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Birds like it Corky: the influence of habitat features and management of 'montados' in breeding bird communities

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Abstract In the southwest part of the Iberian Peninsula the dominant land-use are the Portuguese montados and Spanish dehesas, parkland forested areas of anthropogenic origin dominated by cork oak. They form a wooded matrix with open areas, scattered woodlands and undisturbed patches of Mediterranean forest and scrublands. The montados are characterized by a rich bird community. We have focus our study in a multidisciplinary approach, evaluating how management and landscape patterns influence the bird community in order to identify potential threats to its conservation. The study was conducted in the Site of Community Importance of Serra de Monfurado were 70% of the area is cork and holm oaks. We used data from 120 10-min point counts. Using variation partitioning, we determined the independent and joint effects of Forest, Management and Habitat variables. The variation captured in bird assemblage was 65.06%. Most of the explained variation was related to the Habitat and Management variables. The explanatory variables that were highlighted as important predictors were variables that reflected tree and shrub density and cork removal. Modelling for forest species through generalized linear models (GLM) emphasize that the management plays an important role in the species distribution. The most important variables selected in models reflected cattle grazing and cork removal. Our results point out that the type of management is crucial to maintain the equilibrium in bird community associated to montados. Farmland and forest species will benefit from areas with different tree densities, small patches of Mediterranean scrubs in the understory and correct livestock numbers.

Keywords Montado · Portugal · Bird community · Cork oak · Partition of variance

Introduction

In the southwest part of the Iberian Peninsula the dominant land-use in the countryside are the Portuguese montados and Spanish dehesas, parkland forested areas of anthropogenic origin dominated by cork oak (*Quercus suber*) and/or holm oak (*Q. rotundifolia*). These agro-silvo-pastoral systems (e.g. Pinto-Correia and Mascarenhas 1999; Pinto-Correia 2000) combine the use of woodland products (timber, charcoal and cork) with cereal crops and

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livestock grazing in the understory (Blondel and Aronson 1999) and are a remarkable example of a well-adapted system to climate constrains of the Mediterranean Basin. Depending on the type of management adopted and local geographical features, the understory is often removed to prevent the development of a shrub layer in order to maintain a grass cover for cattle grazing (Díaz et al. 1997; Tellería 2001), to facilitate cork extraction and to endorse an easier access to acorns, an important food resource for wildlife and livestock from October to February.

Portugal supports 33% of the world population of cork oak (≈737000 ha) corresponding to 23% of the country forested area (DGRF 2007). In addition to the recognized economical value of cork oak forested areas, they support a high biological diversity (Rabaça 1990; Díaz et al. 1997, 2003; Blondel and Aronson 1999; Tellería 2001; Tellería et al. 2003; Harrop 2007). Mainly as result of the mosaic created by this dynamic heterogeneous landscape which forms a wooded matrix with open areas, scattered woodlands and undisturbed patches of Mediterranean forest and scrublands (Tellería 2001; Pereira and Fonseca 2003). In the Iberian montados and dehesas the result of the increase presence of edge and open area birds it appears to compensating the loss of forest birds (Tellería 2001). This pattern of bird richness increases in woodlands southwards along the Iberian gradient, with montados and dehesas showing the highest scores was described by Tellería (2001). Although the legal protection of forest oak plantations and the fact that most of cork oak world population is located in the Mediterranean Basin (Carrión et al. 2000), designated as one of the 25 biodiversity hotspots of the world (Myers et al. 2000), this forest areas are threatened by land abandonment, by pathogenic agents and overgrazing (Plieninger 2007).

So, reliable data must be gathered in order to allow the establishment of monitoring programs to assess the relationships between biodiversity and management actions at spatial and temporal scales. The link between this knowledge and the management of this particular ecosystem allow the co-existence of biodiversity and sustainable production. We have focus our study in a multidisciplinary approach, evaluating how management and landscape patterns influence the bird community in order to identify potential threats to its conservation. For common forest species we aim to assess the most important forest features in montado areas that influence their distribution.

Methods

Study area

Our study was conducted in the Site of Community Importance of Serra de Monfurado (PTCON0031—Natura 2000) (Fig. 1), in an area of 23878 ha located in the Alentejo province, southern Portugal (38°33′N, 8°09′W). The climate is meso-Mediterranean with hot and dry summers and moderate rainy winters (Rivas-Martinez and Loidi 1999). Average monthly temperature varies from 9 (January) to 25°C (July) with an annual average of 12.5°C, the annual rainfall ranges from 600 to 1000 mm (Instituto do Ambiente 1999; SNIRH 2007).

Quercus suber and *Q. rotundifolia* are the dominant element of the landscape (≈70% of total surface). Other land uses include meadows, pastures and fallows, olive groves and orchards, arable crops, eucalyptus plantations, pine groves and vineyards. Shrubby areas are dominated by blackberry *Rubus ulmifolius*, rockroses *Cistus* spp. and gorse *Ulex* spp. In some watercourses riparian vegetation create forest galleries with deciduous trees like ash *Fraxinus angustifolia*, alder *Alnus glutinosa*, willows *Salix alba*, *S. atrocinerea*, *S. salvifolia*, poplars *Populus nigra* and, on most shaded areas, Portuguese oak *Quercus faginea*.

Sampling sites and bird surveys

Thirty forested sampling plots (*Q. suber* and/or *Q. rotundifolia*), ranging in size from 16 to 93 ha (mean size 46.7 ± 21.5 ha), were surveyed twice during the breeding season of 2004. In each plot two sampling sites were selected: the first near the plot center and the second at least 250 m apart from this. We sampled birds using point counts with unlimited distance and a counting period of 10 min (e.g. Blondel et al. 1981; Bibby et al. 2005). The first visit occurred between 15 March and 27 April, and the second from 10 May to 4 June. In all 120 point counts were conducted in the early hours after sunrise by the same observer always avoiding windy and rainy weather.

Fig. 1 Location of the SCI Serra de Monfurado and forested sampling plots (*dark grey*). *Light grey* areas are 'montados'

Explanatory variables

Three groups of environmental variables were recorded for each sampling site (Table 1): (1) *Forest*—Forest variables reflected woodland features of the surveyed plots (e.g. *Quercus* spp. dominance, percentage of montado affected by diseases), (2) *Management*—variables include anthropogenic actions and resources exploration associated to forest management (e.g. cork removal, shrub cut), livestock (e.g. foraging area, type of cattle) and water availability (e.g. distance to the nearest water body) and (3) *Habitat*—Habitat variables were accessed visually at each sampling station on the same day of the bird census and reflected particular habitat features like the percentage of vegetation cover in vertical layers. Both *Forest* and *Management* variables were derived from unpublished data (ERENA 2004).

Data analysis

We used the maximum bird abundance detected in one of the two visits, which represents the minimum number of birds at that location (Bibby et al. 2005). We excluded from data treatment species with a wider spatial use of the census area (namely birds of prey, crows and insectivorous aerial flyers), or flocks. Analyzed species were chosen according to patterns of preferential habitat use of the montado: forest birds (e.g. woodpeckers, tits), farmland and hedgerows birds (e.g. common stonechat *Saxicola torquatus*) and shrub understory birds (e.g. sardinian warbler *Sylvia melanocephala*).

In order to assess the influence of each set of explanatory variables on bird community, we used the variation partitioning procedure (e.g. Heikkinen et al. 2004; Godinho et al. 2010) through canonical ordination techniques for multivariate analysis.

For forest species (Appendix) and for specific richness we developed individual models using Generalized Linear Models (GLM) (Table 3). Previously to the construction of the models, the existence of autocorrelation in our bird data was assessed using Moran's I as a function of spatial distance (Legendre and Legendre 1998). If autocorrelation is detected in the response variable, the models should account for it using an autocovariate term, and the autocorrelation in the explanatory variables should be tested (Lennon 2000; Segurado et al. 2006). Afterwards, different data reduction procedures were performed in order to avoid multicollinearity among variables, prior to the statistical modeling phase. All pairwise correlations were assessed by Spearman correlation coefficients (Tabachnick and Fidell 2001). In each pair of highly correlated variables ($r > |0.7|$) (Tabachnick and Fidell 2001), only the most biologically meaningful variable was retained for further analysis. Before the GLM

Table 1 Groups of environmental variables recorded at each one of the sampling stations

Explanatory variables	Code
Forest	
Percentage of the dominant habitat in a 500 m buffer from the point count (%)	HDOM
Area of the forested sampling plot (ha)	AREA
Montado affected by diseases retrieved by percentage of trees affected by at least one biotic agent (%)	MTVIT
Percentage of trees affected by Buprestids beetles per forested sampling plot (%)	CORSP
Percentage of trees affected by Numelaria regia per forested sampling plot (%)	NUMRE
Percentage of trees affected by Gypsy moth per forested sampling plot (%)	LYMDI
Management	
Regulated area for small game hunting (ZCT-turistic, ZCM-municipality, ZCA-associative, RG-open) (%)	GAME
Years from the last cork removed (0—removed in the year of the surveys, 2—in the 2 years prior to surveys, 4—3 to 4 years prior to surveys)	TDESC
Shrub removal by cutting (%)	CUTT
Shrub removal by harrow (%)	ARROW
Tillage (%)	SOILM
Cover and/or fund fertilizers (kg/ha)	FERT
Sheep density foraging per forested sampling plot (*n*/ha)	DSHEE
Cows density foraging per forested sampling plot (*n*/ha)	DCOW
Swine density foraging per forested sampling plot (*n*/ha)	DSWI
Number of cattle species foraging per forested sampling plot (1–4)	CATTLE
Foraging area per forested sampling plot (ha)	FORAR
Total stocking retrieved by the total number of livestock cattle (*n*)	TSTOC
Distance to the nearest water body (m)	DWAT
Number of water points available per forested sampling plot (*n*)	WATER
Habitat	
Vegetation cover with six classes of high (<0.5; 0.6–1 m; 1–2 m; 2–4 m; 4–8 m; >8 m) and six classes of vegetation density (0%; 0–20%; 21–40%; 41–60%; 61–80%; >80%)	VEG
Dominant plant species (cork oak, holm oak, pinus, rockrose, gorse, blackberries, etc.) per stratum (<0.5; 0.6–1 m; 1–2 m; 2–4 m; 4–8 m; >8 m)	SPE
Shrub ecological succession with three classes (1—shrub absence; 2—pioneer species; 3—species of advanced stages of succession)	MTS

Description of the variables associated with the group *Forest*, *Management*, and *Habitat*, as indicated

modeling, univariate models were performed and all variables with significance $P < 0.15$ were retained for the following analysis (Hosmer and Lemeshow 2000). All statistical analysis was performed using SPSS 16.0 (SPSS Inc 2007).

Partition of variance

The multivariate analysis was performed using the program CANOCO for Windows, version 4.5 (ter Braak and Smilauer 2002). Bird community was related to the environmental variables using *Canonical Correspondence Analysis* (CCA) so as to identify which sets of environmental variables better explained the patterns of variation in bird community (ter Braak 1986). The runs were made without transformation of bird data and a forward selection of variables under an unrestricted model with a Monte Carlo test (999 permutations). Similar to Titeux et al. (2004), variables that did not contribute in a significant way to the explained variation and with weaker species-explanatory correlations were removed. Variables with an estimated *P* value lower than 0.05 were retained. In this kind of approach, the inclusion of rare or ubiquitous species in the analysis should be avoided, as they can create modifications in the total inertia of the species dataset or distortion in the ordination (e.g. Titeux et al. 2004). We omitted from analysis species that were detected in less than 5 and more than 27 of the sampling stations.

Following the procedure described in Heikkinen et al. (2004), the variation in our bird dataset was decomposed into the three groups of explanatory variables—*Forest*, *Management* and *Habitat*—using sequential partial regression analyses with CCA (ter Braak and Smilauer 2002). The contribution of each group separately and together was evaluated through the seven CCA runs without the forward selection option, testing the significance of the first ordination axis and the significance of all axes together in CANOCO (999 Monte Carlo permutations tests).

Variation partitioning led to eight fractions: *a*—pure effect of *Forest*; *b*—pure effect of *Management*; *c*—pure effect of *Habitat*; combined variation due to the joint effects of *d*—*Forest* and *Management*; *e*—*Forest* and *Habitat*; *f*—*Management* and *Habitat*; *g*—the three groups of explanatory variables; and *U*—unexplained variation.

GLM

We used GLM to test for the effects of *Forest*, *Management* and *Habitat* variables on forest species and on bird community parameter (species richness). Analyses were carried out with a backward stepwise procedure to point out the most important predictors.

The species models were selected using Akaike's Information Criterion corrected for small samples (AICc) (Burnham and Anderson 2002), i.e. the best fit to the variable data set. AICc is based on the principle of parsimony and helps to identify the model that accounts for the most variation with the fewest variables: the model that best explains the data is the one with the lowest AICc (Burnham and Anderson 2002). Model fit was evaluated using D^2, a measure of the percentage deviance explained according with the formula $D^2 =$ (null deviance − residual deviance)/null deviance (Guisan and Zimmermann 2000).

Results

In all, 74 species were recorded across the surveys, from which 54 were used to calculated specific richness and 24 met the selection criteria for CCA analysis (Appendix). The average species richness and standard deviation, per point count, was 15.70 ± 2.96, ranging from 10 to 24 species. The most frequent species were the short-toed tree-creeper (*Certhia brachydactyla*) (90%), *Sylvia melanocephala* (90%) and the less frequent crested tit (*Lophophanes cristatus*) (20%), golden oriole (*Oriolus oriolus*) (17%) and mistle thush (*Turdus viscivorus*) (17%).

Moran's I test for the forest species modelling through GLM revealed that there is no significant spatial autocorrelation in our bird data. Therefore there was no need to incorporate a group of spatial predictor variables in the analysis of our data structure.

Community analysis—variation partitioning

Fourteen variables were selected in the community analysis (Table 2) and the amount of variation explained by these selected environmental variables was 65.06%.

The decomposition of variance demonstrated that the pure effect of *Habitat* and *Management* (16.49 and 21.39%) and their joint effect (fraction *f* in Fig. 2; 8.93%) together were responsible for the largest fraction of the variability detected in bird community (46.81%). The amount of explained variation shared by all groups of variables represented 5.30% of the total variability.

The CCA ordination results along the first two axes after variance partition is plotted in Fig. 3. Arrows represent the environmental variables included in the model that explain most variation in the species distribution. The proximity of bird species scores to the arrows represents the environmental condition associated to each species.

The first axis accounted for 28.5% of the extracted variance of the species–environment relationship, and 77.2% was the value explained for the four axes. The ability of environmental variables to explain variations in bird community composition is given by species–environment correlations, in this case 0.92 in axis I and 0.93 in axis II. According to the Monte Carlo test, both the first canonical axis and the whole set of canonical axes explained significant bird assemblage data (P value < 0.01).

In the negative direction the first axis was mainly influenced by cork removed in the 2 years previously to the study (TDESC2), vegetation cover between 20 and 40% at 1 m high VEG2(20–40) and total stocking (TSTOC) and, in the opposite direction, by the presence of Holm oak (SPEholm), the presence of

Table 2 Environmental variables included in CCA model and respective canonical coefficients, intra-set correlations, statistics of Monte Carlo significance test (*F*) and the associated probability (*P*)

Variables	Canonical coefficients				Intraset correlations				*F*	*P* value
	Axis 1	Axis 2	Axis 3	Axis 4	Axis 1	Axis 2	Axis 3	Axis 4		
Forest										
HDOM	−0.1064	0.0262	0.5399	0.4218	0.2330	−0.0976	0.3054	0.5921	1.89	0.025
AREA	−0.1270	−0.2105	−0.0543	−0.1880	0.0202	−0.4848	0.1823	0.0913	1.78	0.045
LYMDI25	0.1850	−0.0628	−0.1709	−0.1523	0.4682	0.0168	−0.0920	−0.1690	1.96	0.030
Management										
GAMEzct	0.1820	−0.1261	0.6929	−0.1433	0.2130	−0.1822	0.5796	−0.3869	2.64	0.004
FERTcover	0.4470	0.0842	−0.0979	−0.0287	0.3398	−0.0846	0.0656	−0.0446	1.86	0.048
DSWI	−0.1251	0.4048	−0.1826	0.4217	−0.0308	0.5388	0.1870	0.4563	2.35	0.014
TSTOC	−0.0154	−0.1115	0.4818	0.3300	−0.3800	0.1214	0.3464	0.3089	1.92	0.027
DWAT	−0.3381	−0.0647	−0.0823	0.0206	−0.4162	−0.3196	−0.1754	0.1111	1.77	0.040
TDESC2	−0.5430	0.5199	0.3009	−0.0769	−0.4022	0.2096	0.2288	−0.4837	2.54	0.008
Habitat										
VEG2(20–40)	−0.0494	−0.0358	−0.0074	−0.2804	−0.3000	0.1489	−0.2022	−0.3808	2.00	0.017
VEG3(0–20)	0.2350	−0.2631	0.0974	−0.2532	0.0570	−0.1743	0.3997	−0.3283	1.64	0.057
VEG5(20–40)	0.3350	0.3587	0.2778	−0.1616	0.6365	0.3883	−0.0270	0.2161	3.86	0.003
SPEulex	−0.0882	−0.4219	0.1197	0.1550	−0.2703	−0.3286	0.2876	0.0572	1.89	0.026
SPEholm	0.1194	−0.4829	−0.1419	0.6283	0.3315	−0.3330	−0.3184	0.2005	2.17	0.012

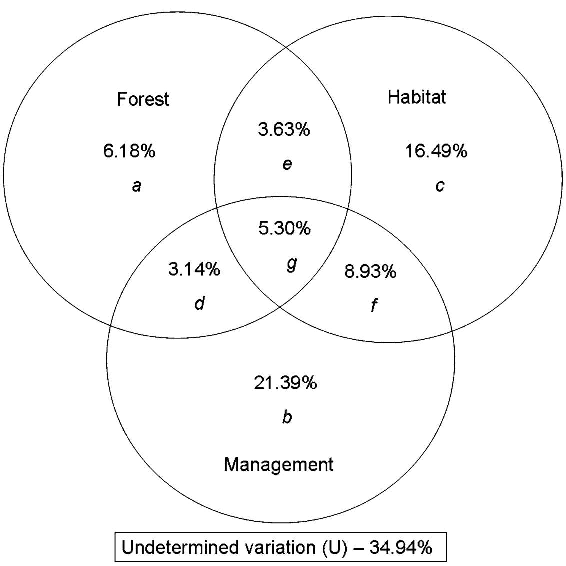

Fig. 2 Results of variation partitioning for bird community in terms of fractions of variation explained. Variation of the species data matrix is explained by three groups of explanatory variables: *Forest*, *Management* and *Habitat*. *U* is the unexplained variation. *a*, *b* and *c* are unique effects of *Forest*, *Management* and *Habitat* variables, respectively. *d*, *e*, *f* and *d* are fractions indicating their joint effects

trees affected by gypsy moth (LYMDI25), vegetation cover between 20 and 40% higher than 4 m VEG5(20–40). This axis separates plots of Cork oak with scrubs from forest patches of Holm oak with low tree cover. The second axis was, on the positive side, influenced by presence of pasture areas herd by pigs (DSWI), and the area of the sampling plot (AREA) are the variable most negatively correlated to the second axis.

Modelling forest species

For nine forest birds' species and for the species richness, minimal adequate models were calculated using GLM. Modelling was not attempt for seven forest species (wryneck *Jynx torquilla*, green woodpecker *Picus viridis*, lesser spotted woodpecker *Dendrocopos minor*, *Turdus viscivorus*, blackcap *Sylvia atricapilla*, *Lophophanes cristatus*, hawfinch *Coccothraustes coccothraustes*) due to scarcity of records. Interactions between species and variables are shown in Table 3. From all the set of predicted variables, 16 occurred in one or more models. Most of the variables selected represent the *Management* group (12 variables), three

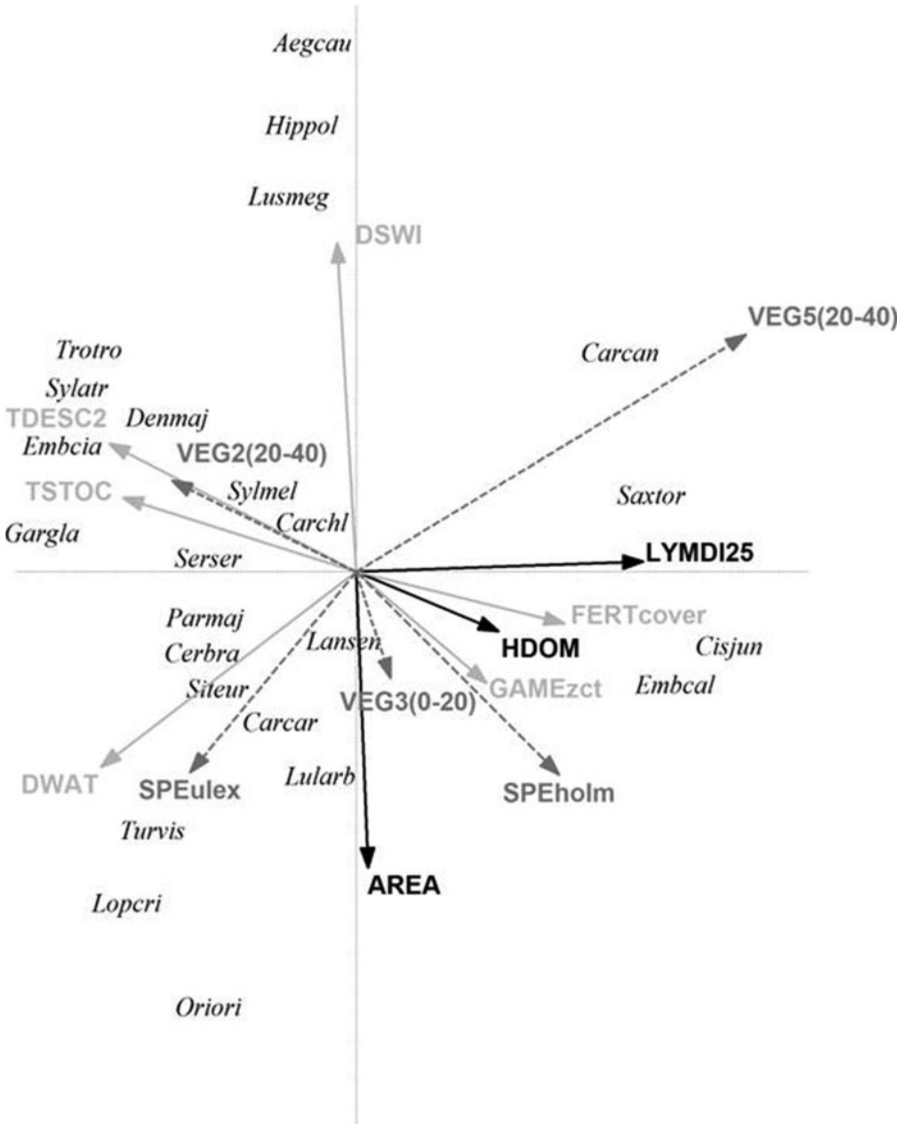

Fig. 3 Ordination biplot of the first two axes of the CCA for bird community. *Forest* variables are represented in *black*, *Management* variables in *grey* and *Habitat* variables in *dashed grey* (see Table 1 for variables names and appendix for species codes)

from the *Forest* and only one from *Habitat*. The most commonly identified predictor variables were cork removed at the same year of the census (TDES0) and grazing by cattle (COWS) occurring in nine and three of the species models respectively and deviance captured range between 17 and 55%.

Discussion

Bird community

The three groups of environmental variables considered in this study captured a variation of 65.06% in bird assemblage. The largest fraction of variability captured results from the pure and shared effect of *Habitat* and *Management* variables—46.81%. The low value explained by *Forest* variables suggests that species are mainly influenced by management activities in the forest and by singular habitat features at a more detailed scale.

Our results suggest that the main bird community gradient is driven by the gradient of montado density and complexity. Poorest forest areas with scattered trees, provide habitat for eurasian linnet *Carduelis cannabina*, *Saxicola toquatus*, zitting cisticola *Cisticola juncidis* and *Emberiza calandra*. This group pulls together species often associated to open area

Table 3 GLM of forest species and species richness, in relation to environmental predictors

Species	*B*	SE	D^2
Dendrocopos major			0.29
Intercept	−3,456	1,041***	
Shrubs removal by harrow	2,187	1,053*	
High cover (78%) of affected trees by Buprestids beetles	−16,033	2,452,146 n.s.	
Cork removed at more than 3 years	0.826	0.067 n.s.	
AICc	59.24		
Parus major			0.19
Intercept	0.922	0.202***	
Cork removed at the same year of the census	−0.444	0.226*	
Grazing by cattle	−0.412	0.221 n.s.	
Montados with high values of pathogenic agents (100%)	−0.743	0.324*	
AICc	183.96		
Sitta europaea			0.27
Intercept	1,039	0.204***	
Grazing by cattle	−0.783	0.277**	
Middle tree cover in the 4–8 m stratum	−0.371	0.313 n.s.	
Cork removed at the same year of the census	−0.464	0.233*	
AICc	170.96		
Certhia brachydactyla			0.17
Intercept	1,178	0.248***	
Cork removed at the same year of the census	−0.438	0.207*	
Montados with low values of pathogenic agents (<28%)	0.380	0.329 n.s.	
High cover (78%) of affected trees by Buprestids beetles	−0.786	0.856 n.s.	
Low cover (<20%) of affected trees by *Numelaria regia*	0.460	0.271 n.s.	
AICc	200.30		
Garrulus glandarius			0.28
Intercept	1,879	0.890*	
Percentage of occupied area by the dominate habitat	−4,374	1,482***	
Cork removed at the same year of the census	−0.778	0.521 n.s.	
AICc	82.19		
Serinus serinus			0.22
Intercept	0.554	0.144***	
Shrub absence	−2,191	1,007*	
Cork removed at the same year of the census	−0.515	0.24*	
AICc	179.46		
Cyanistes caeruleus			0.22
Intercept	1,295	0.099***	
Shrubs removal by cutting	0.342	0.151*	
Montados with low values of pathogenic agents (<28%)	0.456	0.181*	
Cork removed at the same year of the census	−0.287	0.143*	
AICc	253.56		
Fringilla coelebs			0.20
Intercept	1,547	0.177***	
Area of homogenous forest patches	0.004	0.003 n.s.	

Table 3 continued

Species	*B*	SE	D^2
Grazing by cattle	−0.408	0.137**	
Cork removed at the same year of the census	0.320	0.136*	
AICc	258.86		
Aegithalos caudatus			0.55
Intercept	−1,978	0.583***	
Shrubs removal by harrow	1,464	0.630*	
Grazing by pigs	1,835	0.346***	
Cork removed at the same year of the census	−2,264	0.332 n.s.	
AICc	127.04		
Specific richness			0.39
Intercept	2,725	0.050***	
Cork removed in the 2 years prior to the census	−0.042	0.041 n.s.	
Montados with low values of pathogenic agents (<28%)	−0.097	0.075 n.s.	
High cover (78%) of affected trees by Buprestids beetles	−0.325	0.156*	
Total stocking	0.001	0.000***	
AICc	310.36		

Note: Only models with lower AICc are shown

Values for *B*, standard error, deviance explained D^2 and AICc

n.s. non significant

* $P < 0.05$, ** $P < 0.01$, *** $P < 0.001$

habitats (e.g. *Cisticola juncidis*, *Emberiza calandra*) and edge habitats (e.g. *Saxicola torquatus*). In the opposite direction we find species that were associated with dense forest with shrubs, *Turdus viscivorus*, jay *Garrulus glandarius*, *Sylvia atricapilla*, rock bunting *Emberiza cia*, wren *Troglodytes troglodytes*, *Sylvia melanocephala*, great spotted woodpecker (*Dendrocopos major*), european serin (*Serinus serinus*), great tit (*Parus major*), european goldfinch (*Carduelis carduelis*), *Certhia brachydactyla*, wood nuthatch *Sitta europaea*, *Carduelis chloris* and *Lophophanes cristatus*. Generally, most of these species are associated to forest patches with high tree cover and to the presence of Mediterranean shrubs, commonly found in sites with low disturbances (Rabaça 1990).

These species can be divided into forest specialist species (e.g. *Dendrocopos major*), common forest species (e.g. *Certhia brachydactyla*, *Sitta europaea*) and shrubby species (e.g. *Sylvia melanocephala*), according to available ecological niches provided by the montado. These sites are also characterized by a lower intensity of grazing with livestock species turnover, and trees where the cork was removed in the last 2 years.

Three of the analysed species were not included in the previous groups. Melodious warbler *Hippolais polyglotta* and nightingale *Luscinia megarhynchos* are common breeders in riparian galleries in the South of Portugal. The relationship with areas pastured by pigs can be driven from an association between variables that were not total revealed in the analyses.

The unexplained variation in species data were 34.94%. This could be attributed to unmeasured environmental variables that were not accounted for or to species that do not occupy their most suitable habitat (Titeux et al. 2004). The variables included in our analysis dealt with important descriptors directly connected to forest management, similar to other studies conducted in the same area (e.g. Galantinho and Mira 2009).

Forest species modelling

With GLM modelling we identified habitat associations for forest species (Table 3). As in community approach, variables that appeared to be more important to predict the bird species distribution are those reflecting the management of montado. The modelling revealed three particularly important variables: cork removed in the year of sampling had a negative coefficient in eight of the 10 models. The presence of cattle and places with high occurrence of Buprestids beetles where included negatively in three and four models, respectively.

Based on the amount of explained deviance, eight of the 10 GLM models did not describe robust models for the occurrence of each species, with less than 30% of deviance explained. These low values may be mostly due to the ability of species to use a wide range of habitats, as most of the forest species recorded can be considered forest generalists (Gregory et al. 2007). Modelling results for *Aegithalos caudatus* and for total richness revealed stronger associations between variables and species, with an amount of explained deviance of 55 and 39%, respectively.

Time past from the last cork removal seems important to one woodpecker species (*D. major*) perhaps due to least perturbation of sites and to more tree similarities with old forests. Results suggest that when the cork is removed there is an abandonment of those areas by the common forest species (all species modelled), mainly due to disturbance and lack of nesting sites. With the dynamic of the montado and the cork growth the bird community seems to acquire the previous equilibrium after one breeding season. An intensive explotation of the montado, mainly with cattle leads to poor sites with less bird species present. Another set of variables important to forest birds are those describing the sanitary status of the forest. When the prevalence of pathogenic agents is high, forest bird species are absent.

Conclusions

Our results are consistent with the findings of Tellería (2001), showing that montados (and dehesas) act as an ecotonic habitat where a pool of forest and non-forest birds occurs. This diversity results from the forest exploration, the agriculture and foraging in scatter areas. The type of management is highlighted in this study as playing a fundamental role in the maintenance of bird communities. Areas with different tree densities, small patches of Mediterranean shrubs in the understory and well balanced livestock numbers would provide suitable habitat for several farmland and forest bird species. These species are adapted to the forest dynamic system, appearing to have ability to recover in short time even to cork removal.

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Appendix

See Table 4.

Table 4 List of detected species during the field work included in the analysis, common and scientific names (taxonomic order), code (based on scientific names), number of sampling sites where the species was detected (*N*) and habitat specialization according to Equipa Atlas (2008)

Species		Code	*N*	Habitat specialization
Common name	Scientific name			
Red-legged Partridge	*Alectoris rufa*	ALERUF	–	Farmland
Common Quail	*Coturnix coturnix*	COTCOT	–	Farmland
Woodpigeon	*Columba palumbus*	COLPAL	–	Generalist
Collared-Dove	*Streptopelia decaocto*	STRDEC	–	Generalist
Great Spotted Cuckoo	*Clamator glandarius*	CLAGLA	–	Farmland
Common Cuckoo	*Cuculus canorus*	CUCCAN	–	Generalist
Hoopoe	*Upupa epops*	UPUEPO	–	Farmland
Wryneck	*Jynx torquilla*	JYNTOR	–	Forest

Table 4 continued

Species		Code	*N*	Habitat specialization
Common name	Scientific name			
Green Woodpecker	*Picus viridis*	PICVIR	–	Forest
Great Spotted Woodpecker	*Dendrocopos major*	DENMAJ	11	Forest
Lesser Spotted Woodpecker	*Dendrocopos minor*	DENMIN	–	Forest
Crested Lark	*Galerida cristata*	GALCRI	–	Farmland
Thekla Lark	*Galerida theklae*	GALTHE	–	Farmland
Wood Lark	*Lullula arborea*	LULARB	26	Generalist
White Wagtail	*Motacilla alba*	MOTALB	–	Aquatic
Wren	*Troglodytes troglodytes*	TROTRO	19	Forest
European Robin	*Erithacus rubecula*	ERIRUB	–	Generalist
Common Nightingale	*Luscinia megarhynchos*	LUSMEG	9	Forest
Black Redstart	*Phoenicurus ochruros*	PHOOCH	–	Generalist
Common Stonechat	*Saxicola torquata*	SAXTOR	24	Farmland
Common Blackbird	*Turdus merula*	TURMER	–	Generalist
Mistle Thrush	*Turdus viscivorus*	TURVIS	5	Generalist
Cetti's Warbler	*Cettia cetti*	CETCET	–	Aquatic
Zitting Cisticola	*Cisticola juncidis*	CISJUN	19	Farmland
Reed Warbler	*Acrocephalus scirpaceus*	ACRSCI	–	Aquatic
Melodius Warbler	*Hippolais polyglotta*	HIPPOL	7	Shrub
Dartford Warbler	*Sylvia undata*	SYLUND	–	Shrub
Sardinian Warbler	*Sylvia melanocephala*	SYLMEL	27	Shrub
Blackcap	*Sylvia atricapilla*	SYLATR	10	Forest
Common Chiffchaff	*Phylloscopus collybita*	PHYCOL	–	Forest
Long-tailed Tit	*Aegithalos caudatus*	AEGCAU	13	Forest
Crested Tit	*Lophophanes cristatus*	LOPCRI	6	Forest
Blue Tit	*Cyanistes caeruleus*	CYACAE	–	Forest
Great Tit	*Parus major*	PARMAJ	26	Forest
Wood Nuthatch	*Sitta europaea*	SITEUR	26	Forest
Short-toed Tree-creeper	*Certhia brachydactyla*	CERBRA	27	Forest
Eurasian Golden-oriole	*Oriolus oriolus*	ORIORI	5	Forest
Grey Shrike	*Lanius meridionalis*	LANMER	–	Farmland
Woodchat Shrike	*Lanius senator*	LANSEN	17	Farmland
Eurasian Jay	*Garrulus glandarius*	GARGLA	13	Forest
Common Magpie	*Pica pica*	PICPIC	–	Farmland
Spotless Starling	*Sturnus unicolor*	STUUNI	–	Farmland
House Sparrow	*Passer domesticus*	PASDOM	–	Generalist
Tree Sparrow	*Passer montanus*	PASMON	–	Farmland
Rock Sparrow	*Petronia petronia*	PETPET	–	Forest
Chaffinch	*Fringilla coelebs*	FRICOE		Forest
European Serin	*Serinus serinus*	SERSER	26	Forest
European Greenfinch	*Carduelis chloris*	CARCHL	26	Generalist
European Goldfinch	*Carduelis carduelis*	CARCAR	25	Farmland
Eurasian Linnet	*Carduelis cannabina*	CARCAN	18	Farmland
Hawfinch	*Coccothraustes coccothraustes*	COCCOC	–	Forest

Table 4 continued

Species		Code	*N*	Habitat specialization
Common name	Scientific name			
Cirl Bunting	*Emberiza cirlus*	EMBCIR	–	Farmland
Rock Bunting	*Emberiza cia*	EMBCIA	7	Shrub
Corn Bunting	*Emberiza calandra*	EMBCAL	25	Farmland

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