; Fuentes-Santos et al. 2013), and the increased number of extreme dry and hot summer events associated with climate warming (Piñol et al. 1998; Sarris et al. 2013). To mitigate the impact of the most severe fire events, huge resources are invested in fire suppression and prevention every year (Moreira et al. 2011; Keeley et al. 2012). Fuel-reduction treatments (such as prescribed fire and forest thinning) and fire-suppression strategies are, therefore, direct anthropogenic activities that affect fire regime and, indirectly, landscapes (Brotons et al. 2013).

Land abandonment and fire are complex and closely interrelated processes, and their spatial interaction strongly determines vegetation patterns and biodiversity at different spatial scales (Le Viol et al. 2012; Navarro and Pereira 2012; Guilherme and Pereira 2013). While land abandonment favours mature forest species, it simultaneously favours and threatens early-successional species because vegetation maturation may lead to increases or lost of

[1] Gillson et al. (2011) defined rewilding as the passive management of ecological succession with the goal of reducing human control and restoring natural ecosystem processes.

shrubland habitat depending on the initial vegetation characteristics. Thus, some species are declining in abundance and occurrence (loser species) and are being replaced by others (winner species) that are better adapted to the new conditions (Sirami et al. 2008; Gil-Tena et al. 2009; Brambilla et al. 2010; Le Viol et al. 2012). Forest bird species appear to benefit from forest maturation and spread, which has offset the potentially negative effects of fires on forest birds in Mediterranean regions (Preiss et al. 1997; Moreira et al. 2001; Suarez-Seoane et al. 2002; Laiolo et al. 2004; Sirami et al. 2007; Gil-Tena et al. 2009). Furthermore, once succession from shrubland to forest dominates over the creation of new low-vegetation areas derived from wildfire, open-habitat species might be the group most affected by losses of suitable habitat (Vallecillo et al. 2007; De Cáceres et al. 2013).

In this study, we investigated the effects of land abandonment processes on bird assemblages, at both landscape and local scale, over a ten-year period in an area of north-western Iberian Peninsula in which human depopulation dates back to migrations in the 20th century. We combined medium-term data on avifauna distribution in a remote mountainous area with information on temporal changes in land-use/land-cover extracted from satellite data. Our specific aims were to determine: (1) whether land use and vegetation have changed significantly during the study interval; (2) which land use and vegetation types are decreasing (losses) and which are expanding (gains); (3) whether the bird community has changed during the same time interval; and (4) which species are declining (losers) and which are increasing (winners). We then assessed the conservation gains and losses derived from the abandonment processes and discuss the strengths and weakness of rewilding as a land use strategy in this type of ecosystem and suggest management approaches that may mitigate the potential negative effects of rewilding on fire risk and biodiversity.

Methods

Study area

The study was carried out in the Baixa Limia-Serra do Xurés Natural Park (29,345 ha), which extends along the mountains in the south-west of the province of Ourense (Galicia, NW Spain, 42°00′–8°00′) and borders the Peneda-Gerês National Park in Portugal (Fig. 1). The zone is a mountain range, of elevation between 323 and 1,529 m a.s.l. and average slope, 13°. The region is located in the transition between the Mediterranean and Eurosiberian biogeographic zones in the proximity of the Atlantic coast. The climate regime is temperate oceanic sub-Mediterranean, with an average maximum temperature during the hottest month (June) of 22.8 °C and an average minimum temperature during the coldest month (January) of 0.29 °C. Average annual rainfall is 1,223 mm (Martínez-Cortizas and Pérez-Alberti 1999; Ninyerola et al. 2006; Ninyerola and Roure 2007).

The study area is representative of the abandoned mountain landscapes of southern Europe, which are mainly dominated by shrubland (69 %) and forests (21 %). Cropland represents a very small portion of the territory (1.5 %) and is mainly located close to the sparse and scattered human settlements (Regos et al. 2012; see section 2.3 for a more detailed description of land-cover composition). The density of human population in the Xurés area is currently quite low (14.8 inhabitants/km^2), although the landscape was greatly affected by human activity in the past. The low population density is due to migrations that took place in the last century, the low birth rate and high mortality, especially in the early 1950s. Depopulation of the area has been accompanied by the abandonment of traditional agricultural and livestock activities (Macedo et al. 2009). The frequency and intensity of fire are identified as the main problems for wildlife managers, especially during summer (July to late September). The fire regime in the study area is characterized by a large number of small- and medium-sized fires (Cubo et al. 2012). Most of these fires are caused by human activity, and most are classified as arson (87 %). The main land-cover types affected by fire in the Gerês-Xurés Mountains between 2000 and 2010 were open and closed shrubland (49 and 15 % respectively), followed by pine and oak forests (8.8 and 8.7 %) and bare ground (7 %) (Regos et al. 2014b).

Bird data

The bird community in the study region was surveyed in 2000 and 2010 by means of 5-min point counts (179 points × 2 years; Fig. 1) with unlimited distance (Bibby et al. 1992). The censuses were undertaken during the breeding season (May–June). To avoid possible detection biases caused by the time of survey, wind speed or cloud cover, the censuses were carried out during the 4 h after sunrise (peak vocal activity) and under uniform weather conditions (days without marked rainfall or wind).

A census plot was considered to cover an area of about 3 ha, as most individuals were recorded within a radius of 100 m from the point count. This census method is designed to provide information about the distribution and abundance of diurnal songbirds. Raptors, crepuscular species and aerial feeders (mainly swallows and swifts) were not considered in the analysis since the point-count method is not suitable for estimating the abundance of these species

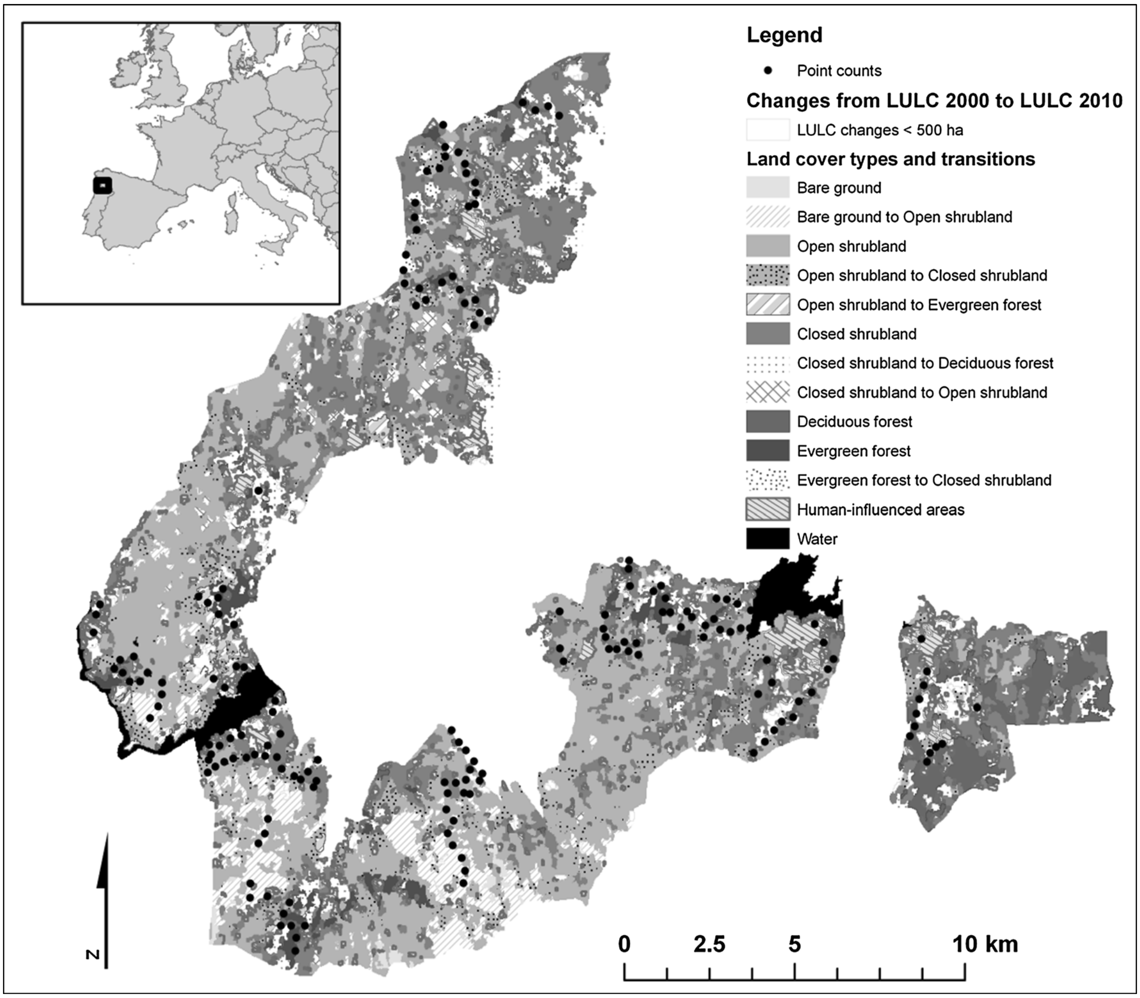

Fig. 1 Map of the study area showing the location of the 179 points at which birds were counted and the main land-use/land-cover changes between 2000 and 2010

of birds (Bibby et al. 1992). Migrants and rare species were also excluded.

The sampling protocol was designed to achieve three objectives: (1) to sample all the land-cover types, (2) to sample a sufficient number of census plots for each land-cover type, and (3) to distribute the census plots over the entire study area (Fig. 1). The census plots were selected to conduct standardized intensive surveys in a stratified fashion to cover the main land-cover types present within each of the 2-km squares in which the study area was divided. The census plots were separated by a minimum distance of 250 m, thus avoiding the overlapping of point counts and possible cases of pseudo-replication. In this respect, the European Green Woodpecker (*Picus viridis*) was also excluded from the analysis because its conspicuous song is easily detected over long distances (more than 250 m).

During each point count, we recorded the bird species that were either observed or heard during 5 min in the census plot. However, only occurrence (presence/absence) data were finally used in the analysis in order to minimize possible observer bias in detection. During the bird surveys, we also characterized the main and secondary land-cover type in situ, within each census plot.

Remote sensing data

We evaluated the land-use and land-cover changes over the whole study area by analysis of two Landsat data-derived maps. A range of cloud-free Landsat satellite images (resolution 30 m) was obtained to map the land use/land cover in 2000 and 2010. Specifically, we used the optical and thermal multispectral bands of Landsat TM and ETM + images acquired over the same temporal sequence as the bird sampling was carried out (March 20th 2000, June 8th 2000, June 24th 2000, May 19th 2010 and July 30th 2010).

The land-cover classification was obtained using a hybrid classifier, a combination of unsupervised and supervised strategies (for details, see Appendix 1). The procedure involves both unsupervised classification and training areas. The training areas were selected on the basis of main land use and vegetation types identified in the study area during the fieldwork: (1) bare ground (rocky soil with less than 20 % of vegetation); (2) open shrubland (rocky soil with a range of shrub between 20 and 80 %, mainly dominated by *Erica* spp., including grazing land); (3) closed shrubland (areas covered between 80 and 100 % of shrub, dominated by *Cytisus* spp., *Ulex* spp. and *Erica* spp.); (4) deciduous forest (oaks forests, dominated by *Quercus robur* and *Q. pyrenaica*, which constitute the climax vegetation of the region); (5) evergreen forest (coniferous mature forests dominated by *Pinus sylvestris* and *P. pinaster*); (6) cropland; (7) human settlements; and (8) water (rivers and dams). Cropland and human settlements were reclassified in a new land-cover category named 'human-influenced areas'.

The Landsat data-derived maps from 2000 to 2010 were generated with an overall accuracy of 91.33 and 92.32 % (Kappa coefficients of 0.90 and 0.91) (see Appendix 1 for more details on the accuracy assessment). Preprocessing of the Landsat images, definition of training and test areas, classification procedures, and the accuracy assessment of the land-cover maps were performed with **MiraMon** software, version 7.0 (Pons 2010).

Analysis at the landscape scale

Once we had constructed the land-cover maps, we evaluated gains and losses in spatial extent, net changes for each land-cover type and the net contribution of each to the overall change over the entire study period (from 2000 to 2010). We also constructed a map summarizing the main land-cover changes between 2000 and 2010 (Fig. 1). We used **Land Use Change Modeller** software for **IDRISI Selva** (Eastman 2012) to perform the land-cover analysis.

To analyse changes in overall occurrence (presence/absence) of breeding bird species in the Xurés Mountains over the study period, we used generalized linear mixed models (GLMM) with a binomial error distribution and logit link function, which included 'year' as a fixed factor and 'point count' as a random factor (i.e. repeated measures analysis). We considered changes as significant at $p < 0.05$. All mixed models were performed with the *lme4* library of the R package (Bolker et al. 2009; R Core Team 2013). The trends over the period of study were compared with national trends obtained from the Monitoring of the Common Breeding Birds programme (SACRE; SEO/BirdLife, 2010). For each species, we also assigned the SPEC category (Species of European Conservation Concern) according to Birdlife International (2004) for assessing the conservation gains and losses derived from the abandonment processes.

Analysis at the local scale

The local-scale analysis was restricted to the (3 ha) plots sampled in the study area for both years. We applied co-inertia analysis to land-cover change data obtained from the Landsat-derived maps and the data from point-count bird censuses carried out in 2000 and 2010. Co-inertia analysis is a robust approach for studying species–environment relationships, especially if the variables are correlated (Dolédec and Chessel 1994; Dray et al. 2003; Sirami et al. 2007). It is therefore particularly well adapted to the study of the modifications in species–environment relationships during the 2 years of surveys. It provides an ordination of census plots based on the co-inertia weights of environmental variables and another based on the co-inertia weights of the bird species. The bird data set consisted of occurrence (presence/absence) of 31 bird species in 358 census plots (179 plots $\times$ 2 years), and the land-cover type data set consisted of the proportion (%) of area occupied by each land-cover category, for each of the 358 census plots. These proportions were calculated within a 100 m radius of the point count. Each census plot was assigned to one of the six land-cover types with greatest coverage in 2000.

We used the Monte-Carlo test (with 999 random permutations) to assess the significance of the co-structure of the data tables (Borcard et al. 2011). Co-inertia analysis and Monte-Carlo test were performed with the *ade4* library of the R package (Dray and Dufour 2007; R Core Team 2013).

Results

Changes at the landscape scale

Analysis of temporal changes in land-cover types in the Xurés Mountains revealed important land-cover changes between 2000 and 2010 at the landscape scale (Figs. 1, 2). Land-cover types associated with open spaces (bare ground and open shrubland) have decreased in the study area, while closed shrubland and forested areas have increased greatly (Fig. 2), particularly those associated with oak tree species (*Quercus* spp.). Bare ground and open shrubland have decreased by 85 and 13 %, respectively (Fig. 1 and 2). Specifically, the spatial extent initially classified as bare ground has mainly changed to open shrubland, while open shrubland has become closed shrubland or evergreen forest (Fig. 2; Appendix 2). Closed shrubland has increased by 17 %, although a fraction of the initial cover has shifted to deciduous forest (Fig. 2; Appendix 2). The area occupied

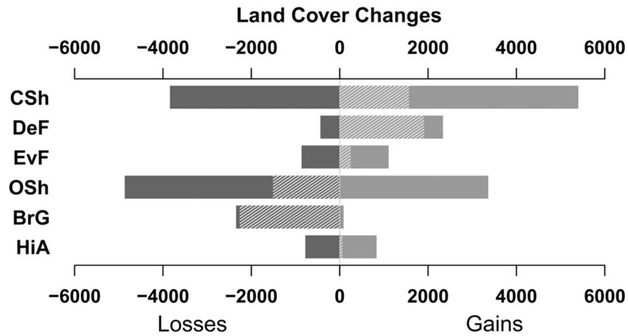

Fig. 2 Land-cover changes: the gains (*light grey bars*) and losses (*dark grey bars*) for different land-cover types are shown. *Bars* indicated by striping show the net changes for each land-cover type (expressed in hectares). *BrG* bare ground, *OSh* open shrubland, *EvF* evergreen forest, *CSh* closed shrubland, *DeF* deciduous forest, *HiA* human-influenced areas

by evergreen and deciduous forest has increased by 14 and 107 %, respectively. The spatial extent of human-influenced areas has remained remarkably constant over the study period (Fig. 2; Appendix 2).

Analysis of temporal changes in the occurrence rate of bird species at the landscape scale revealed an increase in the presence of thirteen species mainly associated with forests and closed shrubland between 2000 and 2010, e.g. Woodpigeon (*Columba palumbus*), Dartford Warbler (*Sylvia undata*) and Iberian Chiffchaff (*Phylloscopus ibericus*), and a significant decrease in the presence of four ecotone species strongly associated with open habitats, e.g. Tree Pipit (*Anthus trivialis*) and Red-backed Shrike (*Lanius collurio*) ($p < 0.05$; Table 1). The remaining fourteen species were considered stable as the differences in occurrence were not significant (Table 1).

From a European conservation perspective, nine species with unfavourable conservation status (SPEC-2 and 3) were detected during the surveys, while the remaining twenty-two species presented a favourable conservation status (Non-SPEC^{E} and Non-SPEC) (Table 1). Three of these nine species with unfavourable conservation status showed a significant increase in Xurés Mountains (Turtle Dove *Streptopelia turtur*, Dartford Warbler and Western Bonelli's Warbler *Phylloscopus bonelli*), five of them remained unchanged, while only one species (Red-backed Shrike) showed a significant negative trend (Table 1). In addition, five species with decreasing trends at the National level, one of which with an unfavourable conservation status (Linnet *Carduelis cannabina*), also showed an increasing occurrence rate in our study area between 2000 and 2010.

Changes at the local scale

Over the ten-year period, land-cover type scores for the census plots have mainly shifted towards higher scores along the axis from shrubland to forested land (axis 1) in the co-inertia analysis (Fig. 3a). In axis 2, the scores for bare ground census plots shifted towards closed shrubland in a gradient of shrub encroachment (Fig. 3a). The composition of bird species shifted along axis 1 from assemblages with a higher proportion of species initially associated with open shrubland, to communities with species correlated with forested areas (deciduous and evergreen forest) (Fig. 3b). The bird species have also shifted from assemblages of species correlated with open spaces (bare ground, open shrubland and human-influenced areas) to closed shrubland along axis 2 (Fig. 3b). Two main assemblages of bird species were identified in the co-inertia analysis (Fig. 3c): one group was strongly associated with shrubland, in which some species were more closely correlated with open spaces (bare ground, open shrubland and human-influenced areas) while others were associated with closed shrubland (Fig. 3c). The other group of species was mainly associated with forest (evergreen and deciduous forest) (Fig. 3c). The thirteen species for which the occurrence rate increased significantly between 2000 and 2010 (see previous section) (Table 1), were mainly associated with closed shrubland and forests, e.g. Dartford Warbler, Blackbird (*Turdus merula*) and Blackcap (*Sylvia atricapilla*) (Fig. 3c). In addition, many of those species considered stable but with a higher occurrence rate in 2010 than in 2000 were also correlated with these land-cover types, e.g. Stonechat (*Saxicola rubicola*) and Whitethroat (*Sylvia communis*) (Fig. 3c). Declining and stable bird species whose occurrence decreased between 2000 and 2010, were mainly associated with bare ground or open shrubland, e.g. Woodlark (*Lullula arborea*) and Rock Bunting (*Emberiza cia*) (Table 1; Fig. 3c), and human-influenced areas, e.g. Tree Pipit (*Anthus trivialis*). These bird species ranged widely along axis 2 of the co-inertia analysis (Fig. 3c), which was associated with shrubland encroachment.

From a conservation viewpoint, six of nine species of conservation concern (SPEC-2 and 3) were associated with closed shrubland or forested areas, while the remaining three species were correlated with bare ground or open shrubland (Fig. 3c; Table 1).

Discussion

Effects of land abandonment on landscape

Land-cover change was similar at both landscape and local scales, and the results are consistent with those of previous studies addressing different aspects of land-use change in southern Europe in the last few decades (Moreira et al. 2001; Falcucci et al. 2006; Stellmes et al.

Table 1 Changes in the occurrence rate of bird species between 2000 and 2010

Species	Scientific name	ABB	GLMM	2000	2010	Trend	SACRE	SPEC
Woodpigeon	*Columba palumbus*	CPAL	<0.0001	8	20	↑***	↑* *	Non-SPEC^E
Turtle Dove	*Streptopelia turtur*	STUR	0.0010	8	17	↑**	–	SPEC-3
Cuckoo	*Cuculus canorus*	CCAN	0.0081	69	48	↓**	↑**	Non-SPEC
Woodlark	*Lullula arborea*	LARB	0.1920	18	14	–	–	SPEC-2
Skylark	*Alauda arvensis*	AARV	0.0733	43	33	–	–	SPEC-3
Tree Pipit	*Anthus trivialis*	ATRI	0.0030	10	4	↓**	↑*	Non-SPEC
Wren	*Troglodytes troglodytes*	TTRO	<0.0001	92	144	↑***	↑*	Non-SPEC
Dunnock	*Prunella modularis*	PMOD	0.9999	46	46	–	–	Non-SPEC^E
Robin	*Erithacus rubecola*	ERUB	<0.0001	25	50	↑***	↑**	Non-SPEC^E
Stonechat	*Saxicola rubicola*	SRUB	0.0949	34	46	–	↓**	Non-SPEC
Blackbird	*Turdus merula*	TMER	<0.0001	37	107	↑***	↑*	Non-SPEC^E
Song thrush	*Turdus philomelos*	TPHI	1	8	8	–	–	Non-SPEC^E
Dartford Warbler	*Sylvia undata*	SUND	<0.0001	33	78	↑***	↓**	SPEC-2
Whitethroat	*Sylvia communis*	SCOM	0.0774	16	27	–	↓*	Non-SPEC^E
Blackcap	*Sylvia atricapilla*	SATR	<0.0001	34	82	↑***	↑**	Non-SPEC^E
Western Bonelli's Warbler	*Phylloscopus bonelli*	PBON	0.0038	3	11	↑**	↑**	SPEC-2
Iberian Chiffchaff	*Phylloscopus ibericus*	PIBE	<0.0001	23	38	↑***	↓**	Non-SPEC^E
Firecrest	*Regulus ignicapilla*	RIGN	0.0708	26	35	–	–	Non-SPEC^E
Crested Tit	*Lophophanes cristatus*	PCRI	0.1020	14	20	–	–	SPEC-2
Coal Tit	*Periparus ater*	PATE	0.8888	34	35	–	↑**	Non-SPEC
Blue Tit	*Cyanistes caeruleus*	PCAE	0.0040	3	10	↑**	–	Non-SPEC^E
Great Tit	*Parus major*	PMAJ	0.0002	7	18	↑***	↑**	Non-SPEC
Short-toed Treecreeper	*Certhia brachydactyla*	CBRA	0.1680	8	11	–	↑*	Non-SPEC^E
Golden Oriole	*Oriolus oriolus*	OORI	0.3960	15	14	–	↑**	Non-SPEC
Red-backed Shrike	*Lanius collurio*	LCOL	0.0042	9	3	↓**	–	SPEC-3
Jay	*Garrulus glandarius*	GGLA	0.0147	14	7	↓*	↑**	Non-SPEC
Chaffinch	*Fringilla coelebs*	FCOE	0.0437	37	51	↑*	↑**	Non-SPEC^E
Serin	*Serinus serinus*	SSER	0.0114	15	24	↑*	↓**	Non-SPEC^E
Greenfinch	*Carduelis chloris*	CCHL	0.6430	8	9	–	↑**	Non-SPEC^E
Linnet	*Carduelis cannabina*	CANB	0.0775	24	36	–	↓*	SPEC-2
Rock Bunting	*Emberiza cia*	ECIA	0.8998	44	43	–	–	SPEC-3

The bird species are ordered by taxonomic group. ABB, abbreviation; GLMM, p value for occurrence trend between 2000 and 2010 in GLMM analysis (* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$); values, number of census plots in which the species were recorded in 2000 and 2010; SACRE, trends from the Spanish monitoring of common breeding birds. ↑ = increasing, '–' = stable, ↓ = decreasing. *SPEC categories* SPEC 2—concentrated in Europe and with unfavourable conservation status, SPEC 3—not concentrated in Europe but with unfavourable conservation status, Non-SPEC^E—concentrated in Europe but with favourable conservation status, Non-SPEC—not concentrated in Europe and with favourable conservation status

2013). The present results are also consistent with the trends in rural abandonment documented in the study region at regional and local scale since the middle of the twentieth century (Calvo-Iglesias et al. 2009; Pôças et al. 2011; Regos et al. 2012), as well as in other Mediterranean regions of the Iberian Peninsula (Romero-Calcerrada and Perry 2004; Roura-Pascual et al. 2005; Gil-Tena et al. 2009; Gracia et al. 2010). Many of these areas are characterized as marginal mountain areas dominated in the past by 'traditional' agricultural landscapes, but which have experienced a strong degree of rural depopulation and the subsequent abandonment of traditional lifestyle in recent decades (e.g. livestock and agricultural practices, grazing).

The results confirm that shrub encroachment and forest maturation and spread have clearly occurred in Xurés Mountains over the last 10 years (Fig. 2 and 3). As stated before, land abandonment has occurred in north-west Iberia since the middle of the twentieth century (Calvo-Iglesias et al. 2006; Regos et al. 2012), therefore recently observed land-cover change may be at least partly due to these longer term processes.

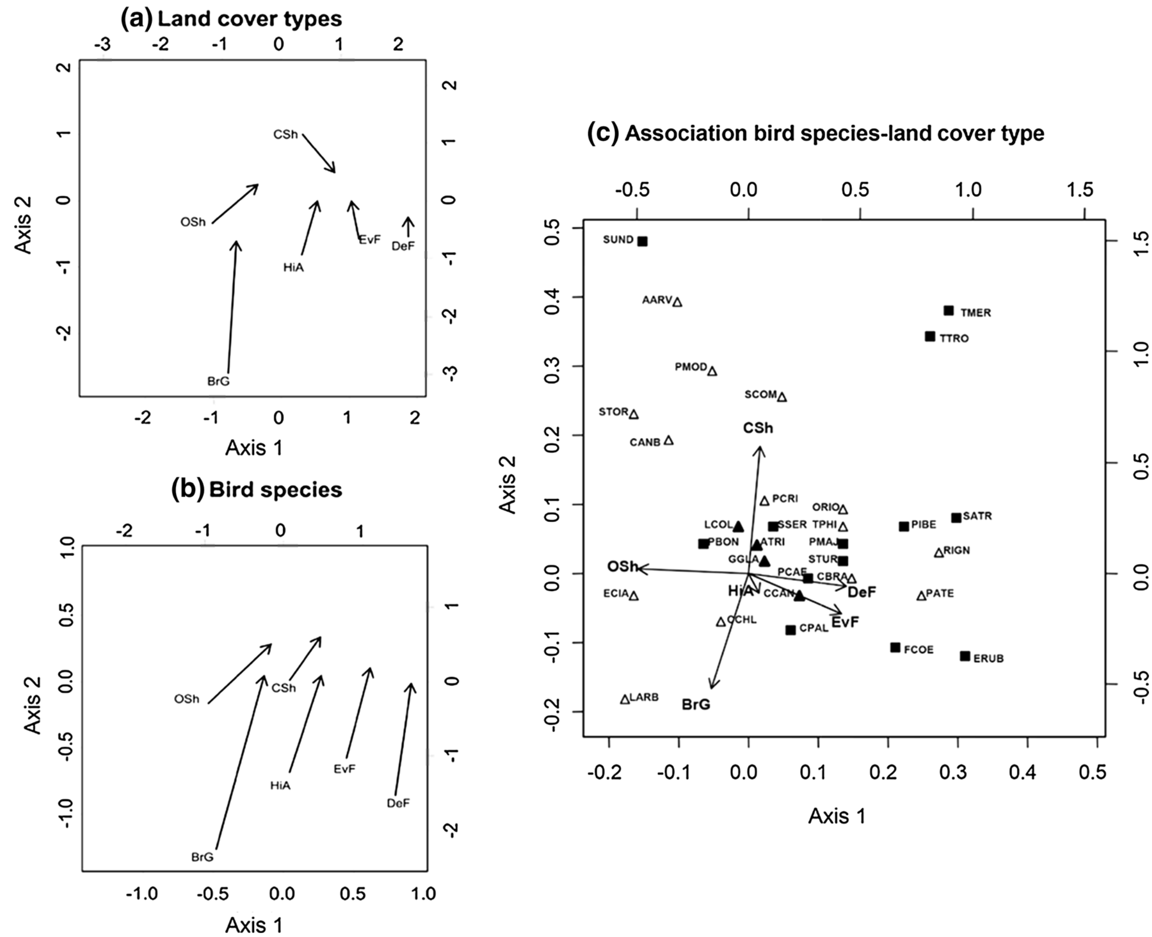

Fig. 3 Axis 1 and axis 2 of co-inertia analysis showing temporal shifts in environmental composition (the six land-cover types), breeding bird community composition and the relationships between land-cover types (environmental variables) and bird species: **a** Temporal shifts in the position of census plots on the axis 1 × axis 2 co-inertia plane, using environmental variable co-inertia weights (normed scores of census plots were averaged within each subset of plots assigned to a given land-cover type in 2000); the base of the *arrows* represents the average scores of a sample in 2000 and the *heads* represent the average scores in 2010; each *arrow* is identified by the abbreviated name of the land-cover type these plots had been assigned to in 2000; **b** temporal shifts in position of census plots on axis 1 × axis 2 co-inertia plane, using bird species co-inertia weights (scores of census plots were averaged within each samples as for the analysis of the vegetation); **c** scores for bird species according to land-cover types on the axis 1 × axis 2 co-inertia plane (bird species symbol refers to species with decreasing (*filled triangle*), increasing (*filled square*) or stable (*open triangle*) occurrence during the period studied according to GLMM analysis in each census plot for each year. Each *arrow* represents the most important environmental variable. Land-cover type and abbreviated species names are shown in Fig. 2 and Table 1, respectively

Forest conservation and expansion have been favoured by the regulation of deciduous forest felling by the Regional Ministry for Environment. This measure was implemented in the 1990s to prevent massive elimination of these forests, thus attenuating forestry and agricultural pressures (Calvo-Iglesias et al. 2009; Regos et al. 2014b). Moreover, the results also showed an increase in evergreen forest cover (represented by *Pinus sylvestris* and *P. pinaster*). In 2000, evergreen forests occupied 1,705 ha, while in 2010, the cover increased to 1,949 ha (Appendix 2). This increase could have been higher if 864 ha of evergreen forests had not disappeared and been substituted by shrubs. Evergreen forests in the region under study are the result of a previous forest management focused on social and economic interests (helped by regional and local programmes). Therefore, the decrease may be due to forest harvesting. In addition, coniferous forest was also found to be the second land-cover type most susceptible to burning in the study region (Moreira et al. 2001; Regos et al. 2014b). Wildfires have thus helped to decrease the total extent of evergreen forests and shrublands and to increase cover by oak forests due to the ability of oak to resprout (Regos et al. 2014b).

Effects of land abandonment on bird assemblages: winners and losers

The occurrence rates of about 50 % of the bird species changed significantly between 2000 and 2010. Bird species shifted from assemblages with a higher proportion of species initially associated with shrubland to assemblages predominantly including species associated with forested areas. There has also been a shift from assemblages of bird species associated with open spaces to assemblages associated with closed shrubland. This pattern of change is a clear response to shrub encroachment, afforestation, and forest maturation processes caused by land abandonment. For the thirteen species with increasing occurrence rate (winner species), eight species are also tending to increase at the national level, according to the SACRE programme (SEO/Birdlife 2010). Turtle Dove (species of conservation concern in Europe, SPEC-3) and Blue Tit (*Cyanistes caeruleus*) were stable between 1996 and 2009 at a national level (SEO/Birdlife 2010), whereas they tended to increase in the Xurés Mountains. This indicates that land abandonment may favour the expansion of forest-dwelling species at both regional and local scales.

In the same way, species that are declining at national level (according to the SACRE programme), such as Dartford Warbler (species of conservation concern in Europe, SPEC-2), Iberian Chiffchaff and Serin (*Serinus serinus*), also tended to increase in the study area. Thus, the land abandonment of the Xurés Mountains may be favouring these declining species at the local level. Specifically, Dartford Warbler may also have been favoured by the wildfires that occurred at the beginning of the 2000–2010 period and by post-fire shrub regeneration (Herrando et al. 2001; Pons et al. 2012).

For decreasing species (loser species), the observed trends were inconsistent with the trends described at the national level. All declining species in the Xurés Mountains were linked to census plots with a high proportion of open shrubland and human-influenced areas, i.e. open-habitat species (Fig. 3c). Nonetheless, in the co-inertia analysis, some other declining species, such as Tree Pipit, Jay (*Garrulus glandarius*) and Cuckoo (*Cuculus canorus*), were associated with elements of both woody habitat (open woodland or shrubland) and open ground, i.e. ecotone species (Fig. 3c) (Cramp 1998; Martí and Del Moral 2003; Domínguez et al. 2012). When the proportion of open ground in a local area declines below a certain threshold, the habitat no longer meets these species' needs (Cramp 1998; Martí and Del Moral 2003; Domínguez et al. 2012). Previous research has also showed that the relative abundance distribution and richness of bird communities is higher in structurally complex forests compared to structurally more simple grasslands when controlling for available energy (Hurlbert 2004). These structurally more complex habitats could provide positive species–energy patterns, which implies that as productivity increases, the number of resource types that can support specialist species increases (Srivastava and Lawton 1998; Monkkonen et al. 2006). Therefore, the progressive homogenization of the landscape could explain the observed negative effect on these ecotone species.

Regarding the fourteen remaining stable species, half of these did not show any significant change in the occurrence rate (Table 1). The populations of other species associated with shrubland, such as Linnet (species of conservation concern in Europe, SPEC-2) and Whitethroat (*Sylvia communis*), have remained constant in the study area, unlike the negative trends reported at national level during the last decade (SEO/BirdLife 2010). Otherwise, the remaining stable species were mainly associated with forest areas, despite the expansion of forest land and the increasing trend according to the SACRE programme (Fig. 3c; Table 1).

These overall trends confirm that land-cover dynamics mainly associated with shrub encroachment and forest spread and forest maturation have played a fundamental role in shifting bird assemblages over the last 10 years. These findings are consistent with previous studies performed in different Mediterranean regions, the results of which showed the positive influence of forest maturation and spread on colonization by forest birds (Seoane and Carrascal 2008; Sirami et al. 2008; Gil-Tena et al. 2009), as well as the negative effects of land abandonment on open-habitat species (Scozzafava and De Sanctis 2006; Vallecillo et al. 2007; Butler et al. 2010). Previous research also demonstrated that in other mountainous areas of southern Europe, shrubland bird species have also been favoured by shrub encroachment brought about by large-scale abandonment of grazing and pastoral habitats (Laiolo et al. 2004; Sirami et al. 2007).

Strengths and weaknesses of rewilding: implications for conservation

Recent studies have presented rewilding as an alternative option for land use in cases of farmland abandonment (Guilherme and Pereira 2013; Navarro and Pereira 2012; Queiroz 2013). The trends in land abandonment could also be seen as an opportunity rather than a threat, even though the conservation of traditional farming systems is also associated with biodiversity and cultural value (Navarro and Pereira 2012). In the area under study, land abandonment has affected vegetation and breeding bird communities in two opposing ways. The range of distribution of forest and shrubland bird species, such as Dartford Warbler (SPEC-2) and Iberian Chiffchaff, have increased in the study area, in contrast to the national trends reported for the last 10 years. This is a clear example of the potential benefits of land abandonment, especially in areas historically affected by wildfire. Nonetheless, a few bird species mainly associated with open habitats and with conservation concern status (SPEC-3), such as Red-backed Shrike and Rock Bunting, have suffered a decrease in their distribution and occurrence, highlighting the need to maintain open habitat areas for the conservation of biodiversity associated with these habitats.

Moreover, two atlases of breeding birds are available for the study area, one from the period 1998–1999 (Domínguez et al. 2005) and another for 2010 (Domínguez et al. 2012). Considering this additional information (see Appendix 3 for the complete list of the bird species included in the two atlases and a comparison of bird species detected in point counts), we found that the occurrence of some open-habitat species, such as the Ortolan Bunting (*Emberiza hortulana*) and the Black-eared Wheatear (*Oenanthe hispanica*), has decreased to only a very local distribution or even the species have disappeared from the study area. Recent studies have demonstrated that the distribution of several bird species is correlated with the frequency and seasonality of fire events (De Cáceres et al. 2013). Open-habitat birds tend to disappear from disturbed sites some years after the fire event (Zozaya et al. 2011). In this case, individual birds might be forced to abandon the areas and colonize new highly suitable areas, suggesting that burnt areas might function as a source of temporary colonizers. Indeed, the local extinction of the Black-eared Wheatear (SPEC-2; Birdlife International 2004) could be partly explained by the decreasing impact of wildfires reported in the study area between 2006 and 2010 (Regos et al. 2014b). In the same way, the Ortolan Bunting (SPEC-2; Birdlife International 2004) was only detected in one site, in contrast with observations reported in the first atlas (Domínguez et al. 2005), and in the neighbouring Peneda-Gerês Natural Park, where the bird is relatively easy to see in shrubland up to 900 m (Pimenta and Santarém, 1996). Thus, when the succession from shrubland to forest dominates over the creation of new low-vegetation areas derived from wildfire, open-habitat specialists may be the most affected by loss of suitable habitat (De Cáceres et al. 2013). Recent studies in Mediterranean ecosystems have suggested that landscape gradients induced by fire, mainly favouring shrubland availability, may enhance the resilience of threatened open-habitat species at the landscape scale by increasing the range of potential habitats used (Vallecillo et al. 2007). This highlights that land abandonment positively affects forest and early- successional shrubland birds, but in the absence of continued disturbance, either natural or human-wrought, it will be necessary to support the shrubland species. Consequently, we suggest that fire management aimed at favouring the creation of small burned areas in progressively homogeneous landscapes may be a sensible alternative in these areas. Modulating fire suppression under mild weather conditions and prescribed fire programmes have resulted in effective fire management for establishing fine-grain age-patch mosaics in which fire spread is limited by the age and spatial pattern of fuels (Moritz 2003; Brotons et al. 2013; Regos et al. 2014a). These new patches would thus favour open-habitat species (De Cáceres et al. 2013; Kelly et al. 2014) and associated ecosystem services (Whelan et al. 2008). We also suggest that further funding of sustainable forest harvesting should be considered in the study area to offset the loss of open habitats and to prevent the occurrence of high-intensity fires as a result of fuel accumulation (Stephens 1998; Drapeau et al. 2000; King et al. 2011; Fenton et al. 2013).

Conclusions and recommendations

This study provides one of the first assessments of rewilding as a land-use option on biodiversity in a context of land abandonment and fire disturbance in Iberian Peninsula. In particular, some bird species showed opposite trends to those reported at National level for the same time period. The four declining species in Xurés Mountains showed a positive trend at the National level while all declining species at this level maintained or increased their occurrence rates in our study area. Moreover, open-habitat species are well represented at regional level (agricultural lowlands in the province of Ourense). Therefore, we conclude that land abandonment in this area provides habitat for high-priority shrub–forest-dwelling bird species at the cost of modest reductions in numbers of open-habitat birds. In light of our results, and adopting a broad conservation perspective, we encourage land managers to consider rewilding as a land-use policy option. However, at natural park level, if wildlife managers want to maintain declining species in Xurés Mountains we recommend including fire-suppression programs into conservation plans. Positive effects of wildfires on such species will hinge on the frequency and extent of affected areas. If small- and medium-sized fires prevail over the long-term, local-scale heterogeneity introduced in the landscape may favour metapopulation dynamics for most of these species by maintaining a dynamic pool of suitable habitat patches that are colonized after perturbation from nearby suitable habitats. On the contrary, a spread of large fires will initially favour open-habitat birds, but the habitat may soon turn unsuitable until new perturbations generate open habitats again (Brotons et al. 2005). Forest management and prescribed burning could temporarily solve the problem but these new open habitats could become ecological traps at long term. Therefore, we recommend using unplanned fires to create an optimal fire regime for these open-habitat species through fire management as it has been successfully implemented in other fire-prone ecosystems.

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