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Small shrubby patches increase bird taxonomic and functional richness of wood-pastures

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Abstract Wood-pastures are semi-natural systems that combine a grazed grassland with a tree layer. Shrubs are often controlled, mostly to improve grazing potential, resulting in a reduction of the available ecological niches. From a conservation perspective, it is thus important to identify management practices that counter this reduction. Our overall objective was to determine the value of small shrubby patches to increase the richness of wood-pasture bird communities. As study model we used Mediterranean oak wood-pastures in southern Portugal, locally known as *montados*. Birds and environmental variables were sampled in 50 m radius plots of wood-pasture with and without small shrubby patches (128–3748 m^2, covering less than 0.5% of the study area), in winter (n = 54) and spring (n = 65). Species assemblages' composition changed between seasons, but in both seasons the assemblages in plots with and without patches were statistically different. Seven species were statistically associated to the presence of patches, in winter and spring, increasing the richness of the respective assemblages. A comparison of the functional composition of communities of patches and matrix revealed that patches increased richness of landscapes by boosting the presence of species with functional traits uncommon in the ecologically simplified matrix. Their presence is promoted by resources added by the patches (e.g. nesting sites, protection, food), but the ranges of individual birds in general extended well beyond the patches. This study demonstrated that the presence of few and small shrubby patches can significantly enrich the bird communities of wood-pastures, both taxonomically and functionally, indicating that promoting them is a cost-effective management measure for these valuable systems.

Keywords Birds · High nature value farmlands · Pasture-woodland · Shrubby patches · Small natural features · *Montados/Dehesas*

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Introduction

Wood-pastures are semi-natural habitats dominated by grasslands and a variable density of trees (Centeri et al. 2016) that cover large areas in temperate zones and are often associated with agro-silvo-pastoral activities. In addition to forestry, the most common economic activity is grazing by domestic ungulates. They are classified as High Nature Value Farmlands, thanks to their strong ecological, social and cultural values (Plieninger et al. 2015). Within these woodland habitats, there are often elements of anthropogenic or natural origin, such as orchards, riparian gallery forests and shrub patches (Pinto-Correia et al. 2011) that greatly diversify the system. Such elements can be considered small natural features—SNF (Hunter 2017) and, despite their small size, have a disproportionately large ecological importance due to the vital resources they provide, which support the presence of a high biodiversity well beyond their limits.

In most of these wood-pastures, the shrub layer is mechanically eliminated, mostly to increase grazing potential, which results in a spatial homogenization, reduction of habitat structural diversity, and impoverishment of ecological niches. However, it has been shown that, in some wood-pasture landscapes, well-developed shrubby vegetation along riparian galleries increases ecological heterogeneity and increases species richness in taxa like birds and carnivores (Leal et al. 2011a, b; Leal et al. 2016; Rosalino et al. 2009). Adding other landscape elements with a developed shrub layer to wood-pastures is likely to bring about further ecological gains to these systems, so the identification of such elements is important to improve landscape management and promote biodiversity.

Small rocky outcrops seem to be one of these elements and are present in many wood-pasture landscapes. They are often formed by exposure of the rocky substrate by erosion from wind and water, or by the partial coverage of rocks by sediments (Hill and Schütt 2000). Moreover, farmers often make piles with large rocks removed from the fields, and these may form structures that are functionally similar to natural rocky outcrops. Regardless of the origin of the outcrops, the rocks usually prevent the mechanical clearing of shrubs, allowing the regeneration or establishment of patches with a shrub layer and, in some cases, a tree layer. These patches greatly vary in area, usually ranging from just a few hundred to several thousand square meters, and often offer resources that are unavailable in the surrounding matrix.

For example, in the western Mediterranean, oak wood-pastures often have outcrops covered by dense vegetation patches that include species like the mastic (*Pistacia lentiscus*), strawberry tree (*Arbutus unedo*), elmleaf blackberry (*Rubus ulmifolius*) and wild olive (*Olea europaea* var. *sylvestris*), which produce berries that are key food resources for mammals and birds (Herrera 1984; Rosalino et al. 2009). Moreover, in landscapes where the shrub layer is scarce because it was artificially repressed, these patches also add niches with distinct land cover, microclimate and invertebrate prey (Oksuz et al. 2020b). Therefore, shrubby patches are likely to bring the animal communities closer to those of original unmanaged ecosystems, in which the shrub layer is not controlled. Given the potential of these shrubby patches to increase the heterogeneity of the wood-pasture landscapes and contribute to the increase of their richness, it is very important to understand their actual ecological role. A few studies have demonstrated the importance that these small patches can have on the richness in organisms that depend on small scale interactions with the environment, such as beetles, lichens and plants (Chozas et al. 2022; Oksuz et al. 2020a, b). However, it remains to be determined if presence of the patches can also influence the richness of animal taxa that depend on habitat at a scale much greater than the size of the patches, such as birds.

The overall objective of this study was to investigate how small patches of shrubby vegetation influence wood-pasture biodiversity, using birds as a model. We first tested if the presence of patches of shrubby vegetation influences the assemblages of bird species in wood-pastures, predicting that the addition of patches would increase species diversity because of the diversification of ecological niches and increase in food resources. We then attempted to understand the mechanisms behind this diversity increase using functional species trait analysis. Finally, we formulated recommendations for the management of wood-pastures to foster their biodiversity value.

Materials and methods

Study area

The study area is dominated by the most abundant type of wood-pasture in the western Mediterranean region, known as *montado* in Portugal and *dehesa* in Spain (Pinto-Correia et al. 2011). This ecosystem covers vast areas and is usually shaped by human activity that led to a progressive transformation of the previously existing native forest (Moreno and Pulido 2009). These agro-silvo-pastoral systems have a more or less sparce tree layer dominated by cork oaks (*Quercus suber*), holm oaks (*Q. rotundifolia*) or, more rarely, Pyrenean oak (*Q. pyrenaica*), and is often used for sheep or cattle grazing, rotation of crops, or allowed to lie fallow (Pinto-Correia et al. 2011). In the most intensively managed areas, the understory is composed of grasses and forbs but, as time passes, a short shrub layer, usually dominated by *Cistus* spp., tends to develop. Further growth of this layer is in general prevented to keep an herbaceous groundcover for grazing livestock, to enable access to acorns, or to facilitate cork extraction.

This study was carried out on eight private farms located in Montemor-o-Novo, Portugal (Fig. 1). All study areas are in cork and holm oak wood-pasture with an herbaceous understory, and are used for raising cattle, sheep, and pigs. Cork extraction and hunting are also important economic activities in the area. Scattered in the wood-pasture matrix there are small rocky outcrops, often covered with a dense growth of native shrubs and trees.

During winter, between December 2011 and February 2012, we sampled 54 plots of wood-pasture with shrub-free undergrowth. In 32 of these plots within the wood-pasture matrix, there was at least one rocky outcrop with a well-developed native shrub layer, and in the remaining 22 plots there were no patches of shrubby vegetation. In the spring of 2012, during April and May, we sampled a total of 65 plots, which included all the plots sampled in winter, 36 of which had shrubby patches. Since shrubby patches are not very abundant and are concentrated in certain areas, we first identified the plots where they were present, and then selected the plots without patches in their vicinity, to be used as controls. To avoid confounding effects, we always chose points well within wood-pastures and away from other habitats, such as riparian galleries. The minimum distance between each plot and its control was of 137 m (mean = 268 m, SD = 113 m). The patches included in the sampled plots varied in vegetation height, density, and composition, with areas ranging from 128 to 3748 m^2. The most common woody plants present in patches were, by order of decreasing prevalence: holm oaks, mastic, wild olive and strawberry tree. Many of these species produce fruits that are an important part of the diet of several native bird species (Debussche and Isenmann 1992).

Bird counts

Bird communities were sampled, always by the same observer, in all the sampling plots referred above,

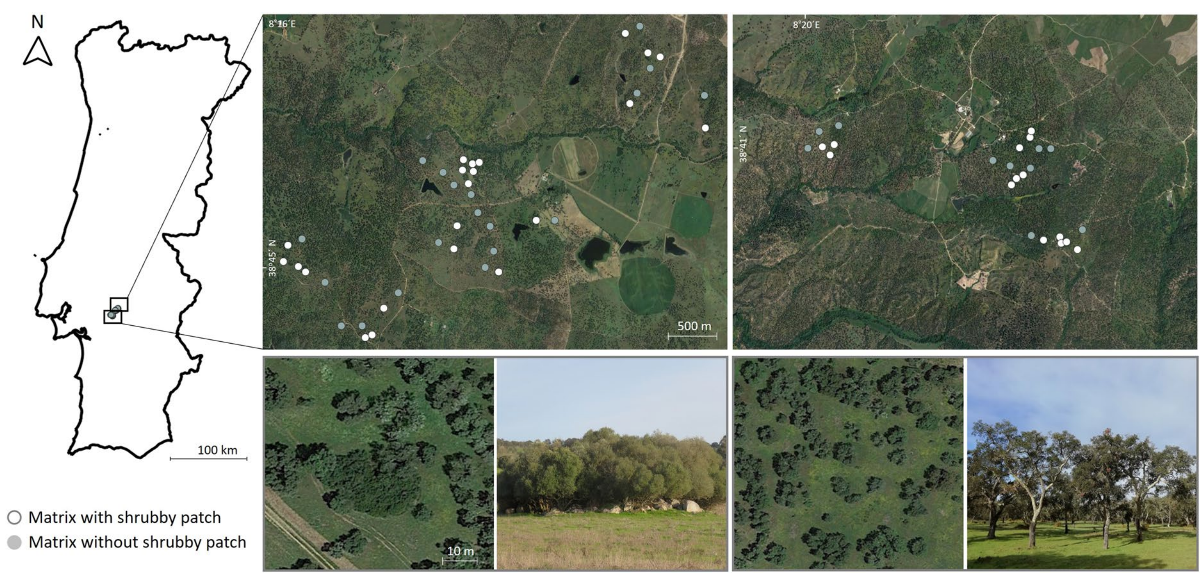


Fig. 1 Study area in Montemor-o-Novo, Portugal. White dots represent the study sites in the oak woodland matrix with shrubby patches. Grey dots represent study sites in the matrix without shrubby patches. Bottom images show examples of sampled sites with (left) and without (right) shrubby patches (Satellite images are from Map data: 2023 Google, CNES/ Airbus,IGP/DGRF,Landsat / Copernicus,Maxar Technologies)

using 5 min point-counts (Bibby et al. 1992). The observer recorded all bird contacts (visual and/or aural) and estimated distance to each bird. Over-flying birds and those detected beyond a 50 m radius from the observer were excluded from the analyses. In the plots with shrubby patches, all birds detected within the patches were registered separately to characterize the species communities using them. In winter, bird counts were carried out within 4 hours after sunrise and 2 hours before sunset, and each plot was visited an average of six times (minimum 4, maximum 12). In spring, bird counts were carried out only in the first 3 hours after sunrise, and each plot was visited four times. For each season, the bird assemblage of each plot was characterized using the average number of birds of each species detected in all the visits.

Characterization of sampling plots

To determine which habitat characteristics influenced its use by birds, we measured the following habitat variables in each plot: mean ground vegetation height (hereafter 'Ground vegetation height'), soil turned over by domestic pigs or wild boar (hereafter 'Disturbed soil'), percentage of arboreal cover (hereafter 'Tree cover'), and percentage of trees that are cork oaks (hereafter '% *Q. suber*'). The area of each shrub patch (hereafter 'Shrubby patch size') was also measured. The first two variables were estimated both in winter and spring.

Ground vegetation height (cm) was measured with a vertical ruler at 15 random points in each of the 50 m radius sampling plots. Soil turned over by domestic pigs or wild boar was estimated visually using a scale from 0 to 2, where 0 corresponded to undisturbed soil, 1 corresponded to less than ¼ of the soil disturbed, and 2 corresponded to more than ¼ of soil disturbed. Percentage of cork oak trees was measured by direct observation and identification of all the trees present in each plot, excluding areas occupied by shrubby patches. Finally, tree cover was estimated, excluding shrubby patches, using satellite images available in Bing Maps from Microsoft Corporation (www.bing.com/maps).

Trait data on bird species

To investigate whether patches of well-developed shrubby vegetation promote the presence of bird species with specific traits, we collected data on six response traits for a total of 21 sampled bird species. This included 18 species observed during the spring season and 15 species observed during the winter season. The traits included in the analysis were: body mass, wing aspect ratio, diet, foraging strata, habitat and species specialization index (Table 1). Data on species traits were extracted from various databases that are listed in Table 1.

Data analysis

Using data from bird point counts in wood-pastures with and without shrubby patches, we estimated species richness and average number of individuals

Table 1 Description of bird traits used in the functional analysis

Trait	Description	Database
Body mass	Genus average body mass (g)	Elton Traits 1.0 database (Wilman et al. 2014)
Wing aspect ratio	Ratio between squared wingspan and wing area	Data compiled in Oksuz (2021) and data from Alvarez et al (2001)
Diet	Percentage use of: Invertebrates, Fruit, Seeds, Other plant material	Elton Traits 1.0 database (Wilman et al. 2014)
Foraging strata	Percentage use of: Ground, Understory (> 2 m), Mid high (> 2 m but bellow canopy), Canopy	Elton Traits 1.0 database (Wilman et al. 2014)
Habitat	Type of habitat mainly used by each species: Forest, Woodland, Shrubland, Grassland	Storchová & Hořák (2018)
Habitat specialization index	Degree of specialization in habitat for each bird species	Morelli (2018), Morelli et al (2019)

detected per visit in each of the sampling plots. To estimate richness, we used all bird species detected in the plots, but for all the remaining analyses, described below, we only used species detected in more than ten sampling sites. Data collected in winter and spring were processed separately, because the species composition and abundance in the two seasons were different. Statistical analyses were performed in R (R Development Core Team 2021), using specific packages when necessary.

Canonical correspondence analysis (CCA) was used to analyse the influence of the characteristics of sampling sites (environmental variables described above and the size of the shrubby patches) on the abundance of different bird species. The statistical significance of the role of each environmental variable in the CCA was evaluated with a permutation test ('vfit' algorithm with 999 permutations). We used ANOSIM similarity analysis (Clarke 1993) to determine the degree of differentiation between the two types of habitats (wood-pasture with and without shrubby patches) and its statistical significance. The resulting R parameter varied between 1 (most similar) and – 1 (least similar). All these analyses were run in the R package 'vegan' (Oksanen et al. 2013).

To test the association of each bird species to the species assemblages of plots with or without shrubby patches we used paired *t*-tests, following a methodology similar to that described in Kalko and Handley (2001).

To understand the impact of the presence of shrubby patches on the functional composition of wood-pasture communities, we compared the functional composition of the avifauna detected inside the shrubby patches with that of the matrix. In this functional analysis we used the community weighted mean index (CWM) for each trait (Table 1), in winter and spring. For continuous traits, the CWM index is the average trait value in the community, weighted by the abundance of each species in that community. For categorical and binary traits, they correspond to the proportion of each category in the assemblage (Lavorel et al. 2008). For each trait, differences between CWM values in the matrix and within the shrubby patches were compared using the Mann–Whitney U-test. Analyses were performed using R package FD (Laliberté et al. 2014) and Past 4 (Hammer et al. 2001).

Results

Bird communities in wood-pasture with and without shrubby patches

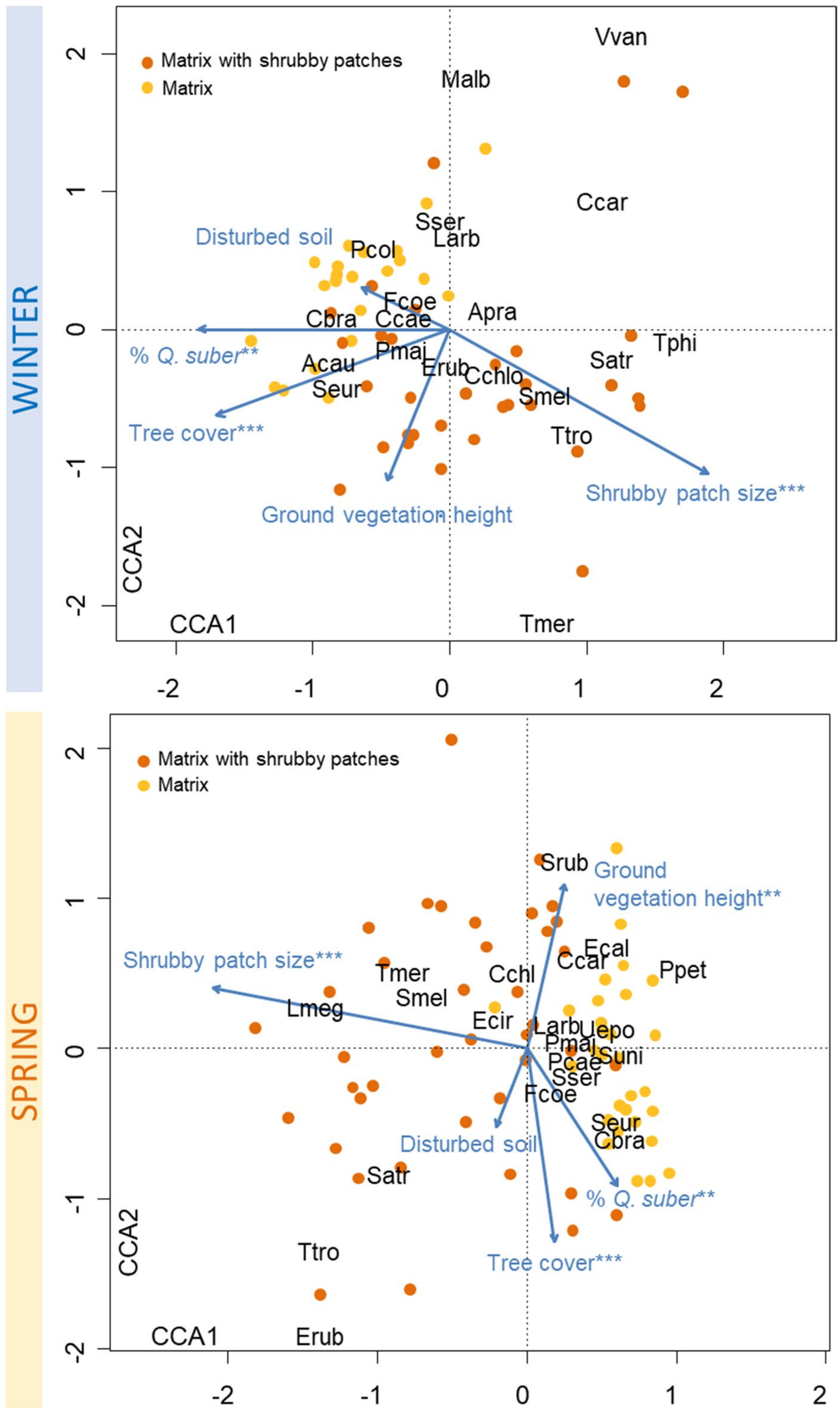
In the 2011/12 winter, 46 bird species were recorded in wood-pasture plots with shrubby patches, and 45 species in plots without patches (mean of 11.7 and 10.3 species per count, respectively). In the 2012 spring, we recorded a total of 56 bird species in wood-pasture plots with shrubby patches, and 50 species in plots without patches (mean of 12.1 and 10.2 species per count, respectively).

The results from the CCA (Fig. 2) show a clear differentiation between bird communities in wood-pasture plots with and without shrub patches. The presence of shrub patches explained the distribution of plots along the first CCA axis, particularly in the spring. It is also evident that some species were clearly associated with plots with shrub patches, such as blackbird (*Turdus merula*) and Sardinian warbler (*Sylvia melanocephala*) both in spring and winter; and robin (*Erithacus rubecula*) and wren (*Troglodytes troglodytes*) in winter. In both winter and spring seasons, the variables 'Shrubby patch size', '% *Q. suber*' trees, and 'Tree cover' exhibited significant influences on the structure of the bird communities. 'Ground vegetation height' only displayed a significant influence during the spring season.

The results of ANOSIM similarity analysis showed that the species composition of the bird communities in wood-pastures with and without shrubby patches are significantly different, both in spring ($R = 0.33$, $p < 0.001$) and winter ($R = 0.23$, $p < 0.001$).

We also analysed which percentage of the total observations of each species was registered in plots with and without patches. The results clearly show that some species are statistically associated to the presence of shrubby patches, as all, or virtually all, observations were in plots with patches (Fig. 3). That is, for example, the case of the wren, robin, and nightingale (*Luscinia megarhynchos*) in spring; wren and song thrush (*Turdus philomelos*) in winter. The wood-pasture matrix proved to be important for treecreepers (*Certhia brachydactyla*) in both seasons. In spring, chaffinches (*Fringilla coelebs*) and serins (*Serinus

Fig. 2 Canonical correspondence analysis (CCA) diagrams showing sampling sites (orange dots are wood-pasture with shrubby vegetation patches and yellow dots are wood-pasture without shrubby patches); bird species (see Table 1 in Supplementary Information for nicknames) and environmental variables are shown in black and blue, respectively. Variables with a statistically significant influence are marked with asterisks (**$p < 0.01$, ***$p < 0.001$)



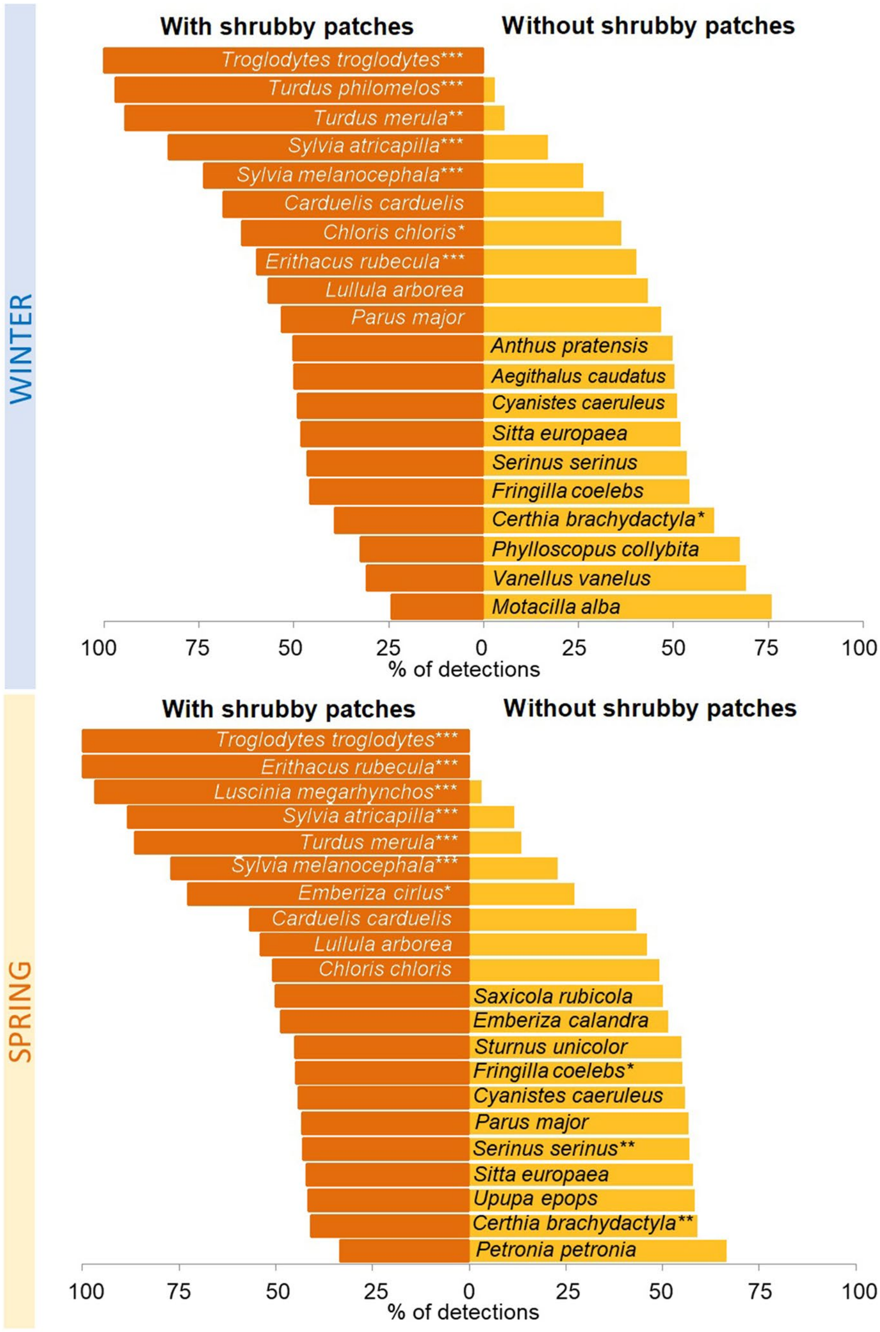


Fig. 3 Percentage of species detected in wood-pastures with (orange) and without shrubby patches (yellow), both in spring and winter. The results of paired t-tests significance are represented by $*p<0.05$; $**p<0.01$; $***p<0.001$

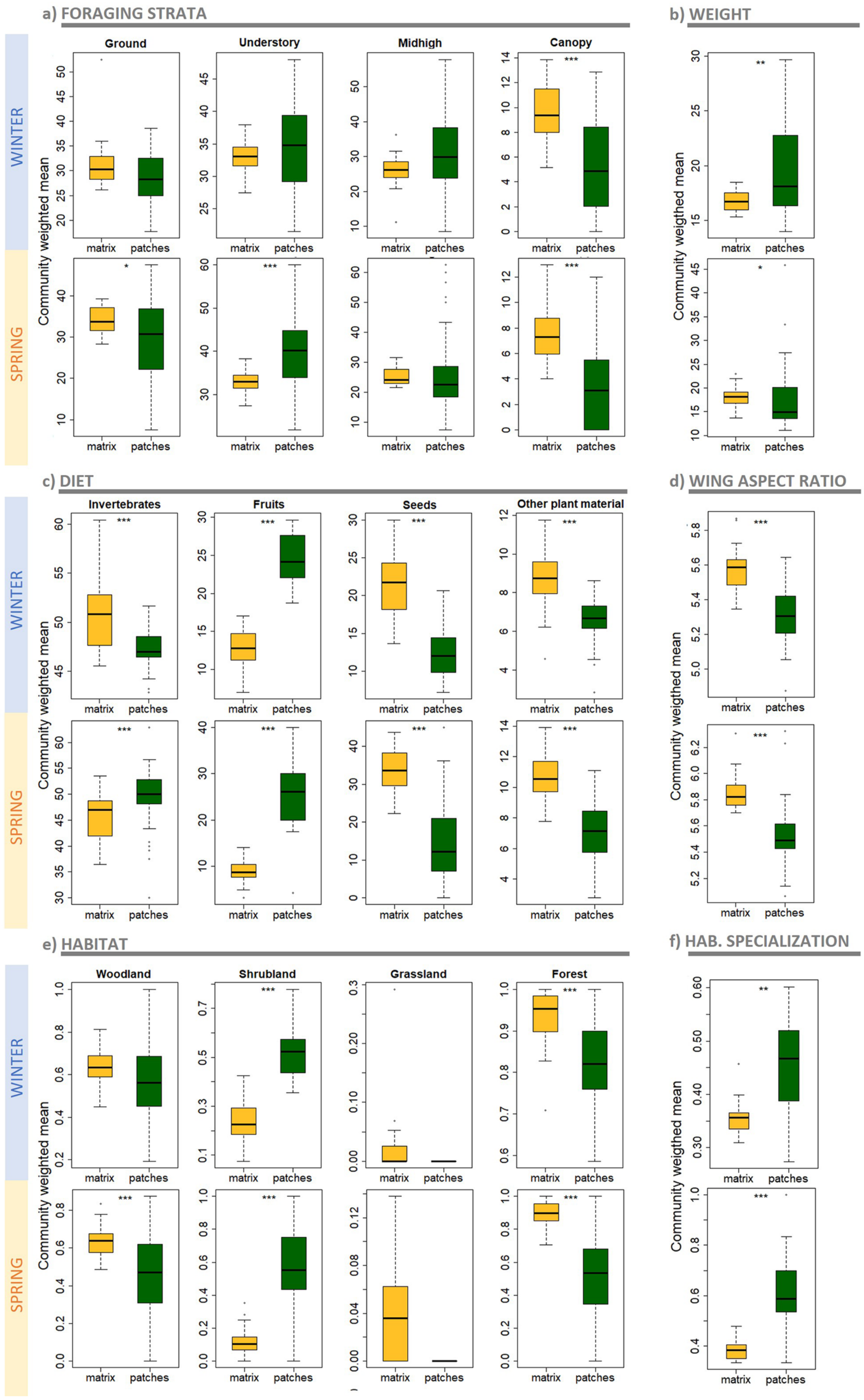


Fig. 4 Community weighted mean values (CWM) for foraging strata (**a**), weight (**b**), diet (**c**), wing aspect ratio (**d**), habitat (**e**) and species habitat specialization index (**f**), in wood-pasture matrix (yellow) and in shrubby patches (green), both in spring and winter. The significance of the paired Mann–Whitney U-test results are represented by $*p<0.05$, $**p<0.01$, $***p<0.001$

serinus) were also significantly more often seen in the matrix.

Differences in functional diversity between the wood-pasture matrix and shrubby patches

In functional analyses we compared CWM values for six species traits in the wood-pasture matrix, without shrubs, to that within shrubby patches, in spring and winter (Fig. 4). For 'foraging strata', the CWM values were higher in the wood-pasture matrix for bird species that mostly feed on the ground (spring: Mann–Whitney U-test = 429.5, $p=0.045$) and on tree canopies (spring: U-test = 217.5, $p<0.001$; winter: U-test = 134, $p<0.001$). In contrast, the CWMs for species that prefer to feed in understory vegetation were higher within shrubby patches (spring: U-test = 248.5, $p<0.001$)(Fig. 4a).

In spring, birds that mostly use the matrix were heavier than those of shrubby patches (CWM values for 'weight': U = 407, $p=0.02$); but this pattern was reversed in winter (U = 233, $p=0.008$) (Fig. 4b).

With respect to 'diet', CWM values for frugivores were higher in shrubby patches in both seasons (spring: U-test = 29, $p<0.001$, winter: U-test = 0, $p<0.001$), whereas the CWMs for a diet of seeds (spring: U-test = 91, $p<0.001$, winter: U-test = 33, $p<0.001$) and other plant material (spring: U-test = 104.5, $p<0.001$, winter: U-test = 107.5, $p<0.001$) were higher in the matrix. Regarding invertebrate diet, CWM values were higher in shrubby patches in spring (U-test = 283, $p<0.001$), but increases in the matrix during the winter (U-test = 148, $p<0.001$) (Fig. 4c).

The CWM of the 'wing aspect ratio' trait, which gives a ratio between birds wingspan and area, was significantly lower in shrubby patches in both seasons (spring: U-test = 81, $p<0.001$, winter: U-test = 103, $p<0.001$) (Fig. 4d).

Regarding the 'habitat' trait, the CWM values were higher in the matrix for woodland (spring: U-test = 293.5, $p<0.001$) and forest guilds (spring: U-test = 100, $p<0.001$, winter: U-test = 138, $p<0.001$) both in spring and winter. In contrast, the CWM value for shrubland birds was much higher in shrubby patches (spring: U-test = 37.5, $p<0.001$, winter: U-test = 17, $p<0.001$) than in the matrix. Data for grassland birds was only available for matrix (Fig. 4e).

Lastly, the CWM values for the species 'habitat specialization index' were higher in shrubby patches in both seasons (spring: U-test = 183, $p<0.001$, winter: U-test = 213, $p<0.002$) (Fig. 4f).

Discussion

Mediterranean wood-pastures are biodiverse rich areas where anthropogenic management activities and natural elements are combined to create a high nature value farmland system. In this study we analysed the effects of patches of native shrubby vegetation on bird communities, particularly on species composition and functional diversity, and we found a positive effect of these elements on both biodiversity components.

Shrubby patches increase the richness of species communities in wood-pastures

We expected that the presence of shrubby patches in a wood-pasture would have a substantial effect on the composition of bird species community, because the structure and floristic composition of the patches are very distinct from the matrix. The results confirmed our hypothesis showing that bird communities were significantly distinct in plots with shrubby patches compared to those without (CCA + ANOSIM). The CCA ordination showed that the difference was mainly explained by the presence of species associated with shrubs, such as wrens, blackcaps and Sardinian warblers (Camprodon and Brotons 2006). Species that use trees, such as the chiffchaff (*Phylloscopus collybita*), tits and treecreepers had a neutral location on the ordination plot because all the plots, with and without patches, had about the same density of trees (23% (± 12 SD) of tree cover in plots with patches; 24% (± 13 SD) in plots without shrubby patches).

The analyses of species abundances corroborated the results of CCA ordination, since bird species associated with shrubs were found in greater numbers in plots with shrubby patches, while forest birds occurred in both types of plots. In fact, shrubs add niches and trophic resources that are not available in the matrix, namely nesting sites, fruits, insects in spring and berries in winter (da Silva et al. 2011; Taboada et al. 2006). Moreover, the insects present in these patches are different from those that occur in the matrix (Oksuz et al. 2020b).

We also found that, the larger the patch, the more it contributes to differentiating the two types of plots. In fact, the size of the patch was the most influential variable in our ordination analysis. The percentage of *Q. suber* trees was significant in both spring and winter and was positively associated with the presence of the treecreeper and nuthatch (*Sitta europaea*), two species that forage mostly on the surface of trunks (Leal et al. 2013). The bark of cork oak is particularly suitable for foraging because it is deeply fissured and harbours numerous arthropods (Leal et al. 2011a, b). Ground vegetation height had a significant effect during the spring season. In fact, it has been demonstrated in Mediterranean wood-pastures that this parameter, which is greatly influenced by grazing, is an important determinant of the use of ground layer by birds (Leal et al. 2019). The other analysed variables did not seem to contribute substantially to the differences observed between plots with and without shrubby patches.

These islands of native vegetation associated with small rocky outcrops seem to play a role similar to that of riparian galleries, promoting the heterogeneity of wood-pasture landscapes (Leal et al. 2011a, b; Leal et al. 2016) and thus may be considered small natural features (Hunter 2017). However, riparian galleries tend to be larger and, in addition to favouring species associated with shrub (as wren, nightingale and Sardinian warbler), also promote the occurrence of species like Cetti´s warbler (*Cettia cetti*) and Iberian chiffchaff (*Phylloscopus ibericus*) (e.g. Leal et al. 2011a, b; Leal et al. 2016; Pereira et al. 2014).

How shrubby patches enrich wood-pastures bird communities: a functional interpretation

As mentioned above, the addition of shrubby patches to the wood-pasture matrix resulted in a substantial difference in the composition of the avifauna. To better understand the specific factors that caused this difference, we carried out a species functional trait analysis, comparing the species community in the shrubby patches with those in the wood-pasture matrix. The analysis revealed marked differences between the two habitats at the level of several traits, and indicated which traits benefitted most from the addition of patches to the landscape. This analysis also showed how the addition of patches functionally enriched bird communities in wood-pasture landscapes. Overall, the results of this analysis were in line with our expectations.

Starting with foraging strata traits, the comparison of spring CWM values showed that species tending to forage in shrubs were much more abundant in patches than in the wood-pasture matrix. This is unsurprising since shrubs are virtually absent in the matrix. While the presence of shrubs favoured some species, it negatively affected those that prefer to forage on the ground, because the shrubs block access to the ground and shrub cover greatly decreases the abundance of grasses that produce the seeds on which many ground- foraging birds feed. This explains why ground foraging birds, such as the serin and chaffinch (Perea et al. 2014) were more abundant in the matrix than in the patches. Birds that feed in the canopy, like the chiffchaff (Almeida and Granadeiro 2000), were clearly less important in the assemblages of patches. Although tree and canopy foragers also use patches, their relative importance declines because of the greater abundance of shrub foragers.

The foraging strata traits differences observed in the winter communities were in the same direction as those observed in spring, but they were only statistically significant in the case of canopy feeders. This was an expected result, considering that patches were dominated by dense, medium height, shrubby vegetation with several fruit producing species. These are important because fruits are a key resource for multiple bird species, and they are virtually absent from the matrix.

The differences observed in the diet traits of the communities of the two habitats were closely related to those for foraging strata. Patches were much richer in frugivore species, both in winter and spring, which is easily explained by the substantial number of shrub species that produce fruits, that are virtually absent in the matrix. In spring, invertebrate consumers were more important in patch assemblages than in the matrix. This could be due to the greater diversity of insects in the patches (Oksuz et al. 2020b), associated with a lower assemblage of granivores, where seeds were less available than in the grass-dominated matrix. Interestingly, in winter the situation was reversed, as invertebrate consumers become more important in the matrix than in patches. This may be due to the arrival in the wood-pastures of large numbers of insectivorous migratory species, such as robins, and to the partial abandonment of this habitat by granivorous species that aggregate in large flocks during winter to feed in treeless habitats.

The results of the analysis of the representation of bird species in patches vs matrix, according to their habitat preference trait, followed expectations. Woodland, forest and grassland species were more prevalent in the matrix, where managers tend to remove the shrub layer and only the tree and herb layers remain. Shrubland bird species are more predominant in the patches which is a direct consequence of the well-developed shrub layer. This human alteration and simplification of the matrix structure, through removal of the shrubby layer also probably explains why the species of patches have, on average, a higher habitat specialization index than those of the matrix. Habitat specialist species live in a smaller range of habitats than generalist species (Morelli et al. 2019). In fact, environments impoverished through humanization tend to be occupied mostly by generalist species (Møller 2009).

In winter, patches attract species larger than the matrix, and this may be explained by the attraction to patches of relatively large birds, such as blackbird and song thrush, which during this season are mostly frugivorous (Morgado et al. 2021). In the spring, this attraction is less marked because, in general, the availability of fruits in this season is low (Carnicer et al. 2009; Debussche and Isenmann 1992).

The patches also enrich the wood-pastures with species that have a smaller wing aspect ratio, that is, species with shorter and more rounded wings, which allow them to move more easily in habitats with a high vegetation clutter. The species that contribute the most to this enrichment are the robin, the song thrush and the wren.

Conclusions and management recommendations

In the oak wood-pastures landscapes studied here, the wood-pasture areas with shrubby patches had a higher taxonomic diversity, and this effect increased with the area of the patch. We concluded that these changes in taxonomic diversity occurred because small shrubby patches create better habitat conditions for guilds that would otherwise be less abundant, or even absent, in these somewhat open landscapes. Shrubby patches also contributed to the functional diversification of the bird species communities of wood-pasture landscapes, attracting species with distinct and potentially important ecological functions, such as seed dispersal. The general conclusions of this study done in Iberian oak woodlands (*montados* or *dehesas*) are likely to apply to a great variety of wood-pasture habitats, as in most of them the shrub layer is repressed, eliminating similar ecological niches for wildlife. However, it would be desirable to carry out similar studies at other locations and wood-pasture types, and preferably during longer periods, to make more robust generalizations.

Our results indicated that protection of these patches could partially compensate for the absence of a well-developed shrub layer in intensively managed oak wood-pastures. This can increase bird diversity without affecting the presence of granivorous and ground foraging species, also common in these landscapes. This effect was evident even though shrubby patches were much smaller than the home range of the birds that are associated to them, most of which do much of their foraging well outside of the patches. It seems evident that these small patches have an effect disproportionate to their size, providing resources, nesting niches and protection, that are comparatively scarce in the matrix. The impact here demonstrated for birds is likely to be present also for other groups of vertebrates including mammals, as observed for riparian galleries (Rosalino et al. 2009).

The importance of small habitat patches has often been neglected in conservation studies, but recent research has demonstrated their great value for biodiversity (Wintle et al. 2019). Riva and Fahrig (2022) showed that groupings of small patches tended to harbour more species than large patches.

We do not suggest that small patches of natural shrubby vegetation can functionally replace large areas of woodland with an intact shrub layer; they are too small to hold viable populations of most types of organisms. However, our study highlights that, despite this limitation, their protection promotes the biodiversity of high nature-value wood-pastures. The cost of their maintenance is minimal and the negative impact on economic productivity is very small, not only because they cover a very small area (less than 0.5% in our study area), but also because the patches are usually established in sites that are not amenable to active exploitation. Small shrubby patches have virtually no impact on grazing potential and, due to their isolation, do not facilitate the propagation of fires. Land managers should protect and promote the expansion of these vegetation patches by allowing their development, in areas where rocky ground makes grazing difficult, or even by creating small, fenced enclosures to allow shrub regeneration and growth, especially of fruit producing species that can be an important and limiting resource in dry Mediterranean wood-pastures (Herrera 1982).

It has been increasingly recognised that there is a great potential for promoting and preserving biodiversity alongside economic exploitation of ecosystems, as long as this exploitation follows sustainability principles. Many wood-pastures afford good examples of this beneficial conciliation, but much still needs to be done to improve their biodiversity value. This study shows that protecting and promoting small shrubby patches is a simple management measure for wood-pasture landscapes that can substantially increase bird richness of the system at both the taxonomic and functional level.

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Declarations

Competing interests The authors declare no competing interests.

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