The influence of forest management on bird communities of Portuguese *montados*

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Doutor Pedro Segurado

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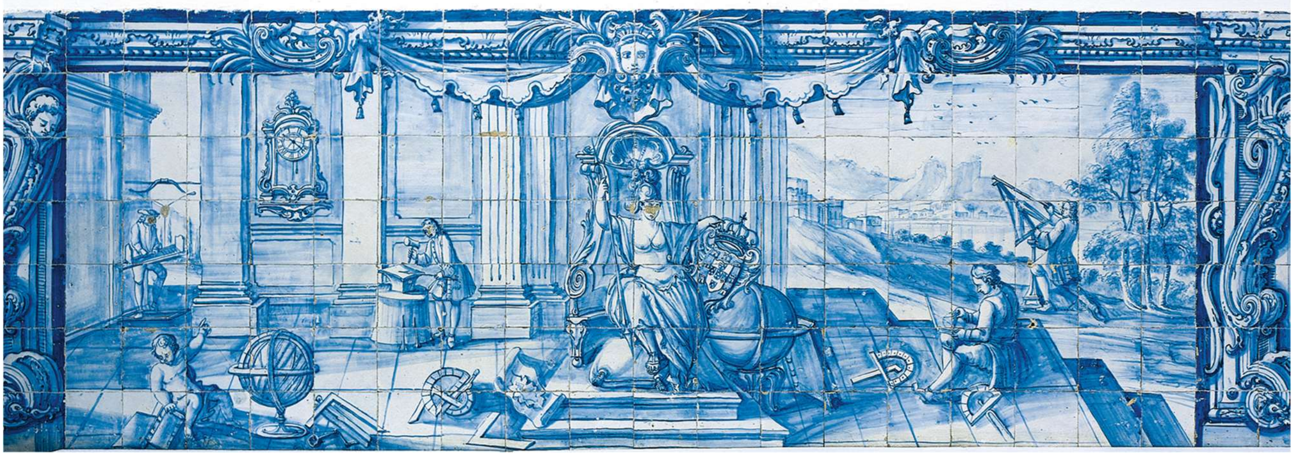

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À Susana, à Marta e à Sofia

Aos meus pais e ao meu irmão

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The influence of forest management on bird communities of Portuguese montados

Abstract

The world distribution of cork oak *Quercus suber* and holm oak *Q. rotundifolia* is basically restricted to the western Mediterranean basin. These two evergreen oaks are the base of the Portuguese *montado* and the Spanish *dehesa.*

This thesis aims to analyse how bird communities of the *montado* are influenced by management practices. We used different approaches to study this relationship, and to evaluate which features are responsible for species distribution in different typologies of *montado*. First, we reviewed the concept of *montado* in order to better understand the system and to set thresholds on what can be considered as *montado*. Afterwards, we studied the elements that promote higher species diversity and individual species, or group of species, that can act as indicators of High Nature Value for *montados*. Finally, we evaluated how the bird communities are structured, and the influence of the main management actions (*e.g.* cattle and cork exploitation) on those communities.

Keywords: cork, forest species, silvopastoral, singular elements, biodiversity

A influência da gestão florestal nas comunidades de aves do montado

Resumo

A distribuição mundial do sobreiro *Quercus suber* e da azinheira *Quercus rotundifolia* é praticamente restrita à bacia do Mediterrâneo. Estas duas espécies de carvalhos são a base dos montados em Portugal e das *dehesas* em Espanha.

No âmbito desta tese analisamos como as comunidades de aves do montado são influenciadas pela gestão florestal. Para este efeito usámos diferentes abordagens e avaliámos quais as características do montado responsáveis pela distribuição das espécies ao longo das suas diferentes tipologias.

Fizemos uma revisão do conceito de montado e proposemos uma definição para o sistema, englobando a sua multifuncionalidade. Estudámos os elementos singulares que promovem a diversidade de aves e que podem ser simultaneamente indicadores de áreas de Alto Valor Natural (HNV). Por fim, avaliámos qual a influência da gestão (p. ex. pastoreio e descortiçamento) na estruturação das comunidades de aves.

Palavras-chave: cortiça, aves florestais, silvopastoral, elementos singulares, biodiversidade

Chapter

1

General introduction

1.1. Thesis focus and main goals

The world distribution of cork oak *Quercus suber* and holm oak *Q. rotundifolia* is basically restricted to the western Mediterranean basin (Costa et al. 1998) (Fig. 1.1). These two evergreen oaks are the base of the Portuguese *montado* and the Spanish *dehesa.* Together, in Portugal, they occupy more than one million hectares representing 34% of the national forest area (ICNF 2010). By itself, this highlights the relevance of the montado in economic, social and environmental terms.

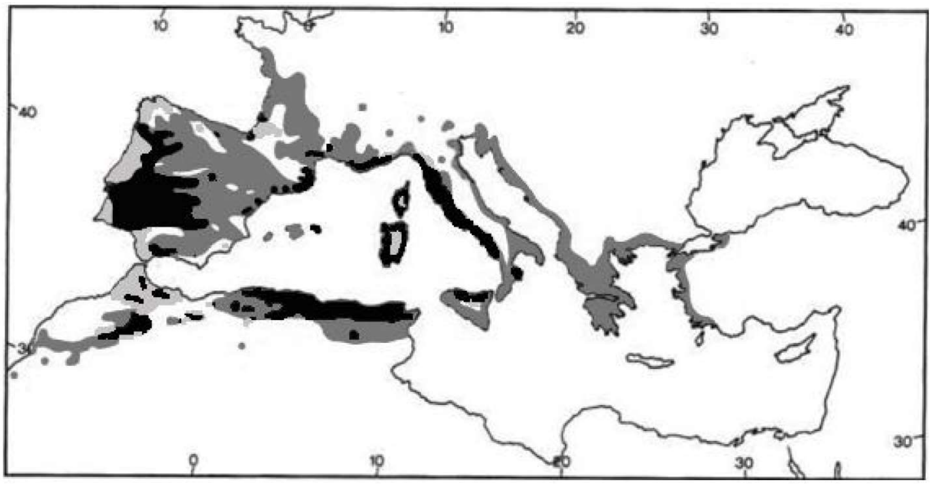

Figure 1.1 – Distribution of cork oak (light grey) and holm oak (dark grey) and species coexistence (black) (adapted from Costa et al. 1998).

Cork and holm oak *montados* are acknowledged as hotspots of biodiversity, which results from the heterogeneous landscape of wooded matrix with open areas, scattered woodlands and semi-natural patches of Mediterranean forest and scrublands (Blondel & Aronson 1999, Díaz et al. 2003, Harrop 2007, Rabaça 1990, Tellería 2001, Telleria et al. 2003). This is mainly the result of the landscape fuzziness, allowing the presence of farmland, edge and forest bird species (Catarino et al. 2016, Godinho & Rabaça 2011, Díaz et al. 1997, Pereira et al. 2015, Pulido & Díaz 1992, Tellería 2001). Despite their importance for several biological groups (*e.g.* vascular plants, mushrooms, insects, mammals, etc.) the abundance and diversity of birds they support is particularly remarkable (Díaz et al. 1997, Pereira et al. 2015).

According to Pereira et al. (2015), the *montado* holds more than one third of the 300 bird species that regularly occur in Portugal. From these, 92 species use the *montado* during the breeding season, and 18 occur exclusively in winter. Additionally, we also must consider the trans-saharian migrants that use the *montado* as stopover during migration. The most emblematic species in the breeding season are the black stork *Ciconia nigra*, imperial eagle *Aquila adalberti*, and black vulture *Aegypius monachus*, all classified as endangered species; while during the winter, species like the common crane *Grus grus*, wood pigeon *Columba palumbus*, and song thrushes *Turdus philomelos* may be found in *montados* (Carrete & Donazar 2005, Díaz et al. 1996, Díaz et al. 1997).

The conservationist relevance of the *montado* for birds is not restricted to endangered species. Very often, the most common bird species (i.e. species widely distributed and often represented with high numbers) are not considered as a parameter to rank habitat quality, but if the trends of common breeding birds at a national and European level (PECBMS 2015) were take in consideration, that should change. For the period between 1980-2014, in south European countries (Portugal, Spain, France and Italy), the common farmland and forest bird species decreased 19% (48 species evaluated) and 16% (32 species evaluated), respectively. Since common species are by definition less susceptible then rare species to environmental stochasticity, the observed negative trends in common breeding birds should be considered a worrisome sign. Therefore, the inclusion of other conservation criteria, such as those proposed by Tavares (2009), based on species of which Portugal hosts significant populations at European level, should be considered. The criteria used by this author to considered species for which the breeding population was higher than the expected, was based on the country's land area. The evaluation showed that 36% of the breeding species in Portugal have a population twice the expected, and 14% of the species have ten times more the number of individuals than the expected. For those species, Portugal has an additional responsibility for their conservation, and several of them can be found in the *montado* (*e.g.* Iberian chiffchaff *Phylloscopus ibericus*, serin *Serinus serinus*, Iberian magpie *Cyanopica cooki*, melodious warbler *Hippolais polyglotta*, booted eagle *Hieraaetus pennatus*, woodlark *Lullula arborea*). Additionally, the *montado* also holds high abundances of species with scattered distribution in the Iberian Peninsula (*e.g.* lesser spotted woodpecker *Dendrocopos minor*, common redstart *Phoenicurus phoenicurus*, Bonelli's warbler *Phylloscopus bonelli*, woodchat shrike *Lanius senator*, hawfinch *Coccothraustes coccothraustes*).

The maintenance of the high bird diversity is dependent on the management and vitality of the *montados*. In this sense, all the threats to the *montado* lead to bird community destabilization and may have impact on their conservation. For this reason, in the last years, research focused on birds associated to the *montado* has increased (*e.g.* Ceia 2016, Correia 2014, Godinho & Rabaça 2011, Leal 2011, Pereira et al. 2014).

This thesis aims to analyse how bird communities of the *montado* are influenced by management practices. We used different approaches to study this relationship, and to evaluate which features are responsible for species distribution in different typologies of *montado*. First, we reviewed the concept of *montado* in order to better understand the system and to set thresholds on what can be considered as *montado*. Afterwards, we studied the elements that promote higher species diversity and individual species, or group of species, that can act as indicators of High Nature Value for *montados*. Finally, we evaluated how the bird communities are structured, and the influence of the main management actions (*e.g.* cattle and cork exploitation) on those communities.

1.2. Outline of the thesis

This thesis contains six data chapters (Chapters 2 to 7), each aiming to answer one of the above main questions. Chapters 2 and 3 are revised and update versions of two chapters published in the book *"O montado e as aves: boas práticas para uma gestão sustentável"* (Pereira et al. 2015). The following Chapters (Chapters 4 to 7) are written in manuscript format in order to be submitted to peer-reviewed journals. Three of them are already published, and Chapter 6 will be submitted in due course. Chapters 4 and 5 results from two thesis that I supervised, a degree in Biology and a master's degree in Conservation Biology. In both cases I worked closely with the first author in all the stages of the research: designing the work, conducting field work, data analyses, and paper writing.

Concerning the overall structure, Chapter 1 provides a general introduction and the scientific context of the thesis. Chapter 2 provides the historical background of the *montado* and the main components of their multifunctionality; Additionally, it reviews and proposes a definition for the system. Chapter 3 identifies the singular elements that locally provide different ecological requirements for birds in areas of *montado*. Chapter 4 evaluates the use of riparian galleries as surrogate habitats for forest bird communities along a gradient of tree density in *montado*. Chapter 5 assesses which features of *montado* contribute to higher species diversity and richness, identifying the potential of birds as indicators of High Nature Value areas. Chapter 6 compares the bird community composition between native and non-native forests, and how management can influence biodiversity. Chapter 7 evaluates the influence of habitat and management of *montados* in breeding bird communities. Finally, Chapter 8 compiles the key-findings of the research and discusses them according to the current knowledge. It also identifies main research needs for the future.

Chapter

2

The *montado*: a review of the concept

Godinho C., Pereira P., Roque I., Segurado P. & Rabaça J.E.

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Improved and reviewed for the English version of the book

2.1. Introduction

The *montado* is a secular system deeply established in the Iberian Peninsula (*montado* in Portugal and *dehesa* in Spain). For centuries, the most valuable product of the *montado* were the acorns, used for flour by local populations, but above all as a food resource for livestock (mainly for pigs). In fact, this use is in the etymological origin of the system name, the word *montado* appeared as the name given to the payment by livestock farmers to landowners where the cattle graze (Pinto-Correia & Fonseca 2009). Although the economic importance of the *montado* was initially based on acorn, this trend has been reversed in the cork oak *Quercus suber montados*, where cork is since several decades the most important source of income.

In a brief historical perspective (for more details see Pinto-Correia & Fonseca 2009), interventions in oaks forests goes back to 6,000 BC (Riera-Mora 2006). Later, following human settlements, many of these forests have been thinned out to allow and enhance better grazing areas (Pinto-Correia & Fonseca 2009). The recognition that clear-cutting such forested areas could impoverish an important resource comes with the seventh century by the Visigoth Code, which defines the rights and restrictions on the use of trees and grazing, and prohibits cutting down cork and holm oaks (Vieira 1991). In Portugal, from the fourteenth century onwards, gradually emerge regulations for vegetation protection, specially focus on trees and shrubs as well as in pastoral areas (Pinto-Correia & Fonseca 2009). Despite a recognition of the importance of the tree in the system, this has not prevented the occurrence of four crucial periods, during the last 150 years, that shaped the system as we know: *Lei dos Cereais de Elvino de Brito* (1889), *Campanha do Trigo* (1929-38), *Reforma Agrária* (1975-79) and European Common Agricultural Policy review (1992). The first three periods were characterized by the intensification of farming and depreciation of the tree layer, leading in some cases to their progressive destruction.

The temporal and spatial combination at regional and sectorial levels of all these actions created a confusing tree cover gradient, with fuzzy boundaries among different typologies of *montado* and mixed with other small/medium land uses (Pereira et al. 2015, Pinto-Correia & Vos 2004). This patchwork landscape greatly shaped by humans enhances the multifunctional use of the forest matrix, which is one of the main features of the *montado*.

Three main components of the system must be highlighted in a review of the concept: tree composition, tree density and production systems. Among these, tree composition and production systems are the most consensual pillars for a definition of *montado*. On the other hand, the density of trees that should be considered in order to classify a given forested area as *montado* (minimum and maximum) is the less consensual component.

2.2. Arboreal composition

There is a general agreement in that cork and holm oak are the dominant tree species in the *montado*, which can form homogeneous stands or occur in codominance with other oaks (Portuguese oak *Quercus faginea*, Pyrenean oak *Q. pyrenaica*, English oak *Q. robur*), conifers such as stone pine *Pinus pinea* and maritime pine *P. pinaster*, or even with the wild olive *Olea europaea* var. sylvestris (*e.g.* Bugalho et al. 2009, Carreiras et al. 2006, Pinto-Correia & Mascarenhas

1999). In Spain, the importance of oaks is evident in the definition of *dehesa* "... acorn producing scattered trees..." (Pulido & Picardo 2010).

2.3. Systems of production / main activities

Potes (2011) suggested that the *montado*, as a multifunctional system oriented to agro-forestry-pastoral production, consists in multiple systems and subsystems, integrated and interdependent, whose form of extensive exploitation allies economic and environmental sustainability. The nine production systems proposed (Potes 2011) can be gathered in four main activities: forestry (cork, wood, charcoal, honey, aromatic and medicinal plants, mushrooms), including the under-cover, grazing (meat, cheese, wool), game and tourism. All these activities can be carried out in areas of cork and holm oak, except of course the cork extraction.

2.3.1. Cork harvesting

Most of the economic input of cork oak *montados* is based on cork harvesting, activity which Portugal is the world leader in production (ca. 50% of world production) (FAO 2010). In 2006 the WWF - World Wide Fund for Nature estimated that only in Portugal ca. 28,000 people were employed in this sector. If we take into account the permanent and temporary jobs, from cork removal to the final products (*e.g.* stoppers, isolation panels, props, etc.) it is easy to recognize the economic and social importance of this activity. Based on this information, it would be expected that the cork harvesting was subject of detailed research, not only in cork quality and transformation processes, but also on the impact on the tree and biodiversity. However, research focused on the growth and cork quality (*e.g.* Costa & Oliveira 2001, Costa & Pereira 2010) and the impact of cork extraction on biodiversity is uneven, particularly in birds, where only three studies exist (Godinho & Rabaça 2011, Leal et al. 2011a, Margalida et al. 2011).

Margalida and co-authors (2011) found that the noise made by fieldworkers, during cork removal, was the main factor of disturbance in the reproductive success of the black vulture *Aegypius monachus*. This result raises important questions, since the balance between management and conservation of species with threatened status is not linear. On the one hand it is advisable to limit activities in the vicinity of nesting sites, although these conditions may not be feasible considering the economic sustainability of cork oak stands which are the species habitat.

Godinho & Rabaça (2011) and Leal et al. (2011a) have studied the influence of cork removal on bird communities. Godinho & Rabaça (2011) evaluated the influence of three groups of variables (forest, habitat and management) in the bird communities of the *montado*. The results highlighted the importance of two decisive factors for bird communities: vegetation density (trees and shrubs) and age of cork removal. An evaluation at species level, shows that for most forest generalist species the recent debark (<2 years) has a negative influence on their abundances (great tit *Parus major*, blue tit *Cyanistes caeruleus*, short-toed treecreper *Certhia brachydactyla*, jay *Garrulus glandarius*, serin *Serinus serinus* and chaffinch *Fringilla coelebs*). The same pattern was detected for the nuthatch *Sitta europaea*, a forest specialist species. The great spotted woodpecker *Dendrocopos major* showed a different pattern, being associated to sites where the cork was removed for more than 3 years.

Leal et al. (2011a) have focused also on this subject, assessing how birds use *montados* with different ages of cork removal. In addition, they also evaluated the availability of potential prey (arthropods) in the same areas. The results show the same trend of the previous study, with blue tit, great tit, nuthatch and the short-toed treecreeper negatively related with areas where the cork was recently removed. The availability of trunk arthropods significantly increases throughout the cycle of cork, which after nine years has identical values to those recorded in trees that have never been debarked.

These studies stress out an influence of debarking in the abundance of forest species, although not affecting the species richness. Birds appear to be adapted to this forest dynamics, exhibiting some resilience shortly after cork removal. As a conservation measure, heterogeneous stands with different ages of cork removal appear to benefit birds, since these areas had similar densities values to stands where the cork was removed six years ago (Leal et al. 2011a).

This result is consistent with the guideline to maintain the viability of trees, i.e. not synchronized debarking in the same plot (Oliveira & Costa 2012).

2.3.2. Livestock

Livestock production, along with cork harvesting, ensures the sustainability of the *montado*, mainly through low intensity grazing in vast areas (Sales-Baptista et al. 2015). Due to the economic preponderance, grazing has a decisive role in the long term sustainability of the *montado* (Almeida et al. 2015), especially when we assist to a general decline, both in area and density (*e.g.* Bugalho et al. 2011). Therefore, it is necessary to assess the impact of this activity on the *montado* and biodiversity, a subject that is not consensual and is possibly one of the largest gaps in knowledge in the system dynamics.

The effect of grazing on the structural diversity of the *montado* (connectivity and heterogeneity) was recently evaluated by Almeida et al. (2015). Their results indicate that cattle promote fragmentation in the system and sheep homogeneity. These changes of structure may have an effect on the potential of the *montado* to host high biodiversity values, and even in the viability of the system, since they reduce the natural regeneration of forest stands (Ribeiro et al. 2010). A common goal among studies on the relation between grazing and biodiversity has been finding an optimum stocking rate that allows cattle production and maintain high biodiversity values (*e.g.* Godinho et al. 2011, Gonçalves et al. 2012).

In the case of birds, several studies addressing the effects of grazing are focused on agricultural crops (*e.g.* Baldi et al. 2005), which is expected, since agricultural intensification is responsible for the strong decline in European bird population, many of them with high threatened status. Studies on *montado* are scarce (Acácio 2012, Godinho & Rabaça 2011) and have additional challenges, since target species ranges from farmland to forest specialist (Pereira et al. 2015). In the study of Godinho & Rabaça (2011) it was possible to detect a trend to lower abundances of forest species (great tit, chaffinch and serin) and forest specialists (nuthatch), in patches with the presence of cattle. Acácio (2012) evaluated the influence of grazing by sheep during the winter, through an intensity gradient, and results shows that the diversity of soil arthropods decreases along the gradient, but not all bird species follows this pattern. These results are important because they highlight one of the advantages of the *montado*: its spatial heterogeneity.

At a time when we are witnessing a decline in the *montado* mainly due to changes in traditional management practices, either through intensification of production systems or abandonment (Pinto-Correia & Godinho 2013, Pinto-Correia & Mascarenhas 1999), it is essential to assess the real impact that grazing can have on biodiversity. The specificities of different areas, as tree density, management history, vitality of trees, natural regeneration, soil type, water availability and productivity, enable different grazing pressures, making almost impossible the finding of a cross-solution to all the *montado* areas.

2.3.3. Game

Game in *montado* is an activity with a long tradition. In many areas can be a source of significant revenues, contributing to the system sustainability (*e.g.* landscape maintenance). Game regulation has evolved over the last 30 years and most of *montado* are currently classified as game reserves.

According to Carvalho (2007) hunting wood pigeon *Columba palumbus* can pay the fixed costs of land management, including their rent. In the *Companhia das Lezírias* S.A. (more details in chapters 5 and 7) Forest Plan Management, game activity (although not restricted to the *montado*), contributes ca.13% to the annual income. Merlo & Croitoru (2005) suggest that the value generated by hunting in the Portuguese Mediterranean forests is around 21 million euros.

If properly regulated and monitored hunting activity appears to be compatible with the biological diversity of the *montado*. Often, the maintenance of game species requires low level of disturbance, a higher structured system (*e.g.* existence of shrubs) and higher tree densities. Some of these features overlap with the most important variables considered in the definition of HNV - High Natural Value areas in *montado*, thus fostering a greater abundance of forest birds (Catarino et al. 2016). The landscapes preferred by hunters are the sparse *montado* and the dense *montado* with and without shrubs (Surová & Pinto-Correia 2008, Surová & Pinto-Correia 2009, Surová et al. 2011). These preferences are associated with security, visibility, tradition, and of course, the target game species.

The impact of hunting on non-game bird species is unknown but it is an important research challenge for balancing game activity and conservation. Research on this subject aims to find answers to questions such as: what is the impact of hunting days on birds? Do non-game birds modify their activity and/or behavioural (*e.g.* aural communication) patterns in hunting days? Do similar *montado* areas with and without game activities hold different bird assemblages (species composition and abundances)? Is there a yield gap among *montado* areas with and without hunting? Is there a greater diversity of birds of prey in *montado* areas where hunting is not allowed?

2.4. Tree density/cover

The density of trees can be influenced, among other things, by the age of the *montado*. Natividade (1950) suggested that different age classes of *montado* hold different tree densities. On the scope of this thesis, tree density refers to *montados* under exploitation or pre-exploitation, i.e. constitute by mature trees. At the European level the land cover classifications take in to account the tree cover, since the density (number of trees per area) does not distinguish between tree ages. Based on Doorn & Correia (2007), *Decreto Lei 169/2001 de 25 de Maio*, and in our own experience, we considered that 20 trees/ha correspond to ca. 10% of tree cover.

The density of trees and the trend in tree cover is distinct between the cork and holm oak *montados*. For the period 1995-2010 the cork oak area in Portugal remained stable, but the holm oak decreased 10% (ICNF 2013). In most cases the density of cork oak forests is higher, mainly due to the commercial value of the cork. Along the centuries the management of holm oak *montados* for acorn production has selected the most productive trees. This selection, and the change in livestock species and stocking density derived from agricultural policies (*e.g.* Diaz et al. 1997, Diaz et al. 2003, Olea & Miguel-Ayanz 2006), led to a decrease in tree cover. Due to these reasons, the majority of holm oak *montados* exhibit reduced tree density.

The density of the *montado* is often represented by three classes (sparse, medium and dense), whose limits may differ among authors (Fig. 2.1) Nevertheless, these classifications reflect a tree cover gradient encompassing areas that can be considered agricultural or forestry. For example, in cartographic series of land cover classification (CORINE), areas with more than 30% cover are considered forests (Bossad et al. 2000), which includes a large proportion of *montado* areas.

Similarly, Rois-Diaz et al. (2006) from the European Forest Institute consider *montado* within the definition of forest. This approach of medium and dense *montado* to the forest is also considered in the National Forest Inventory (DGF 2001, ICNF 2013), which considered that half of the cork oak area has 10-30% tree cover, one fourth 30-50 % and the remaining more than 50% coverage. The areas of holm oak are sparser, with a tree cover of 10-30% in about 85% of its distribution area.

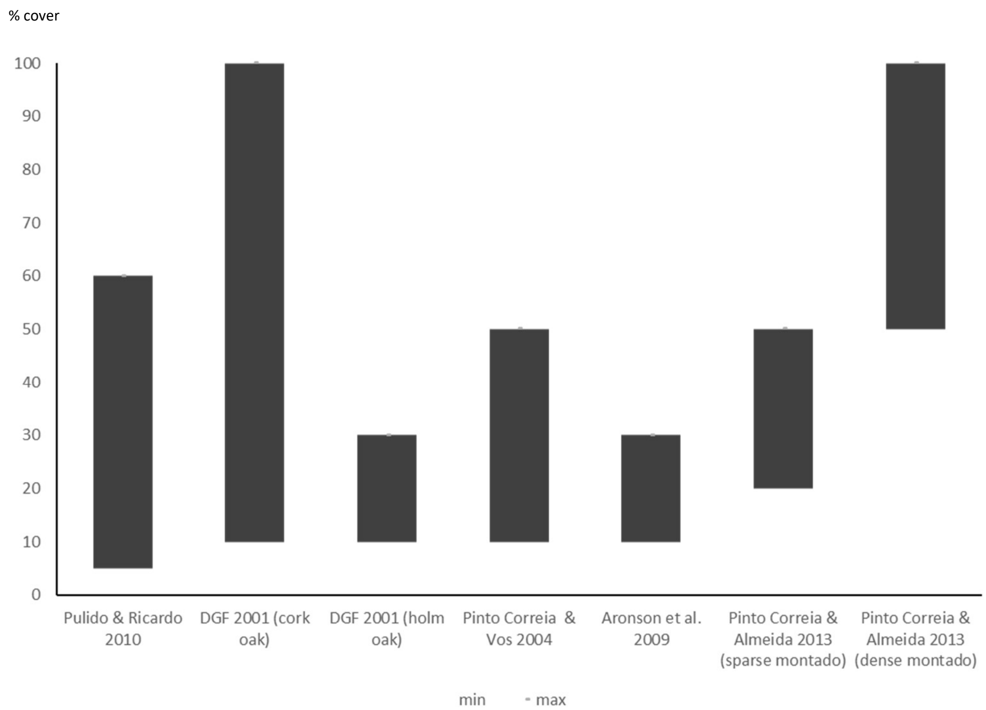

Figure 2.1 – Tree cover in *montado* considered by several authors

2.5. Landscape fuzziness

Due to their nature, *montado* landscapes are distinguished by fuzzy boundaries with overlapping land cover classes (diverse combinations of forest cover, grass and shrubs) (Pinto-Correia & Vos 2004). This overlap creates a somehow confusing landscape (Van Doorn & Pinto-Correia 2007). This contrasts with landscapes of intensive and specialized land use that tend to be characterized by regular patches and well defined boundaries between patches, or between two areas of different land cover, for example pasture and forest, or pasture and cultivated fields (Pinto-Correia et al. 2011). The matrix-patch-corridor framework of landscape ecology (*e.g.* Forman & Godron 1986), is based on this context, but cannot easily be applied to all types of landscapes (Pinto-Correia et al. 2011) namely to Mediterranean agro-silvo-pastoral landscapes, such as *montado*. The *montado* contain continuous gradients in terms of land cover, often characterized by gradual changes in shrub and tree densities, resulting from the combination of different levels of land use and of variable, extensive land use practices. Consequently, these landscapes are usually marked by an overlapping of land cover classes, which results in fuzzy boundaries (Pinto-Correia et al. 2011). These authors suggested that two levels of fuzziness may be considered: (1) overlapping land cover classes, since they are combinations of tree cover and understory, and (2) indistinctive boundaries in-between land cover classes, i.e. the boundaries between two different land cover classes are not discrete edges but rather indeterminate boundaries, representing a gradual transition from one category to another. The fuzziness of the boundaries is inherent to the land use system and should be accepted as such. Small differences in terms of tree density and shrub cover reflect important differences in abiotic factors (Joffre et al. 1999), types of the management in the past and present (Pinto-Correia 1993) and levels of biodiversity (Ojeda et al. 1995).

2.6. *Montado* typologies and bird species

Habitat structure is a key factor for determining the species composition and abundances in temperate terrestrial bird assemblages, namely during the breeding season. In fact, evidence has been gathered since the last decades of the twentieth century that the distribution and occurrence of songbirds is more influenced by structural features of the habitat (i.e. the number of vertical layers of vegetation, the level of vegetation coverage in each layer, the existence of small patches of different habitats within a matrix) than its plant species composition. In order to understand the distribution of the bird's communities associated to the *montado,* in the south of Portugal, Pereira et al. (2015) suggested five typologies for the *montado*, following a gradient of structural complexity of vegetation and frequency of human interventions. Five years was the criteria to distinguish between occasional and frequent management, based on the fact that shrub species tend to increase their densities, in that time, without undercover management. The typologies are:

- Oak woodlands and dense *montado* with occasional management
- Dense *montado* with frequent management
- Sparse *montado* with occasional management
- Sparse *montado* with frequent management
- Open areas with tree regeneration

There is a parallel between the gradient of vegetation complexity and the ecological guilds of birds (Farmland Species, Edge Species, Forest Generalists and Forest Specialists) (Catarino et al. 2016, Pereira et al. 2015). These guilds were defined according to habitat preferences of bird species in the Mediterranean part of Portugal during the breeding season. Farmland Species mostly occur in association with open fields or, at most, with scattered shrubs or trees; Edge Species are associated with transitional areas that can occur at boundaries between two or more habitats (*e.g.* forest and open areas); Forest Generalists occur at any woody areas, regardless of the density and height of the tree formations; Forest Specialists tend to occupy stable forest environments and are therefore more sensitive to human disturbance than generalist forest species. Most of these species occur in natural or semi-natural forests with the following features: (1) high canopy of great maturity, (2) large stratification of woody vegetation, and (3) moist microclimate.

2.7. The concept

Finally, from our point of view, an area to be considered as *montado* should fulfil several assumptions related to tree composition and density, and production systems. The definition proposed on the scope of this thesis is: "*the* montado *is a system dominated by oak trees, with a cover higher than 10%, depending of the human interference and where one or more of the following activities can occur: forestry, grazing, hunting and tourism*".

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Chapter

3

The landscape heterogeneity of *montado*: singular elements for birds

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3.1. Introduction

Local variations in tree density are responsible for the heterogeneity of the *montado*, influencing the undercover management, and consequently the land use (Pereira et al. 2014b, Catarino et al. 2015), which in turn influence biodiversity (Diaz et. al. 1997, 2003). Beyond the direct effects of management, *montado* areas are also influenced by natural and/or anthropogenic disturbances with repercussions in the landscape (Loehle et al. 2005, Warren et al. 2005).

The discontinuity caused by the presence of external elements/habitats to the montado (hereafter singular elements) locally provides different ecological requirements than those offered by the forest matrix. These requirements allow the occurrence of species that are not characteristic of a particular typology (Pereira et al. 2015). As an example, in sparse montados with frequent management or open areas with tree regeneration, the existence of patches with higher vegetation density (riparian galleries and/or natural hedges) can foster the occurrence of forest specialist species. In addition to hedges and riparian corridors (linear structures in the landscape), we will cover in this chapter other land uses (such as pinewoods, permanent crops), rocky areas and quarries, waterbodies (ponds and reservoirs), rural infrastructures (*e.g.*

fences and unpaved roads) and buildings. The functional significance of these elements for birds, depend on landscape features (*e.g.* location and extension of water bodies, etc.) but also from changes introduced by man, such as buildings and management options.

It will be certainly possible to identify other singularities in the *montado* landscape but those, we have named are, in our opinion, the most frequent. Throughout this chapter we will show the importance of these elements to birds and we will refer species that can benefit from its presence. We will use an approach based on the ecological requirements of birds, considering that a singular element should have a maximum dimension of 1 ha, particularly in the case of forest patches and permanent woody crops (*e.g.* pine stands, olive groves and vineyards). This dimension is based on the assumption that the singular element should be influence by the edge effect of the *montado*. We adopted the distance of 50 m reported by Leal et al. (2011b) as the limit up to which the diversity of birds in *montado* is higher, resulting from the presence of another habitat fragment. Following the same criteria, and despite their importance for birds, we will not consider in this chapter agricultural habitats, like arable crops and rice fields.

3.2. Linear structures: natural hedges and riparian galleries

3.2.1. Natural hedges

Natural hedges (hereinafter hedges) are narrow lines of vegetation normally associated with the limits of plots or properties. Hedges can be planted, spontaneous (when they grow naturally from seeds dispersed by wind or animals) or remnants of native vegetation confined to the properties boundaries. In the *montado* the most frequent species associated to hedges are the brambles *Rubus ulmifolius*, hawthorn *Crataegus monogyna*, Iberian pear *Pyrus bourgaeana* and mastic *Pistacia lentiscus*. At the landscape level, the hedges perform the functions of (1) habitat, especially for edge species, (2) barrier, as frontier between adjacent fields, (3) source of biotic and abiotic influences on adjacent fields and (4) dispersion corridor (Forman et al. 1984). Hedges provide conditions for nesting, shelter and feeding, allowing local and long distance movements for some species (Hinsley & Bellamy 2000).

The value of hedges for birds depends on several factors: (1) size, composition and structure in relation to habitat preferences of each species, (2) density and spatial configuration in the landscape and (3) management of hedge and surrounding habitats. The interaction between birds and hedges ranges between local effects (limited to hedge) and large-scale effects, such as the influence of the surrounding habitat and the availability of other hedges and habitats in the landscape. Similarly, the level of interaction between birds and hedges ranges from occasional (e.g. as singing perch) to an almost exclusive use of hedge (Hinsley & Bellamy 2000).

The high diversity of species in hedges is apparently related to their microhabitat heterogeneity. Among factors that influence the diversity and abundance of birds in these singular elements we highlight: (1) the size of the hedge - narrow and low hedges are generally unfavourable to most birds, as they provide fewer resources and greater exposure to weather and predators; (2) the presence or abundance of trees in the hedge - hedge trees attract forest birds; (3) vegetation density in the lower strata of the hedge - important for the selection of nesting sites and breeding success of several species; (4) plant diversity - influences the variety and availability of food resources throughout the year.

The number of bird species that are able to use different types of hedges is high, ranging from farmland species to forest specialists (Pereira et al. 2015). In general, birds use hedges with similar characteristics to their nesting habitat: farmland species (*e.g*. common linnet *Carduelis cannabina*) occurs in dense low hedges; edge species (*e.g.* cirl bunting *Emberiza cirlus*) occurs at intermediate height hedges; forest generalists (*e.g*. blackbird *Turdus merula*) use preferably high and wide hedges with trees; forest specialists (*e.g.* Iberian chiffchaff *Phylloscopus ibericus*) occurs in hedges with high structural complexity.

Hedges can play a distinctive role in the breeding season because they sustain and increase breeding success in several ways. A greater availability of food reduces the effort invested by the parents during the breeding season to feed the young. Additionally, the hedge structural diversity and the diversity of adjacent habitats can also help to decrease the incidence of predation (Hinsley & Bellamy 2000). Moreover, since there is a high proportion of plants which are dispersed by birds, hedges also benefit from bird's presence: plants produce fruits that attract a large numbers of birds and these, when feeding, contribute to seed dispersal, fostering natural regeneration (Pereira et al. 2015).

Hedge management for birds must take into account that there is no optimal configuration for all species simultaneously. So, the management of these structures can be adapted to the requirements of a species or group of species. As an example, if the goal is to increase species richness in a particular typology of *montado*, the implementation of an hedge providing different ecological conditions from the matrix should be an option. It is noteworthy that, in addition to birds, other groups may benefit from hedges management, particularly as an ecological corridor. When planning a hedge, managers must be aware that plant species should be native to the geographical area, always avoiding exotic species.

3.2.2. Riparian galleries

On a global scale riparian areas are among the most complex, dynamic and rich ecosystems in terrestrial biomes (Naiman et al. 1993), and even though they occupy a relatively small surface, they provide habitat for a considerably large number of animal and plant species (Rodewald & Bakermans 2006). In dry regions, where water is a limiting factor, the role of riparian corridors in maintaining biodiversity is even more relevant, often being the only forested areas, within large landscape extents (Rodewald & Bakermans 2006). Riparian galleries provide nesting sites during the breeding season, food throughout the annual cycle (high availability of invertebrates and fruits), which are very important in autumn and winter, and act as ecological corridors for many species during migration and/or for juvenile's dispersion (Machtans et al. 1996, Mönkkönen & Reuanen 1999). In the south of Portugal, the most abundant tree species in riparian galleries are the alder *Alnus glutinosa*, ash *Fraxinus angustifolia* and willows *Salix sp.*.

The presence of a watercourse with natural vegetation in areas of *montado* contributes locally to increase the diversity of bird species. For example, in areas with a reduced tree density, the shrub layer is totally or partially removed to enable cereal crops and livestock grazing (Aguiar et al. 2005). When management involves the simplification of the vertical strata, bird diversity can be endorsed with the presence of riparian areas, which provides similar conditions to a forest area with shrubs. The increase of landscape complexity caused by the existence of riparian galleries contributes to the presence of species that usually do not occur in the *montado* (*e.g.* Cetti's warbler *Cettia cetti*), irrespective of their typology. For example, in areas of sparse *montado* it will be possible the occurrence of forest specialist species like lesser spotted woodpecker *Dendrocopos minor* or blackcap *Sylvia atricapilla*. Additionally, for same typology of *montado*, the species richness is positively influenced by the presence of a riparian gallery (Fig. 3.1).

In the spring of 2012 we surveyed two similar areas of *montado* (*e.g.* tree cover, shrub cover, plant composition), with only one difference: the presence of a riparian gallery in one of them. This study was part of the project: *Increasing biodiversity in montado areas* conducted in the Companhia Lezírias S.A. under the Business & Biodiversity program. Overall, 32 species were observed of which 22 were common to both areas, and 8 occurred only in the area containing a riparian gallery (long-tailed tit *Aegithalos caudatus*, nightingale *Luscinia megarhynchos*, Cetti's warbler, woodchat shrike *Lanius senator*, southern grey shrike *Lanius meridionalis*, crested tit *Lophophanes cristatus*, Iberian chiffchaff, blackcap) and 2 in the other area. For some species recorded in both areas, the abundances were higher in the area with riparian vegetation: forest specialists – wren *Troglodytes troglodytes*; forest generalists – blackbird, Sardanian warbler *Sylvia melanocephala*; edge species – melodious warbler *Hippolais polyglotta*; farmland species – stonechat *Saxicola rubicola*, zitting cisticola *Cisticola juncidis*. Similar results were also recorded by Leal et al. (2011b) who evaluated the influence of riparian galleries in the bird community of the *montado*.

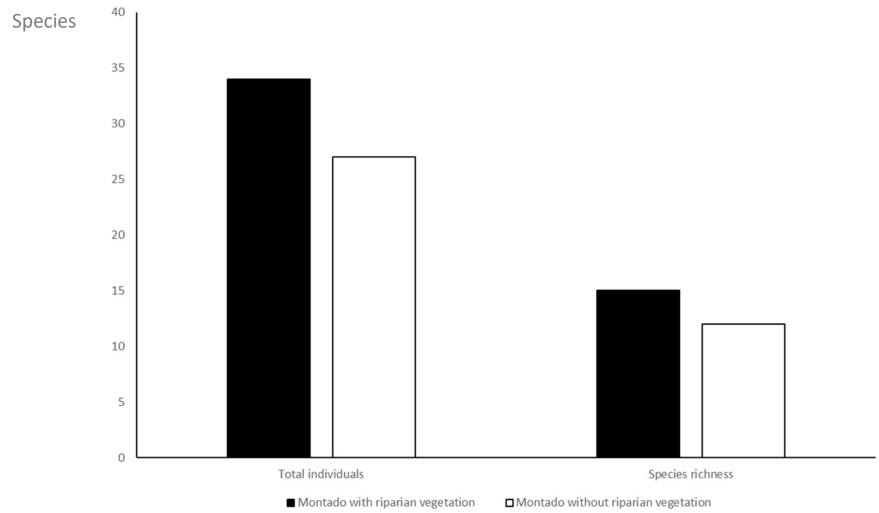

Figure 3.1 – Number of individuals and species observed in two areas of *montado*, with (left) and without (right) riparian vegetation, in the spring of 2012 (seven 10 minutes' point counts in each area). Data from the project *Increasing biodiversity in montado areas* developed in the Companhia Lezírias S.A. under the Business & Biodiversity program.

In brief, the existence of riparian galleries in *montado* areas has a positive effect on bird communities, and an adequate management of watercourses should be considered in the overall system. Despite the great pressures riparian areas are often facing, its global value can be easily enhanced. Small watercourses are common elements in many *montado*s and if managed properly even on a small scale (*e.g.* restoring riparian gallery, recovering banks and channel), they may have important implications in biodiversity conservation. For example, for forest certification one of the principles is to maintain or restore ecosystems, biodiversity, forestry and landscape. If part of this effort is focused on watercourses, even across different owners of adjacent properties, there will be a positive effect in conservation.

3.2.3. Other land uses: pine forests and permanent woody crops

3.2.3.1. Pine forests

It is not uncommon the presence of scattered pine trees in *montado*s, but to be considered a singular element we must have a homogeneous stand of maritime pine *Pinus pinaster* or stone pine *P. pinea*. This increase in diversity of tree cover has benefits to the forest and to biodiversity promotion. The tree richness has positive effects on plant health, once it decreases the likelihood of phytophagous insects to find favourable hosts, reducing the probability of pest's outbreaks (*e.g.* pine processionary *Thaumetopoea pityocampa* and pine wood nematode *Bursaphelenchus xylophilus*).

Patches of pine stands whithin the *montado* promotes the diversification of food, nesting sites and perches, favouring bird species richness and other wildlife groups (Gil-Tena et al. 2008, Harvey et al. 2006). Forest specialists are the most sensitive group to the characteristics of forest patches, although the availability of tree cover, and tree diversity also favour forest generalist species (Gil-Tena et al. 2007, Mitchell et al. 2001). These areas can also promote the presence of raptors that require large trees to build their nests, as the booted eagle or Bonelli's eagle (Pereira et al. 2015). Species with high conservation status such as nightjars (European nightjar *Caprimulgus europaeus* and red-necked nightjar *Caprimulgus ruficollis*), nest in pine stands. Another interesting example is the Bonelli's warbler *Phylloscopus bonelli*, a migrant songbird that occurs in pine forest areas and *montado* with pine trees. All these examples highlight the importance of the pine stands, improving the conservationist interest and the birdwatching in *montado* areas (Pereira et al. 2015). Game is also promoted thus raising the local income, because pine stands are often used as wintering roosting sites for the wood pigeon, while *montado* is mainly used as feeding ground.

3.2.3.2. Permanent woody crops: olive groves and vineyards

The functional importance of permanent woody crops for birds in the *montado* is somehow similar to linear structures, because they correspond to interruptions in the matrix acting as a complementary habitat for feeding and providing shelter and nesting conditions. For some species, this role is noticeable during the winter when there is less food available in the *montado*. This is the case of traditional olive groves, which appear to compensate for the low availability in fleshy fruits in *montado*, mainly caused by the frequent shrub removal (Pereira et al. 2015), which reduces their suitability for various species, such as Robin *Erithacus rubecula*, song thrush *Turdus philomelos* and blackcap. Traditional olive groves have a positive effect on bird diversity and the number of species in the *montado* is higher close to these habitats (Leal et al. 2011b). In addition, when the availability of trees is a limiting factor (*e.g. montado* in regeneration) there are species positively associated with olive groves, especially due to the availability of nesting sites and shelter. Examples include the little owl *Athene noctua*, the hoopoe *Upupa epops* and the kestrel *Falco tinnunculus*.

Structurally, vineyards resemble areas of shrubs and, like olive groves, they provide an additional source of food outside the nesting period. The harvesting of the grapes takes place after the nesting period for most species, matching the period of juvenile dispersion and the post-nuptial migration, just as the birds require more energy consumption. Studies on vineyards and bird communities are scarce, except those who approach the birds as a threat to these orchards (*e.g.* Somers & Morris 2002). In some parts of the world some bird species can cause important economic impact, and research has therefore been focused over the years in just finding ways to minimize those impacts, which results in gaps in the knowledge on the biodiversity of this system.

An assessment of the seasonal patterns of bird communities in Italian agro-systems, found that there is a rotation between groups of birds using the vineyards in winter and spring (Laiolo 2005). In spring the abundance of species feeding on the ground accounts for more than 50% of the bird community. This pattern is reversed in winter, during which, forest species are the most representative group. According to these results and surpassed them with the necessary prudence in the context of the *montado*, the vineyards as a singular element provide habitat for farmland species, and also constitute an important resource for forest generalist species during the winter. The vineyards considered in this Chapter occupy a small surface, corresponding mostly to an extensive regime. Vineyards with these features can support great numbers and diversity of species (Verhuslt et al. 2004), and finches are the group with utmost expression (*e.g.* goldfinch *Carduelis carduelis*, linnet, greenfinch *Carduelis chloris*, chaffinch *Fringilla coelebs*, serin *Serinus serinus*).

3.2.3.3. Rocky outcrops and quarries

Although representing a small percentage in terms of land use, the rocky outcrops are disproportionately important as habitat. Direct benefits to birds are relate to the availability of nesting sites and shelter, especially for species that depend on them directly (Ward & Anderson 1988). Indirectly, they have the advantage of causing a discontinuity in the matrix, promoting the diversification of the composition and structure of vegetation, which, as already noted, promotes diversity of bird species.

In Portugal there are essentially three areas of *montado* with adjacent rocky outcrops: *Tejo Internacional, Mourão-Barrancos* and *Moura-Mértola*. These areas are places of interest for birdwatching due to the uniqueness of the communities they host, being also protected areas due to their importance for bird conservation (Pereira et al. 2015). Some rupestrian species that occur in these rocky outcrops are emblematic, especially large birds of preys and/or priority in conservation. A few examples are the Egyptian vulture *Neophron percnopterus*, the golden eagle *Aquila chrysaetos* and Bonelli's eagle *Hieraaetus fasciatus*, the peregrine falcon *Falco peregrinus* and the griffon *Gyps fulvus*. Other examples of rupestrian species also emblematic are the red-billed chough *Pyrrhocorax pyrrhocorax* and the black stork *Ciconia nigra*. There are also species such as the eagle owl *Bubo bubo*, which does not depend exclusively on rocky outcrops to nest, but occur mostly associated with these elements.

Some of these species may occur associated to disabled quarries, once they provide nesting sites, that otherwise would not exist, in areas where rock outcrops do not occur naturally (*e.g.* peregrine falcon in Ireland; Moore et al. 2010). Vertical slopes of the quarries can be compared to natural escarpment, because they have a topography and a floristic composition sometimes similar (Khater & Arnaud 2007). Thus, the ecological restoration of quarries must always respect the potential of the site, using the existing outcrops as reference ecosystems.

These areas are repeatedly used as nesting habitat for very specialized birds, due to the stability and persistence of the rocky outcrops. It is essential that managers understand the importance of rocky outcrops and carefully allow activities likely to cause disturbance or changes in these habitats. The disturbance of birds may be caused by the presence of man, noise and erosion (*e.g.* rock extraction, construction of artificial structures - buildings, roads, etc., and recreational activities - climbing, hiking, etc.).

3.2.3.4. Waterbodies: ponds and reservoirs

Small ponds or medium-sized reservoirs are common elements in *montado* areas, mainly to provide water for livestock or irrigation for agricultural fields. In addition, they can also be used for game activities, promoting the establishment of waterfowl species during the fall/winter. Most of these elements may be included in one of two categories - with or without natural vegetation.

If these elements are managed to birds, the presence of vegetation is critical for providing shelter or structures for building nests. We suggest to promote vegetation growth, at least in one part of the pond, creating the conditions for birds to use it. Natural vegetation associated with the margins of ponds is sometimes identical to the riparian gallery, composed mainly by willows, being also possible to find some emerging rooted vegetation (*e.g.* reedmace *Typha sp.*). In ponds with these conditions we can find in spring, species like the nightingale, Cetti´s warbler, great reed warbler *Acrocephalus arundinaceus* and Iberian chiffchaff. During the winter, ducks and waders will find refuge and feeding areas. In addition, during the post-nuptial migration these areas can act as stopover for migrant birds on their route to Africa.

3.2.3.5. Rural infrastructures: buildings, roads and fences

Artificial structures present in the *montado* tend, in general, to be aggregated in space: buildings (if any) are generally spatially concentrated in the property, together with the infrastructures for forestry and farm activities (*e.g.* warehouses, shelters for cattle, etc.). For the same reason, these infrastructures are also close to the main access roads to the property. The remaining unpaved roads permit the assess to areas of *montado* and are often parallel to fences. Generally, there is a fence around the entire property and some on the interior to demarcate the plots with grazing. We can classify these elements in a very low level of urbanization. Usually, these structures tend to promote species of widespread distribution and adapted to artificialized environments. This artificiality level promotes the diversity and abundance of resources for birds by increasing the structural diversity of habitats, which increase the sites used as perches or for building nests (*e.g.* Beissinger & Osborne 1982).

Buildings promote, above all, cave dwelling species adapted to use artificial structures to nest: birds of prey like the kestrel *Falco tinnunculus*, the little-owl, and barn owl *Tyto alba*; Coraciiformes as the roller *Coracias garrulus* and the hoopoe; and passerines like the black redstart *Phoenicurus ochruros*, the spotless starling *Sturnus unicolor* and the house sparrow *Passer domesticus*. Although some of these are common species with a widespread distribution (*e.g.* starling and house sparrow) at the opposite side is the roller, a priority species in conservation, with a fragmented distribution in Portugal. In some areas the growing number of abandoned buildings seems to benefit the roller (Cabral et al. 2005). In these cases, it is important that the buildings are maintained, avoiding their collapse, and when necessary interventions should be planned to restore cavities and installation of nest boxes (Pereira et al. 2015). The nest boxes are easily occupied by generalists and opportunistic species (kestrels, barn owl and little-owl), with the benefit of helping the control of micromammals and insect populations, which are the natural prey of these birds.

In this chapter, the relevance of roads concerns exclusively private roads that serve the properties. Typically, they are unpaved roads, with a reduced bandwidth and low traffic intensity. The influence of these roads have on bird communities depends on their characteristics and their difference in relation to the matrix. Most of the roads can be included in one of two categories: main access roads to the urban area, thus more frequently used and slightly wider, and working roads widespread in the property, sometimes used seasonally. If these roads create an edge effect (providing different habitats from the matrix, promoting the development of herbaceous/shrubby vegetation) they may contribute to the occurrence of farmland species. Most of the roads we found in *montado* do not create a discontinuity in the tree cover, once they are embedding in the landscape. Probably the biggest difference that the unpaved roads have is the availability of bare soil, where ground feeders can easily capture insects. If some of these unpaved roads are not used throughout the year, they can sometimes evolve to a hedge like structure, providing the development of pioneer vegetation.

Fences create two main types of effects: on one hand they allow the development of herbaceous and woody vegetation along the base of the poles; and they also provide perches for several bird species, whether in the pole or in the wire. The vegetation developed on the basis of poles create conditions for farmland species to nest (*e.g.* stonechat *Saxicola rubicula* and corn bunting *Emberiza calandra*). Sometimes there is a small draining channel along fences, and when vegetated it creates particular conditions for the existence of micromammals. This is a very important food resource for birds of prey such as the krestel, black-shoulder kite *Elanus caeruleus*, barn owl and tawny owl *Strix aluco*. In addition to the species that use fences as hunting perch (like shrikes), there are others that use them to sing (corn bunting, stonechat, larks). The southern grey shrike and the woodchat shrike have the particularity of storing prey (mostly insects) on thorns, often using barbed wire to the same effect, possibly due to the absence of such plants.

3.3. Conclusion

With the exception of the rocky outcrops, all the other singular elements are common in *montado*s (Fig. 3.2). They only need to be considered as an added value that contributes to increase the *montado* sustainability for birds. When singular elements are combined with the typology of *montado*, the result may rise the number of species present in that typology. As an example, promoting riparian vegetation in an area of sparse *montado* will create the conditions to the occurrence of forest specialist species. On the opposite side, in areas of dense *montado*, the existence of small patches of other land uses (*e.g.* olive grove or vineyards) edge species and farmland species are promote.

Figure 3.2 – Examples of singular elements in *montado* areas. Top left - small pound with riparian vegetation; top right – unpaved road and fence; down left – unpaved road; down right – barn. All photos were taken at Companhia das Lezírias S.A.

Chapter

4

The importance of the surroundings: are bird communities of riparian galleries influenced by agroforestry matrices in SW Iberian Peninsula?

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4.1. Abstract

The remaining riparian stretches are often the unique suitable habitats for forest breeding birds in Mediterranean landscapes undergoing long-term changes. Understanding the interactions between riparian zones and their surroundings is critical to establish successful management actions. We assessed the influence of surrounding matrix on riparian bird communities and the use of riparian galleries as surrogate habitats for the forest passerine communities of southwestern Iberia. We used point counts in three simultaneous sampling stations, one in the riparian gallery and two in the adjacent matrix. Three matrix types were selected with a decreasing tree density gradient: dense *montado*, sparse *montado* and open agricultural areas. Data were analysed with redundancy analysis and differences in species' occurrences were tested with one-way ANOVA. In riparian galleries, we found bird species belong to three ecological guilds: riparian, woodland and edge. The richness of bird guilds and the occurrence of some species depended on the surrounding matrix type. Riparian bird richness was constant in all surrounding matrices; woodland bird guild was richer in galleries embedded in dense *montados* and edge guild in riparian galleries surrounded by sparse *montados*. Five among nineteen assessed species were influenced by matrix type, in particular a few strictly riparian species. Species richness increased close to riparian galleries, due to the increase in habitat heterogeneity and resource availability for birds in densely-vegetated riversides. However, the occurrence of some bird species differed according to the type of surrounding matrix. The matrix type explained most of the variance in riparian bird assemblages. Some woodland birds have used riparian galleries as surrogate habitat. Our study suggests that land use in the surrounding matrices must be taking into account for the management and rehabilitation of watercourses and bird conservation actions.

Keywords: breeding bird assemblages, agroforestry gradient, *montado*

4.2. Introduction

Mediterranean landscapes have changed over time due to intensive land use for centuries, resulting in highly fragmented woodlands and reduced riparian galleries (*e.g.* Covas & Blondel 1998; Blondel & Aronson 1999; Larsen et al. 2010). In central-southern areas of the Iberian Peninsula, this long-term process of human interference in dense and continuous woodlands of evergreen oaks (mainly holm oak *Quercus rotundifolia* and/or cork oak *Q. suber*) shaped the Portuguese *montados* and Spanish *dehesas*. Currently, these habitats are extensive agro-silvo-pastoral systems with reduced or eliminated shrubby layer in order to promote cereal crops and/or livestock grazing. The result is a heterogeneous matrix of different tree densities composed by a farmland and woodland mosaic crossed by natural corridors like riparian galleries and natural hedgerows. The process of forest clearing (past and present) in the low-density *montados* can modify the landscape structure and eventually promote edge effects, as observed in other fragmented forests (Murcia 1995). However, these parkland forested areas support a higher alpha and beta diversity of bird communities compared with other European forests, mostly due to a high abundance of farmland birds (*e.g.* Blondel & Aronson 1999; Díaz et al. 1997; Tellería 2001). Several authors have documented that bird communities' composition are determined not only by the regional pool of species, but mainly by landscape and patch features like the matrix type, patch width, size and shape, habitat configuration, floristic and physiognomic vegetation structure (*e.g.* Davis 2004; Gil-Tena et al. 2007). Forest features like tree and shrub densities are within the most important influences for bird assemblages in *montados* (Godinho & Rabaça 2011; Rabaça 1990). Furthermore, applying an ecological guild approach based on functional traits of habitat use often facilitates the understanding of birds' response to habitat and landscape features (Bryce et al. 2002; Bub et al. 2004; Mayer and Cameron 2003; Sullivan et al. 2007).

In river corridors, the structure of a well-developed riparian gallery can be comparable to woodland with shrubs in the understory, creating a dense vegetation cover with particular shade and wet conditions (*e.g.* Tubelis et al. 2004). Birds are often used as indicators of environmental changes in riparian systems, since they have a high ability to use corridors, move among habitat patches and react fast to ecological disturbances (*e.g.* Bryce et al. 2002; Larsen et al. 2010; Mayer & Cameron 2003; Sullivan et al. 2007). Nevertheless, studies on ecological relations among breeding birds, landscape elements and riparian galleries are scarce from a community perspective (*e.g.* Bub et al. 2004; Strong & Bock 1990; Woinarski et al. 2000), especially in the Mediterranean Region (see Godinho et al. 2010; Larsen et al. 2010).

Our study aims to evaluate (1) if surrounding agroforestry matrices with different tree densities influence the composition of breeding bird communities associated with riparian galleries, and (2) if riparian galleries can be a surrogate habitat for forest breeding birds in SW Iberian Peninsula. Knowledge about the interactions between riparian ecosystems and their surroundings is critical to establish successful management actions in agroforestry systems (see Martin et al. 2006), especially considering the relevance of river corridors in landscape planning and regional biodiversity maintenance (Bub et al. 2004; Deschênes et al. 2003; Naiman et al. 1993).

4.3. Material and Methods

4.3.1. Study area

Fieldwork was conducted in Central Alentejo in the municipalities of Évora and Montemor-o-Novo (7º40'W-8º16'W and 38º27'N-38º41'N) (Fig. 4.1). The area is characterized by smooth plains with an average altitude around 250 m (the highest elevation in the Monfurado Mountain, 420 m). The climate is Mediterranean with hot and dry summers and moderate rainy winters. Average annual temperature is 12.5 ºC (from 9 ºC in January to 25 ºC in July) and annual rainfall ranges from 600 mm to 1000 mm (SNIRH 2007). Woody vegetation is dominated by cork and holm oaks in the tree layer, olive tree *Olea europaea* var*. sylvestris*, kermes oak *Quercus coccifera* and hawthorn *Crataegus monogyna* in intermediate layers, and gorses *Ulex* spp. and rock roses *Cistus* spp. in shrub layer. Common land uses are *montados*, cereal fields and fallows, creating a landscape gradient from decreasing forestry use to increasing agropastoral use. Stands with a higher density and diversity of woody vegetation are located in the western part; a gently undulating landscape with scattered oaks and crop cultures in the north and east; and a vast plain with cereal crops, pastures and fallows and nearly no trees in the south. Cattle dominate the livestock, but sheep and pigs are also raised. Selected rivers are tributaries of the three major basins of central and south Portugal: the Tagus River in the northern part of the area, the Guadiana River in the south-eastern part, and the Sado River in southwest. Surveyed stretches are characterized by soft slopes and a well-developed and continuous riparian gallery with deciduous trees like ash *Fraxinus angustifolia*, alder *Alnus glutinosa*, willows *Salix alba, S. atrocinerea, S. salvifolia* and poplar *Populus nigra*. The riparian understory is dominated by bramble *Rubus ulmifolius*.

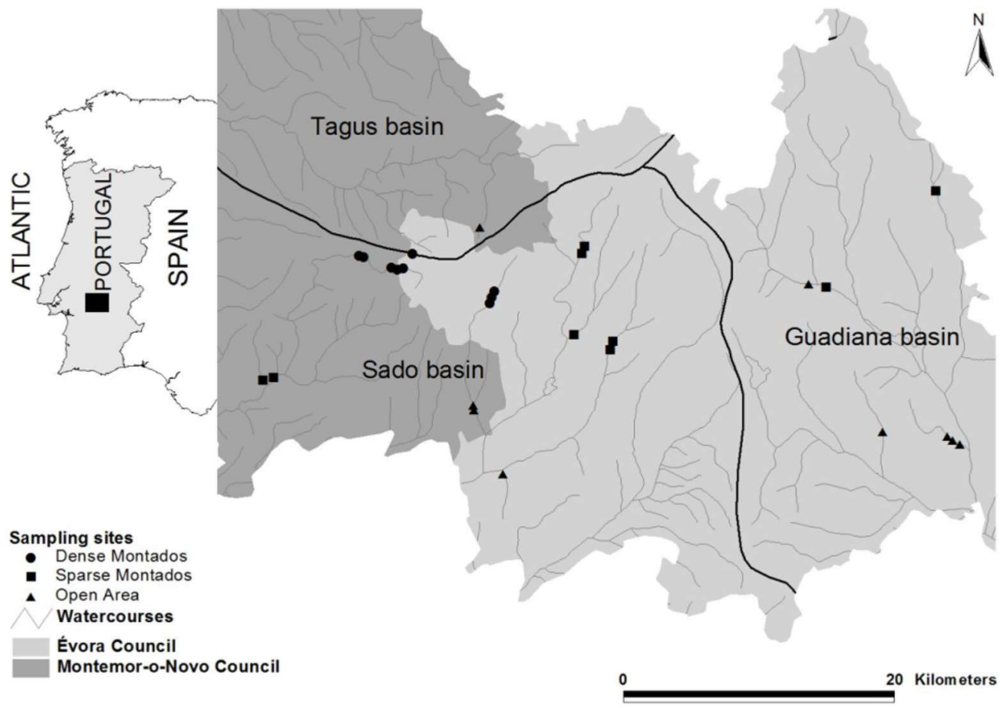

Figure 4.1 - Location of the study area and sampling sites, by each matrix type.

4.3.2. Site selection and sampling procedures

We selected study sites according to the following criteria: (1) stretches with continuous riparian vegetation (no less than 100 m length) in (2) small-sized streams with a band of riparian vegetation in both riversides, and (3) a uniform habitat typology in the surrounding matrix on both sides of the channel. We selected permanent small-sized streams (although in winter it may present torrential flow) with a narrow riparian zone (c.15 m including the channel) because they are the dominant watercourses in the rural landscape of SW Iberia. Three types of matrix were chosen based on a forested gradient: dense *montados* (DM, with tree density > 40 trees/ha), sparse *montados* (SM, tree density between 5 - 40 trees/ha), and open agricultural areas (OA, < 5 trees/ha) (Fig. 4.2).

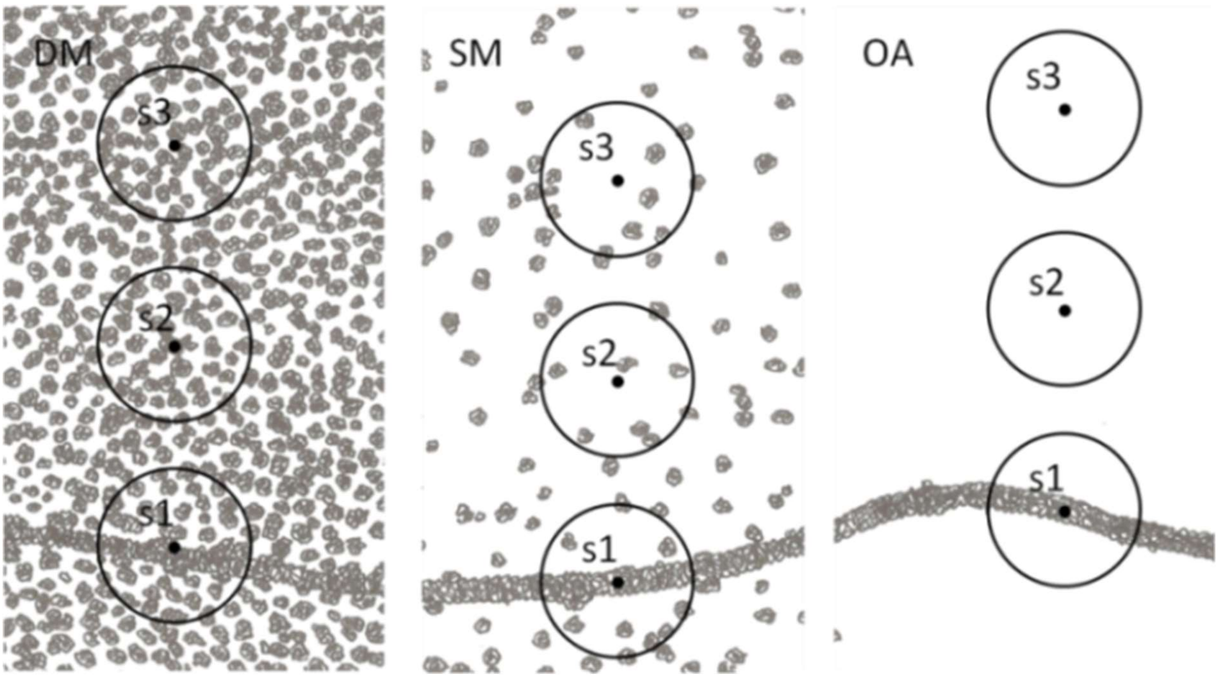

Figure 4.2 - Scheme showing an example of sampling site by each matrix type (DM: dense *montados*, SM: sparse *montados* and OA: open areas) with the location of the three stations: s1 in the riparian gallery, s2 at 125 m from s1 and s3 at 125 m from s2. The circles (with a 50 m radius) represent the census area by each station. Three simultaneous observers were located in the centre of each census area, recording all birds observed within the census area during 10 minutes.

In order to detect areas that fitted our criteria we used ArcGis 9.1 (ESRI 2004). Subsequently, potential areas were checked in the field and sampling sites established according to their easier access. We selected nine sampling sites in each agroforestry matrix type (totalizing 27 sampling sites) located at least 500 m apart from each other. In each sampling site, three 10 min point counts (sampling stations) with a 50 m radius limited distance (*e.g.* Bibby et al. 2005) were conducted exactly at the same time by three observers with similar aural and visual detection skills. Censuses started simultaneously after all the observers arrived to their assigned stations. In each sampling site, stations were located on the same riverside along a perpendicular line to the channel. The first station (s1) was close to the channel and the following stations were located in the matrix: the second (s2) 125 m from s1 and the third (s3) was located 125 m from s2 (Fig. 4.1). S2 and s3 were used in order to verify the homogeneity of bird community within matrix. This procedure provided us with a simultaneous snapshot of the birds present in each sampled area, and a better understanding of the birds' use of two different landscape elements: riparian galleries and matrices. Bias due to differences in the observers' bird detection was controlled through previous training in distance estimation. However, in spite of our heavy design, we could not preclude that matrix types could have affected differently the conspicuousness of the observer, which is expected to increase from DM to OA. As a result, we could not exclude the possibility of a subtle reduction in birds' detections in open areas. In order to increase the probability of detection of a given species, bird surveys were carried out twice during the breeding season of 2007 (totalizing 162 point counts). The first survey was conducted in late April and the second in the end of May. Surveys were conducted between 6:00 and 11:00 am and adverse weather conditions such as moderate rain or strong winds were avoided.

Bird species were grouped into three ecological guilds according to their functional use of ecological space (riparian, woodland and edge guilds; Table 4.I) based on species occurrence. Guild names follow a woodland perspective: riparian guild is composed by bird species dependent on riparian forests, woodland guild species includes bird species dependent on matrix forests and edge guild species do not have any forest dependence, being mostly ground nesters. Species richness and the frequency of bird occurrence were assessed for the riparian gallery (s1 stations) as well as for the surroundings (s2 and s3 stations). We excluded from our initial bird data set (1) species with a wider spatial use of the census area, i.e., similar or larger than a common blackbird *Turdus merula*, insectivorous aerial flyers like swifts *Apus* spp., swallows *Hirundo* spp., *Riparia riparia* and house martins *Delichon urbicum*; (2) birds detected only outside the census area; (3) unidentified birds species (belonging to these groups: sparrows *Passer* spp. and crested larks *Galerida* spp.) in order to avoid bias in analysis interpretation resulting from habitat differences of species within each species group; and (4) species recorded in less than 15% of all 81 sampling sites (*e.g.* kingfisher *Alcedo atthis* and grey wagtail *Motacilla cinerea*).

Table 4.I - Bird species included in the analysis, acronyms, English names and ecological guilds (RG – riparian guild; EG – edge guild; WG – woodland guild). Frequency of occurrence for bird species in riparian galleries (n=27) and proportion of occurrences in riparian galleries in relation to the number of stations with species occurrences.

Species	Acronym	English name	Guild	Frequency in Galleries (%)	Proportion of total occurrence in Galleries (%)
Troglodytes troglodytes	Tro tro	wren	RG	81.5	100
Luscinia megarhynchos	Lus meg	nightingale	RG	100	90
Cettia cetti	Cet cet	Cetti's warbler	RG	51.9	100
Hippolais polyglotta	Hip pol	melodious warbler	RG	48.2	81.3
Sylvia atricapilla	Syl atr	blackcap	RG	85.2	85.2
Serinus serinus	Ser ser	serin	RG	70.4	70.4
Carduelis chloris	Car chl	greenfinch	RG	40.7	78.6
Carduelis carduelis	Car car	goldfinch	RG	70.4	67.9
Saxicola rubicula	Sax tor	stonechat	EG	33.3	69.2
Cisticola juncidis	Cis jun	zitting cisticola	EG	25.9	53.9
Sylvia melanocephala	Syl mel	Sardanian warbler	EG	85.2	54.7
Lanius senator	Lan sen	woodchat shrike	EG	14.8	28.6
Emberiza calandra	Emb cal	corn bunting	EG	48.2	36.1
Fringilla coelebs	Fri coe	chaffinch	WG	48.2	33.0
Aegithalos caudatus	Aeg cau	long-tailed tit	WG	40.7	50.0
Cyanistes caeruleus	Cya cae	blue tit	WG	88.9	45.3
Parus major	Par maj	great tit	WG	59.3	45.7
Sitta europaea	Sit eur	Nuthatch	WG	7.41	7.69
Certhia brachydactyla	Cer bra	short-toed treecreeper	WG	44.4	29.4

4.3.3. Explanatory variables and data analysis

For each bird species, we determined the frequency of occurrence in galleries (percentage of sampled galleries where a given species has occurred) and the proportion of total occurrence in galleries: percentage of occurrences in s1 in relation to all stations (s1, s2 and s3) where a given species has occurred. The first value is related with the consistency of the species occurrence along riparian galleries, despite the surrounding matrix; the second highlights the relevance of galleries for each species in the study area.

We recorded two groups of environmental variables in each sampling station: vegetation structure (seven variables) and matrix type (three variables). We divided the matrix type according to tree cover in dense *montados*, sparse *montados* and open areas. Vegetation variables were grouped according to their ecological relevance and cover: large riparian trees (ash, alder and poplar), willows, oak trees (holm and cork oaks), small woodland trees (olive tree, kermes oak and hawthorn), woodland shrubs (gorses and rockroses), riparian shrubs (bramble) and herbaceous plants. We used redundancy analysis (RDA) as a descriptive and exploratory technique, using data multivariate analysis in Canoco for Windows 4.5 (ter Braak & Smilauer 2002). To evaluate the associations between environmental variables and bird assemblages, three different RDA were run, associating (1) agroforestry matrices (DM, SM and OA), environmental variables and stations (s1, s2 and s3), (2) matrices and environmental variables and (3) matrices, stations and bird species. Variables were selected manually under an unrestricted model with Monte Carlo permutation tests (999 permutations).

Differences in the occurrences of bird guilds were tested using three separate one-way ANOVA (*e.g.* Bub et al. 2004; Deschênes et al. 2003; Strong & Bock 1990), using SPSS 16.0 for Windows (SPSS 2007). With all the 81 stations, we performed analysis using station and matrix type as independent variables. For all guilds, we tested the existence of differences in their richness in matrix stations (s2 and s3). Subsequently, the influence of the agroforestry matrix on riparian bird communities was assessed for each guild (with matrix type as an independent variable), using species occurrences in s1 stations.

4.4. Results

In all, 19 bird species satisfied our criteria and were included in our bird data set for subsequent analysis (Table 4.I). All these species were recorded in riparian galleries but richness values were different depending on the matrix type: 19, 18 and 17 species were detected in s1 stations surrounded respectively by dense *montados*, sparse *montados* and open areas. The average species richness in s2 was significantly different within the studied matrices, as well for s3 (Table 4.II).

Matrix type, environmental variables and stations represented 68.1% of total explained variance for our data (Table 4.III). Strong similarities among stations from the same matrix type were found (78.1% of explained variance). Since similarity of riparian galleries among all sites and matrix homogeneity in each class was verified, testing species-environmental correlations and the influence of the matrix in a riparian bird community was justifiable.

Table 4.II - Independent One-way ANOVA for bird species richness in the three stations (s1, s2, s3; n=27) at three different matrix types: dense *montados*, sparse *montados* and open areas.

Stations	**Dense *montados***	**Sparse *montados***	**Open areas**	**F**	**p**
s1	10.9 ± 3.63	10.3 ± 3.44	10.1 ± 3.37	0.62	0.56
s2	6.67 ± 2.22	3.44 ± 1.15	2.11 ± 0.70	8.90	0.01
s3	5.67 ± 1.89	6.56 ± 2.19	1.11 ± 0.37	31.2	< 0.01

Table 4.III - Canonical eigenvalues, species variance, species-environmental correlations and total explained variance for the first two axes of the Redundancy Analysis.

		Axis I	Axis II	Total variance explained (%)
Matrices / environmental variables / stations	Canonical eigenvalues	0.245	0.215	68.1
	Cumulative variance of species data (%)	24.5	46.0	
	Species – environmental correlations	0.989	0.927	
Matrices / environmental variables	Canonical eigenvalues	0.430	0.351	78.1
	Cumulative variance of species data (%)	43.0	78.1	
	Species – environmental correlations	0.927	0.838	
Matrix / stations / species	Canonical eigenvalues	0.236	0.103	36.7
	Cumulative variance of species data (%)	23.6	33.9	
	Species – environmental correlations	0.942	0.804	

The RDA ordination results along the first two axes are plotted in Fig. 4.3. Arrows represent the environmental variables included in the model that explain most of the variation in species distribution. The length of each arrow expresses the relative importance of the corresponding variable in the model. The arrow direction in relation to the axes shows how well the environmental variable is correlated with each axis. The environmental condition associated with the presence of each species is showed by the closeness of bird species scores to the arrows. Bird species were highly correlated with selected environmental variables (explained variance 36.7%). Species from the same guild are closely positioned in the RDA biplot and show a close relation with stations and matrices: riparian guild species were strictly associated with the riparian gallery (s1); woodland guild species dominated in dense *montados*; and edge guild species were associated with biplot centre and with open areas. The richness in riparian and woodland guilds increased from open areas to dense *montados* ($F = 4.36$, $p < 0.05$ and $F = 35.3$, $p < 0.05$, respectively), whereas the edge guild species richness was higher in sparse *montados* and lower in dense *montados* ($F = 3.73$, $p < 0.05$).

In riparian galleries, the frequency of occurrence ranged from 7.41% for nuthatch *Sitta europaea* to 100% for nightingale *Luscinia megarhynchos* (Table 4.I). When we look to the proportion of the species occurrence in riparian galleries in relation to the total of the three stations (s1, s2 and s3), we found that wren *Troglodytes troglodytes* and Cetti's warbler *Cettia cetti* occurred strictly in galleries (proportion of total occurrence in galleries = 100%), whereas nuthatch occurred mostly at matrices (only 7.69% in galleries) (Table 4.I). Some species were detected in all s1 stations of a given matrix surrounding and were more frequent in s1 than in the surroundings (Table 4.IV): blue tit *Cyanistes caeruleus*, blackcap *Sylvia atricapilla* and wren in dense *montados*, serin *Serinus serinus* in sparse *montados* and Sardinian warbler *Sylvia melanocephala* in open areas.

In s1 station, when we compared the richness of each guild among each matrix type, differences were obtained for woodland and edge species. Accordingly, species richness of the riparian guild was constant in all types of matrix ($F = 0.155$, $p = 0.860$), woodland guild richness was higher in galleries embedded in dense *montados* ($F = 11.9$, $p < 0.01$) and edge guild richness was higher in riparian galleries surrounded by sparse *montados* ($F = 11.2$, $p < 0.01$). Five species from the three guilds showed significant differences ($p \leq 0.05$) in their frequencies in riparian galleries depending on the matrix type (Table 4.IV). Cetti's warbler and serin (riparian guild species) occurred mainly in galleries surrounded respectively by open areas and *montados* (sparse or dense).

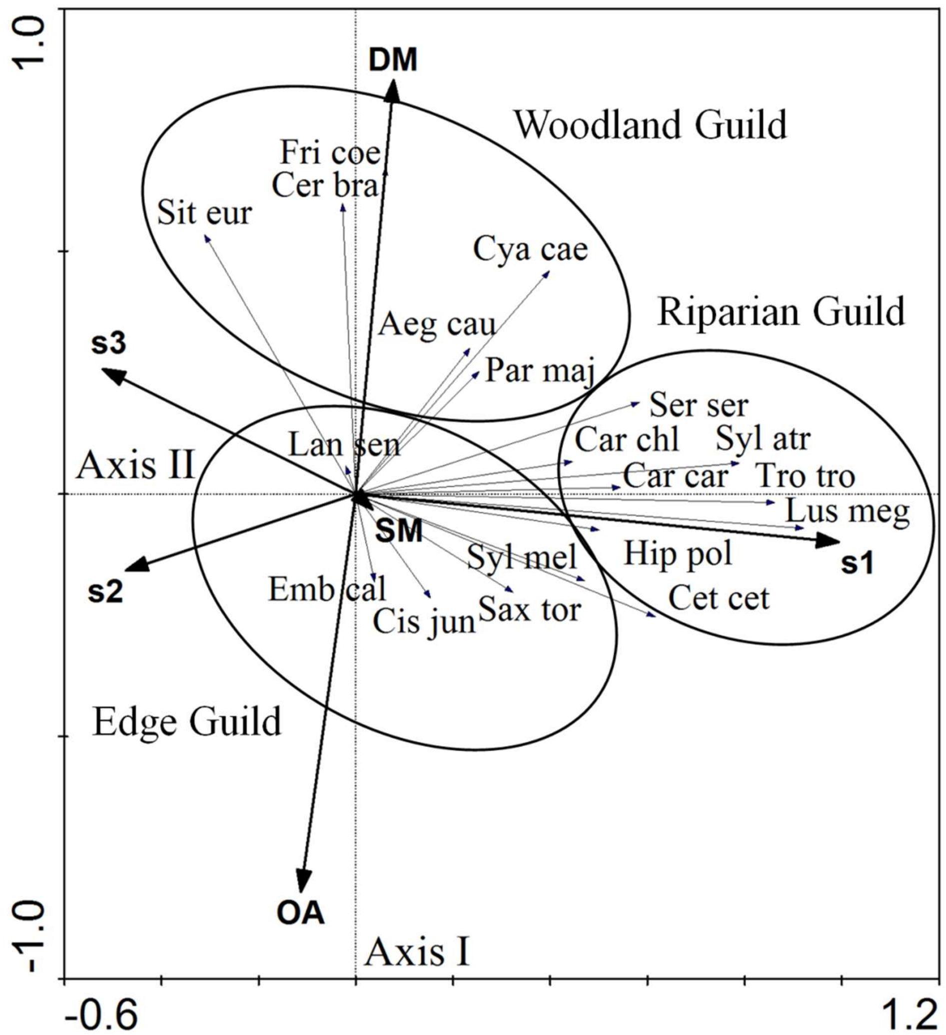

Figure 4.3 - Ordination biplot of the first two axes of the RDA for bird species, sampling stations (s1, s2 and s3) and matrix types (DM: dense *montados*, SM: sparse *montados*, OA: open areas). For species' acronyms, see Table 1. The clusters grouped the three ecological guilds considered.

Species from the edge guild like stonechat *Saxicola rubicula* and corn bunting *Emberiza calandra*, were observed in galleries bordered respectively by sparse *montados* and open areas. Finally, the chaffinch *Fringilla coelebs*, a species from the woodland guild, occurred mainly in galleries surrounded by dense *montados*. These results suggest the existence of a driving influence from the surrounding matrix on bird communities associated with the riparian gallery. Concerning the guild richness of the matrix stations, there were no differences detected for all guild richness between s2 and s3: riparian ($F = 0.774$, $p = 0.472$), woodland ($F = 0.901$, $p = 0.418$) and edge species ($F = 0.230$, $p = 0.796$).

Table 4.IV - Independent One-way ANOVA for bird species occurrence in the three stations (s1, s2, s3; n=27), and for occurrences in riparian galleries (s1) embedded in three different matrix types (n=9). For species' acronyms, see Table 4.I.

	Stations		Galleries	
Acronym	**F**	***p***	**F**	***p***
Tro tro	114	< 0.01	1.75	0.195
Lus meg	223	< 0.01	-	-
Cet cet	28.0	< 0.01	4.55	0.0212
Hip pol	14.2	< 0.01	0.13	0.876
Syl atr	60.8	< 0.01	1.14	0.336
Ser ser	17.4	< 0.01	7.00	< 0.01
Car chl	16.1	< 0.01	0.160	0.853
Car car	9.39	< 0.01	0.138	0.872
Sax rub	4.86	0.01	6.00	0.01
Cis jun	2.64	0.0779	0.174	0.841
Syl mel	2.68	< 0.01	2.15	0.138
Lan sen	2.48	0.0906	2.15	0.138
Emb cal	0.14	0.865	4.55	0.0212
Fri coe	2.43	0.0949	6.20	< 0.01
Aeg cau	4.49	0.0143	2.08	0.147
Cya cae	6.72	< 0.01	1.09	0.352
Par maj	2.20	0.118	2.08	0.147
Sit eur	6.34	< 0.01	2.29	0.123
Cer bra	1.23	0.299	1.85	0.180

4.5. Discussion

4.5.1. Bird guilds and woodland traits

Common and widespread European forest resident birds dominated the breeding bird communities in studied well-developed forests, such as riparian galleries and dense *montados*. This trait is similar to what has been detected in other riparian forests from Europe (*e.g.* Larsen et al. 2010; Godinho et al. 2010; Roché et al. 2010) and in European mature woodlands (Brotons et al. 2004; Gil-Tena et al. 2007; Rabaça 1990). Blondel & Farré (1988) described this observation as a tendency to convergence in the composition of bird communities associated with the last stages of different successional habitat gradients from several parts of Europe.

The selected stations in matrix (s2 and s3) were homogenous in terms of bird community composition. This is consistent with the uniformity of habitat typology in matrices, which was a criteria used for the selection of sampling sites. In the case of dense *montados*, it means continuity of suitable habitat available for woodland birds. We expect that in mature and continuous forests, woodland species might reach a higher reproductive performance than in disturbed or fragmented woodlands. Accordingly, in Mediterranean oak forests in Spain, Arriero et al. (2006) found that habitat maturity was an important factor determining the condition of blue tit females and therefore their breeding success. Since tree nesters (crown or cavity nesters) represent the major part of the woodland species, a higher cover of woody vegetation should increase their habitat suitability.

The higher fragmentation of woodland habitats observed in sparse *montados* can be responsible for the lower suitability of this matrix type for woodland birds. As discussed by Murcia (1995) in relation to other fragmented forest habitats, sparse *montados* are affected by edge effect through several reasons: intermediate habitat structure between DM and OA; dominance of edge guild instead of woodland guild; eventual predation levels similar to those observed in open areas (*e.g.* Santos & Tellería 1992). Birds from the edge guild are the major part of bird communities in sparse *montados* and open areas. This result can indicate that a tree reduction below 40 trees/ha have high negative effects in the composition of woodland guild. Forest fragmentation through the reduction of vegetation complexity and microclimatic conditions in sparse *montados* can create edge effects reducing the habitat availability for woodland birds (see for instance Murcia 1995). However, in Iberian agroforestry landscapes, edges and farmlands can show lower predation rates on ground nests than forest interiors, based on absence of specialist forest predators (Santos & Tellería 1992). Therefore, similar levels of low predation can contribute to increase bird community similarities between sparse *montados* and open areas. Moreover, in our study, the presence of isolated trees within the sampled area of three stations conducted in open areas could also contribute, even marginally, to increase such similarities. Notwithstanding, the species richness was lower in open areas. A higher human disturbance and lower complexity of vegetation in open areas result in a low availability of niches for birds (see for instance Atauri & Lucio 2001). However, this fact can be also overinflated because (1) large species with wide territories were not included in the bird data set (*e.g.* species belonging to Phasionidae, Ciconiidae and Otidae) and (2) the conspicuousness of the observer eventually affected bird detections as previous mentioned.

With different degrees of human disturbance, all habitats used by edge bird guild are associated with forest fragmentation: open areas with scattered shrubs or trees, sparse *montados* and, more rarely, in glades within a dense *montado* matrix. However, within edge guild we found birds with different tolerance to fragmentation. The fan-tailed warbler *Cisticola juncidis* and corn bunting are ground foragers and nesters well adapted to farming landscapes, although with different habitat preferences. The fan-tailed warbler, a bird of open areas with dense vegetation (*e.g.* cereal fields and fallows; see Delgado & Moreira 2000), was recorded mainly in open areas, while corn bunting was detected more often in sparse *montados*, similarly to what was found by Stoate et al. (2000) in extensive farming landscapes of Southern Portugal. This preference for sparse *montados* instead of open areas is also consistent with the habitat profile of corn buntings favouring the presence of wooded edges (*e.g.* Reino et al. 2009).

4.5.2. The influence of the surroundings

Generally, species richness increased close to the riparian gallery, due to greater habitat heterogeneity (see Berg 1997) and the availability of resources for birds provided by well-vegetated riversides (*e.g.* Bub et al. 2004). Several authors have documented that riparian bird assemblages are influenced by intrinsic gallery traits such as width, dominant tree species, and understory vegetation density (*e.g.* Bub et al. 2004; Godinho et al. 2010; Hodges et al. 1996; Strong & Bock 1990). The structural complexity of our riparian galleries is underlined by the most frequent bird species detected, associated with dense-understory (Sardinian warbler, nightingale, wren) and forested habitats in other European landscapes (*e.g.* blue tit, blackcap). The high diversity of food resources in riverside vegetation endorses the existence of different trophic categories in the riparian guild: exclusively insectivorous species (*e.g.* wren) or seedeater species (*e.g.* serin) and partly frugivorous birds (*e.g.* blackcap).

Climatic variables like rainfall precipitation (see Tellería & Santos 1993) are known to affect insectivorous birds, namely in matrix woodlands. Notwithstanding, the microclimatic conditions in riparian galleries can play an important role in the composition of bird community (*e.g.* Moore et al. 2005). Accordingly, these conditions can result not only from intrinsic gallery traits (*e.g.* vegetation typology) but also from extrinsic traits (*e.g.* surrounding matrix type). Our studied galleries showed a similar typology with well-developed and dense vegetation, creating higher moist conditions than surroundings matrix woodlands. These microclimatic conditions allow some typically woodland passerines of temperate Europe to occur in Mediterranean landscapes (*e.g.* wren and blackcap), since they are rare or absent from matrix woods (Godinho & Rabaça 2011; Tellería 2001). On the other hand, we admit that the occurrence of Cetti's warbler (a riparian species of Mediterranean origin) might be dependent on microclimatic conditions with an extrinsic source. Moore et al. (2005) discussed the existence of sharp differences in maximum temperatures if the surroundings are forests or open areas. The marked thermal variation between riparian galleries and open areas will influence ecological conditions for several organisms, namely ectothermic animals such as insects, whose levels of parasitism are lower in strong edge habitats (see for instance Murcia 1995; Roland et al. 1997). Therefore, the high source of food and the warm and dry conditions can eventually justify the high frequency of the Cetti's warbler in the riparian galleries embedded in open areas.

Some bird species occurred preferentially in galleries although they are not typically riparian species. The serin was included in the riparian guild, although it is usually considered a ubiquitous species. Ultimately, tallest trees in riparian galleries might have been selected as song perches rather than smaller trees in surroundings (authors' pers. obs.). Therefore, the low preference for the matrix drives the serin into the riparian gallery. This suggests a high attractiveness of the gallery for woodland species (*e.g.* great tit and short-toed treecreeper) which can use riparian galleries as a surrogate habitat, mainly due to the increase of agropastoral activities in the matrix, which in the end will lead to a treeless landscape. Moreover, riparian galleries are frequently the single forested patches in an open area landscape, thus representing the only breeding and feeding site available to several bird species (*e.g.* Deschênes et al. 2003; Strong & Bock 1990).

Our studied stretches were selected mainly in second-order streams (in the sense of Strahler number). We are aware that this fact associated with sampling constrains (number of sampling sites and geographical location) preclude inferences at a broader scale. However, we believe that the agroforestry gradient used in this study and selected sampling sites provide a satisfactory picture of the rural landscapes from SW Iberian Peninsula, especially in areas with a similar geomorphology (smooth plains with scattered and soft elevations), which indeed are dominant in the region.

4.6. Conclusion

The agroforestry matrix types explained most of the variance in riparian breeding bird assemblages, which seemed to be more dependent on matrix traits than on the riparian gallery vegetation. We should underline that a well-structured gallery with dense and diverse woody vegetation on river edges is important to breeding bird assemblages, namely in areas dominated by forest-depleted landscapes such as extensive Mediterranean farming systems. In our study area, the occurrence of woodland or edge guild species in riparian galleries was consistent with their dominance in neighbourhood matrices. Some edge species can occur mostly near the edge, highlighting the importance of the mosaic structure of *montados* where patches of wooded areas, clearings and shrubs create a patchwork of habitats providing trophic and habitat conditions for birds of different ecological guilds. Similar to Martin et al. (2006), our study suggests that land use in the surroundings should be taken into consideration in the management and rehabilitation of watercourses and in bird conservation actions. This should be relevant for the stakeholders involved with agroforestry ecosystems (landowners, land managers, decision makers) and to the society in highlighting the different values of riparian ecosystems (economic, social and biological; see Malanson 1993). Additionally, since every landowner should protect a riparian stretch in order to preserve biodiversity, fulfilling the EU legislation, the importance of watercourses protection is highlighted since stretches are the connecting element in the landscape.

Chapter

5

Can birds play a role as High Nature Value indicators of *montado* system?

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5.1. Abstract

Montados form a heterogeneous landscape of wooded matrix dominated by cork and/or holm oak with open areas characterized by fuzzy boundaries. *Montado* supports a high biological diversity associated to low intensity management and a landscape diversity provided by a continuous gradient of land cover. Among other features this permits the classification of *montados* as a High Nature Value (HNV) system. We assessed the role of birds as HNV indicators for *montado*, and tested several bird groups – Farmland, Edge, Forest Generalists and Forest Specialists species; and some universal indicators such as species conservation status, Shannon's diversity index and species richness. Our study areas covered the North-South distribution of cork oak in Portugal, and we surveyed the breeding bird communities across 117 sampling sites. In addition to variables related to management and sanitary status, we considered variables that characterize the landscape heterogeneity within the *montado* – trees and shrub density and richness of woody vegetation. Our results suggest that specific bird guilds can be used as HNV indicators of particular typologies of *montado*, and highlight the need to develop an indicator that could be transversally applied to all types of *montado*.

Keywords: *Montados*, Birds, HNV farmland, indicators, landscape composition

5.2. Introduction

Portuguese *montados* and Spanish *dehesas* are silvopastoral systems of anthropogenic origin derived from ancient Mediterranean forests of cork oaks (*Quercus suber*) or holm oaks (*Quercus rotundifolia*). These systems can combine the use of woodland products (*e.g.* timber, charcoal and cork) with cereal crops and livestock grazing in the understory (Blondel & Aronson 1999). Such diversified activities allow *montados* to form a heterogeneous landscape of wooded matrix with open areas, scattered woodlands and semi-natural patches of Mediterranean forest and scrublands, resulting in a system with high biological diversity (Rabaça 1990, Blondel & Aronson 1999, Tellería 2001, Díaz et al. 2003, Telleria et al. 2003, Harrop 2007). This mosaic of habitats has been widely recognized as a hotspot of farmland biodiversity and exponents of landscape multifunctionality (Pinto-Correia et al. 2011a).

We focused our study on cork oak *montados* due to the relevance of the area they occupy in Portugal – c. 737 000 ha (DGRF 2007) – and its influence on national economy, representing 1% of the GNP (APCOR 2012). Currently, Portugal harbours 34% of the world distribution of *montados*, holding half of the cork production of the world. Cork exploitation is highly sustainable, since the cork oak tree possesses the particular ability of producing a cork layer in the bark that regenerates after the debarking process. This biological feature allows the extraction of the bark from the tree in nine-year cycles without resulting in the death of the tree.

Despite its economic and environmental relevance, *montados* have been exposed to several pressures and threats, mainly intensification, overgrazing, land abandonment and the spreading of pathogenic agents (Plieninger 2007), but also extensification through lower grazing density and lower shrub control (Pinto-Correia & Almeida 2013). Therefore, management options able to conciliate the maintenance of biodiversity and the economic values of the *montado* are critical, and objective criteria must be described for the functioning of the system and for the services it provides (Andersen et al. 2003). This is particularly relevant regarding the High Nature Value (HNV) classification, which aims to integrate biodiversity and environmental concerns in the agricultural sector (Beaufoy & Cooper 2008). The HNV concept involves low intensity farming, presence of semi-natural vegetation (*e.g.* hedgerows, uncultivated fields/patch's, shrubs, scattered trees) and diversity of land cover, that sustains or is associated to areas with high species diversity or to the presence of priority species for conservation at European, national or regional scale (Andersen et al. 2003, Hoffmann & Greef 2003, Kleijn et al. 2009).

According to the classification proposed by the European Environment Agency, most of the silvopastoral systems in the Iberian Peninsula are considered HNV systems (Hoogeveen et al. 2004). However, unlike forestry systems such as pine (*Pinus* spp.) plantations (Scarascia-Mugnozza et al. 2000), the diverse and most common management activities conducted in *montados* throughout the year (*e.g.* agriculture, pasture, grazing, livestock, game, etc.) are known to increase the structural complexity of the system, producing several types of *montado* in different natural conditions and different management contexts (Correia 1993, Pinto-Correia & Almeida 2013). Hence, the question raised by Pinto-Correia & Almeida (2013) remains: can all *montados* typologies be classified as HNV systems?

It is recognized that *montados* exhibit the highest richness of communities of breeding birds associated with forested areas in the Iberian Peninsula (Tellería 2001). Moreover, many bird species seem to be well adapted to this system and several species even show a tolerance to debark (Godinho & Rabaça 2011, Leal et al. 2011). When compared with other HNV systems, *montados* have a major forest component which increases its structural complexity. Since communities of breeding birds have long been recognized as good indicators of the structural complexity of forested areas (*e.g.* Willson 1974, Rabaça 1990, Whelan 2001, Pereira et al. 2014), we used assemblages of breeding birds to evaluate: (1) which features of *montado* contribute to higher species diversity and richness, (2) if these parameters – diversity and richness – and/or bird guilds can be used to identify *montado* areas to be classified as HNV, and (3) if a specific bird guild can better represent *montado* natural values than community parameters like species richness or diversity.

5.3. Methods

5.3.1. Study area

We sampled four areas covering the main distribution range of cork oak in Portugal (Fig 5.1): the Site of Community Importance (SCI) of Romeu (hereafter Romeu) with several private owners (7º 1'-7º 6'W and 41º 33'-41º 28'N), Companhia das Lezírias S.A. (Lezírias) a public ownership farm (8°48'W and 38°50'N), SCI Serra de Monfurado (Monfurado) (7° 40'–8° 16'W and 38° 27'–38° 41'N) and Serra de Grândola (Grândola) (8º 34'-8º 38' W and 38º 9'-38º 08' N) both with several private owners. These areas reflect the most common typologies of *montados*, half of the national distribution of cork oak has a tree coverage between 10-30%, a quarter between 30-50% and a quarter superior to 50% (Carreiras et al. 2006). Our sampling sites represent these three categories in a similar proportion. Lezírias and Monfurado had sites belonging to all categories; sites with higher tree cover were absent and in Romeu and Grândola (Fig 5.2). These areas are located in the Mediterranean part of the country (Northeast and the entire Southern half of Portugal), characterized by hot and dry summers and moderate rainy winters. Altitude ranges between 15 m (Lezírias) and 600 m (Romeu). Romeu and Monfurado showed the lowest mean annual temperature (12.3ºC and 12.5ºC, respectively) and the highest levels of mean annual precipitation (760 and 800 mm, respectively). Lezírias and Grândola showed a mean annual temperature of 15.7ºC and 15.6ºC, respectively, and lower levels of mean annual precipitation (644 and 500 mm, correspondingly). The woodland area is dominated by cork oaks, but holm oak settlements can be found in Monfurado and mixed stands with cork oak, maritime pine (*Pinus pinaster*) and stone pine (*Pinus pinea*) occur in Lezírias. Other common land uses are: rice fields, vineyards and pine woods in Lezírias; olive groves, small orchards, dry cereal fields and fallows in Monfurado; and olive groves and vineyards in Romeu. Riparian galleries are present in all areas.

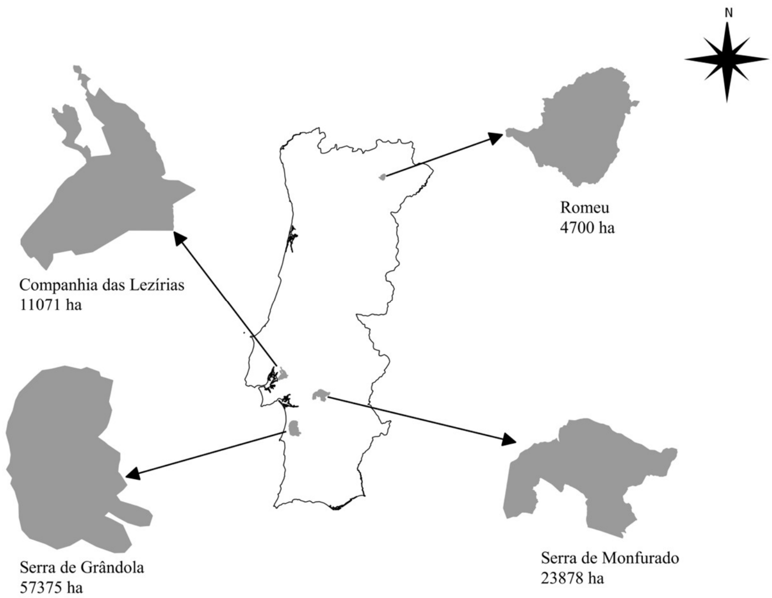

Figure 5.1 – Location of the study areas in Portugal.

5.3.2. Bird census

We carried out bird censuses in Monfurado (2011) and in other areas (2012) during the breeding seasons (between April and May). We gathered data on bird species using 10 min point counts (*e.g.* Bibby et al. 2000) with 100 m radius. We conducted surveys between 6:00 and 11:00 a.m., when birds are more active, and we avoided days with hard wind and rain. In each study area we surveyed 30 sites except in Romeu where we sampled 27 points. Our four areas covered a wide range of the different *montado* typologies present in Portugal (Fig 5.2), and sites were randomly selected, as long as they satisfied two criteria: (1) accessibility and (2) being situated at least 500 m apart from each other to minimize the probability of double counting birds. Three experienced observers with similar skills of bird detection conducted the surveys.

We excluded aerial-feeding birds (*e.g.* barn swallow *Hirundo rustica*) from data treatment, as well as species with known large home-ranges (*e.g.* carrion crow *Corvus corone* and raven *C. corax*).

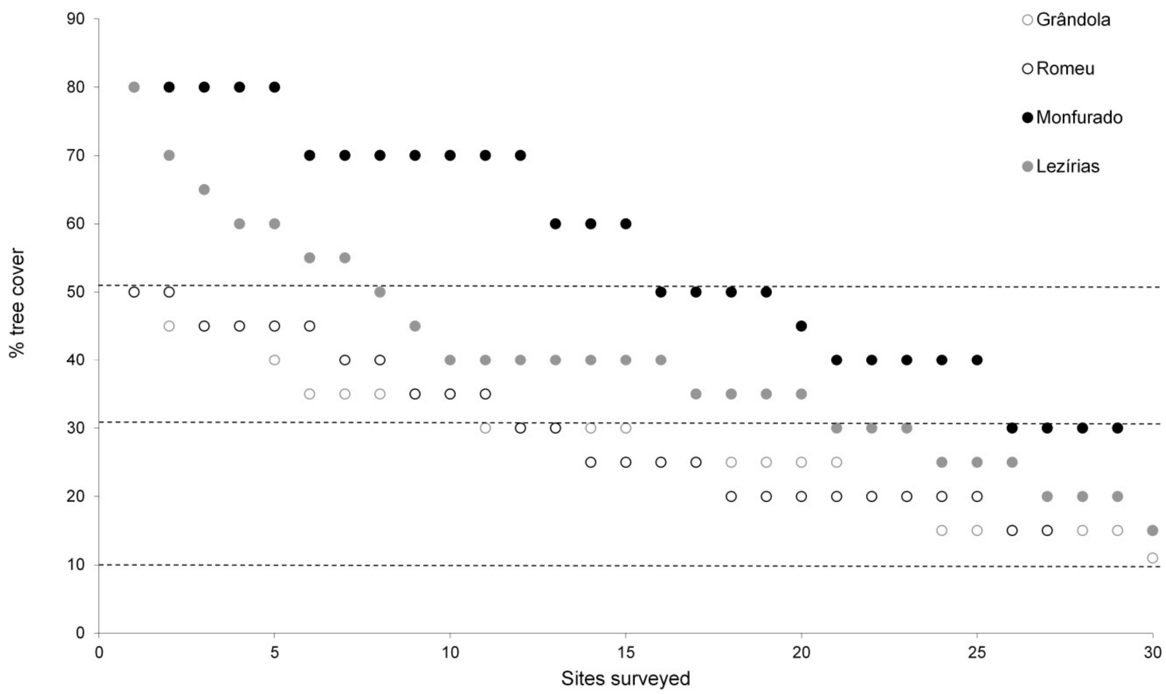

Figure 5.2 – Distribution of sampling sites along a gradient of *montado* coverage.

We used the species richness of each of the following four ecological guilds (Farmland Species, Edge Species, Forest Generalists and Forest Specialists) defined according to their habitat preferences in the Mediterranean part of Portugal during the breeding season (Table 5.I). Species classification is related to the specialization degree taking into account the habitats occupied along a gradient of natural terrestrial habitats, and may not be applicable outside this geographic area or time of year. This gradient can be represented by an increased complexity of vegetation structure, from structurally simpler habitats such as grasslands to intermediate habitats as heathlands and scrublands culminating in oak forests (such as cork oak or holm oak). To this end, we used the available information regarding places and strategies used to capture food, sites used for territorial defence as well as nesting sites. Farmland Species mostly occur in association with open fields or, at most, with scattered shrubs or trees; Edge Species are associated with transitional areas that can occur at boundaries between two or more habitats (*e.g.* forest and open areas); Forest Generalists occur at any woody areas, regardless of the density and height of the tree formations; Forest Specialists tend to occupy stable forest environments and are therefore more sensitive to human disturbance than generalist forest species. Most occur in natural or semi-natural forests with the following features: (1) high canopy of great maturity, (2) large stratification of woody vegetation, and (3) humid microclimate.

In addition to ecological guilds we also considered Shannon's diversity index (ShInd), total species richness (SpRich) and a variable that takes into account the richness of species with conservation status (ConSt). This variable was estimated as the richness by point count of species listed in at least one of these lists: the Red Book of Vertebrate of Portugal (Cabral et al. 2005), Species of European Conservation Concern (Birdlife 2004) and IUCN Red List for Birds (Birdlife 2014).

Table 5.I – Ecological guilds based on species habitat preferences

Bird Guild	Definition criteria	Species
Forest Specialists	Species that occur only in certain forest types	*Dendrocopos minor, Troglodytes troglodytes, Erithacus rubecula, Phoenicurus phoenicurus, Sylvia atricapilla, Phylloscopus bonelli, Phylloscopus ibericus, Aegithalos caudatus, Sitta europaea, Coccothraustes coccothraustes*
Forest Generalists	Forest species that occur in any woody areas, regardless of the density and height of the plant formations, as well as bioclimatic conditions of the site	*Columba palumbus, Cuculus canorus, Dendrocopos major, Luscinia megarhynchos, Turdus merula, Sylvia melanocephala, Lophophanes cristatus, Cyanistes caeruleus, Parus major, Certhia brachydactyla, Garrulus glandarius, Oriolus oriolus, Fringilla coelebs, Serinus serinus, Carduelis chloris*
Edge Species	Species that occur at the boundary between two or more habitats	*Streptopelia turtur, Clamator glandarius, Jynx torquilla, Lullula arborea, Hippolais polyglotta, Sylvia undata, Sylvia cantillans, Lanius meridionalis, Lanius senator, Passer montanus, Petronia petronia, Carduelis carduelis, Carduelis cannabina, Emberiza cirlus, Emberiza cia*
Farmland Species	Farmland species that tolerate low tree densities	*Alectoris rufa, Coturnix coturnix, Upupa epops, Galerida theklae, Oenanthe hispanica, Saxicola rubicula, Cisticola juncidis, Sturnus unicolor, Passer domesticus, Emberiza calandra*

5.3.3. HNV features and explanatory variables

Due to their nature, *montado* landscapes are distinguished by fuzzy boundaries with overlapping land cover classes (diverse combinations of forest cover, grass and shrubs) (Pinto-Correia & Vos 2004), they are often characterized by gradual changes in shrub and tree densities, resulting from the combination of different levels of land use and of variable, extensive land use practices. The fuzziness of the boundaries is inherent to the land use system and should be accepted as such. Small differences in terms of tree density and shrub cover reflect important differences in abiotic factors (Joffre et al. 1999), types of the management in the past and present (Pinto-Correia 1993) and levels of biodiversity (Ojeda et al. 1995).

We recorded environmental variables for each sampling site that, according to our rationale, could represent the heterogeneity within the *montado*: (1) tree density; (2) shrub density; (3) woody richness; (4) type of edge and; (5) distance to edge (Table 5.II). We also recorded geographical variables (location and altitude), management variables (trunk diameter at breast height, debark), and variables associated with the sanitary status of the settlements (occurrence of pest's outbreaks and fungal presence) (Table 5.II). Immediately after conducting the bird censuses, we evaluated the vegetation features within a 100 m radius around the centre of the point count.

Table 5.II – Environmental variables recorded at each one of the sampling sites

Environmental variables	**Code**
Geographical variables	
Geographical location (coordinates)	Point
Identification of the four areas surveyed	Study Area
Altitude (m)	Alt
Vegetation features	
Shrubs density	Shrubs
Trees density	Trees
Woody richness including tree and shrub species (categorical; 1-one or two woody species; 2-three or more woody species)	Woody
Management practices	
Trunk diameter at breast height (cm)	DBH
Year of the last cork removal	Debark
Type of edge (categorical; 1-open area; 2-shrubs and vineyards; 3-eucalyptus, pine plantations, orchards, olive groves)	Edge
Distance to the edge (m)	EdgeD
Sanitary status	
Presence/absence of *Biscogniauxia mediterranea*	Bmed
Presence/absence of *Coroebus florentinus* damage	Cflo
Presence/absence of *Coroebus undatus* damage	Cund
Presence/absence of bark beetles (Platypodidae and Scolytidae) and cerambycids (Cerambycidae) damage	BarkB

At each point of the study areas, the sanitary status of the oak woodlands was evaluated through visual assessment of five oaks separated 10 m from each other, avoiding trees with adjoined crowns. We detected the damage made by buprestids *Coroebus florentinus* and *Coroebus undatus* through the presence of typical dead branches on outer-canopy and the presence of feeding galleries of larvae on the cork layer, respectively. These measures were used as individual variables, but also incorporated together with insect trunk holes of bark beetle (Platypodidae and Scolytidae), cerambycids (Cerambycidae) and signs of fungal disease *Biscogniauxia* *mediterranea* to create a sanitary index (San). We created the sanitary index for *montado* according to the level of harm done by insect pests on the sampling sites. For each insect pest and fungus we attributed a coefficient of impact according to the intensity of their damage on the tree: 1 – high aesthetic impact with low economic or ecological relevance (*C. florentinus*), 3 – high economic relevance due to loss of cork value (*C. undatus*), 5 – associated with tree decline or death (bark beetles, cerambycids and *B. mediterranea*).

We created the sanitary index through the sum of the proportion of each pest or disease, which was multiplied by the respective impact coefficient.

$$San = 1\left(\frac{OA\ Cflo}{5\ oaks}\right) + 3\left(\frac{OA\ Cund}{5\ oaks}\right) + 5\left(\frac{OA\ Barkb}{5\ oaks}\right) + 5\left(\frac{OA\ Bmed}{5\ oaks}\right)$$

OA - oaks affected by each pest or disease

5.3.4. Data analysis

Prior to data analysis and in order to avoid multicollinearity among variables, we performed data reduction procedures. According to Tabachnick & Fidell (2001), we assessed all pairwise correlations through Spearman correlation coefficients and retained only one in each pair of highly correlated variables (r>|0.7|) for further analyses. Only a pair of variables showed strong collinearity Altitude and Study Area (r = 0.934). Altitude was removed due to the autocorrelation of this variable between sampling sites belonging to the same study area. We used one-way ANOVA (Zar 1999) to determine if there were differences between areas in terms of ecological guilds and environmental variables.

We modelled the effects of environmental variables in function of groups of species through linear mixed-effects models (Pinheiro & Bates 2000). We treated Study Area as random effect and all other explanatory variables as fixed effects. To deal with model selection uncertainty we analysed our data based on the Information Theoretic Approach (ITA) (Burnham & Anderson 2002). In the analyses of species groups (bird richness of every guild), Shannon’s diversity index and total species richness, we considered as fixed effects the following six variables which are representative of the heterogeneity inside the *montado*: shrubs density; trees density; woody richness; type of edge; distance to edge; and sanitary index.

We generated all possible models combining from none to seven explanatory variables. We used this option, classified as data dredging (Burnham & Anderson 2002), because all explanatory variables considered could potentially influence the response variables. Using all possible combinations, we guaranteed that the explanatory variables were included in the model-averaging procedure in identical manner. In accordance with Burnham & Anderson (2002), we fitted the models one by one and ordered them by their values of AICc (second-order Akaike's information criterion). We used AICc as a measure of information loss for each candidate model, with the best fitting model having the lowest AICc and the highest Akaike weight (wi), which measures the posterior probability of a given model being true, given the data and the set of competing candidate models (Burnham & Anderson 2002). Additionally, we also calculated the number of parameters (degrees of freedom), log-likelihood value and AICc difference (ΔAICc), and the model-averaged coefficients of all explanatory variables for each model (Burnham & Anderson 2002, Lukacs et al. 2010, Symonds & Moussali 2011). Finally, we estimated the relative importance of each explanatory variable, by adding the Akaike weights of all models in which the variable appeared (Burnham & Anderson 2002). The relative importance of the variables that appear in all top models tends towards 1. In variables that only appear in less likely models, their relative importance tends towards 0. We then ranked the explanatory variables according to their relative importance, and the direction and magnitude of the effect of each variable was based on the model-averaged coefficients (Burnham & Anderson 2002).

We carried out the statistical analysis using SPSS 21 for Windows (IBMCorp. 2012) and software R v. 3.0.2 (RCoreTeam 2013), with package MuMIn (Barton 2013) and nlme (Pinheiro et al. 2014).

5.4. Results

From 74 species recorded in surveys, we used 50 in the analyses and hereafter we will refer only to those. Almost 40% of these species show some level of threat, according to the Species of European Conservation Concern (SPEC) (BirdLife International 2004) or have conservation status by the Portuguese Red Book of

Vertebrates (Cabral et al. 2005) or the IUCN Red List (BirdLife International 2014) (Supplementary material). We detected 17 of the 50 species in all areas. On the other hand, we detected five bird species exclusive from Romeu, three exclusive from Monfurado and Lezírias and one exclusive from Grândola (Supplementary material). Average species richness and standard deviation, per point count, was 6.8±1.3 in Grândola, 7.3±1.2 in Romeu, 8.5±2.1 in Lezírias and 11.2±2.4 in Monfurado.

5.4.1. Environmental variables

In order to evaluate how our environmental variables range along the four areas we run one-way ANOVAs for each variable, with a Bonferroni correction post-hoc test (Table 5.III). The average age of cork removal (Debark) and the distance to the edge (EdgeD) were similar between all areas. On the contrary, *Altitude* was significantly different among all areas. Although shrub coverage was higher in Grândola, being almost the double than in Lezírias and Monfurado, tree coverage and woody diversity were the lowest observed. Monfurado was the area with higher tree coverage and significantly different from all the others. Diversity of woody vegetation was higher in Lezírias and Monfurado and statistically different from Grândola and Romeu. The oldest settlements were observed in Romeu and Lezírias (based on trunk diameter at breast high – DBH), being statistically different from Monfurado.

We observed a similar pattern for both *Coroebus* species, with lower values of affectation in Romeu and higher values in Grândola and Monfurado. In this sense, these areas were significantly different for both pests. Romeu emerges as the area with less evidence of affectation in regard to the sanitary status index.

Table 5.III - One-way ANOVA for environmental variables (Shrubs – density of shrubs, Trees – density of trees, Woody – woody richness including trees and shrubs, Debark – year of the last cork removal, DBH – trunk diameter at breast high, Cund – damage by *Coroebus undatus*, Cflo – damage by *Coroebus florentinus*, San – sanitary index, Alt – altitude and EdgeD – distance to edge) according to each area (G - Serra de Grândola, L – Companhia das Lezírias, M - Serra de Monfurado and R - Romeu).

Areas	**Shrubs**	**Trees**	**Woody**	**Debark**	**DBH**	***Cund***	***Cflo***	**San**	**Alt**	**EdgeD**
G (n=30)	60±30.73	28±10.64	1.13±0.35	5.13±3.27	35.28±5.76	2.13±0.73	1.70±0.88	7.63±2.35	205.83±43.56	115.27±85.03
L (n=30)	32.90±27.96	40±15.97	1.87±0.35	6.13±2.54	39.51±8.22	1.73±0.74	1.73±0.91	6.95±1.08	32.27±8.24	86.53±53.26
M (n=30)	38.50±32.56	55±18.75	1.87±0.35	5.23±1.94	33.16±5.74	2.23±0.86	1.80±0.55	7.31±1.11	294.33±52.89	77.30±76.83
R (n=27)	52.96±26.86	30.19±11.31	1.15±0.36	6.89±2.59	39.04±7.37	1.48±0.51	1.15±0.36	5.15±1.65	454±91.08	106.41±101.06
F	5.53	20.87	42.08	2.81	5.84	6.67	4.87	12.86	282.58	1.41
P	<0.001	<0.001	<0.001	<0.05	<0.001	<0.001	<0.01	<0.001	<0.001	0.244
					Bonferroni correction					
GxR	-	-	-	-	-	<0.01	<0.05	<0.001	<0.001	-
GxL	<0.01	<0.05	<0.001	-	-	-	-	-	<0.001	-
GxM	<0.05	<0.001	<0.001	-	-	-	-	-	<0.001	-
RxL	-	-	<0.001	-	-	-	<0.05	<0.001	<0.001	-
RxM	-	<0.001	<0.001	-	<0.01	<0.01	<0.01	<0.001	<0.001	-
LxM	-	<0.05	-	-	<0.01	-	-	-	<0.001	-

Note: Values represent average richness and respectively standard deviation, and results with significant differences after applying the Bonferroni correction.

5.4.2. Bird guilds

In order to evaluate how our species ranged along the four areas we run a one-way ANOVA among areas for each species guild, with a Bonferroni correction post-hoc test. Significant differences were observed between areas for all guilds analyzed, and also for total bird richness, species diversity and conservation status (Table 5.IV). Monfurado was the area with highest species richness for all bird guilds, with the exception of Farmland Species. Lezírias had the highest values for this guild whereas it appears to be residual in Romeu. Romeu had the lowest value for species with conservation status, and Monfurado presented the highest species richness of this guild. As expected, based on guilds results, Monfurado stood out from the other areas regarding species diversity and total species richness. The other areas did not present significant statistical differences, with the exception of higher species richness in Lezírias than in Grândola.

Table 5.IV - One-way ANOVA for species richness by ecological guild (Fa – Farmland Species, ES – Edge species, FoG – Forest Generalists, FoS – Forest Specialists, ConSt – Conservation Status), Shannon's diversity index (ShInd) and total species richness (SpRich) according to each area (G - Serra de Grândola, L – Companhia das Lezírias, M - Serra de Monfurado and R - Romeu).

Areas	**Fa**	**ES**	**FoG**	**FoS**	**ConSt**	**ShInd**	**SpRich**
G (n=30)	0.97±1.10	0.50±0.63	4.03±1.16	1.30±0.70	1.20±0.85	0.79±0.10	6.80±1.32
L (n=30)	1.90±1.21	1.20±0.93	4.37±1.38	1.07±0.94	1.57±0.90	0.86±0.12	8.53±2.10
M (n=30)	1.77±1.43	1.80±1.00	5.77±2.37	1.90±1.37	2.23±1.41	0.99±0.15	11.23±2.43
R (n=27)	0.15±0.36	0.85±0.95	5.19±1.39	1.15±0.86	0.63±0.74	0.83±0.08	7.33±1.24
F	14.96	11.69	6.77	4.17	12.62	16.56	33.61
P	<0.001	<0.001	<0.001	<0.01	<0.001	<0.001	<0.001
			Bonferroni correction				
GxR	<0.05	-	-	-	-	-	-
GxL	<0.01	<0.05	-	-	-	-	<0.01
GxM	<0.05	<0.001	<0.01	-	<0.01	<0.001	<0.001
RxL	<0.001	-	-	-	<0.01	-	-
RxM	<0.001	<0.01	-	<0.05	<0.001	<0.001	<0.001
LxM	-	-	<0.01	<0.05	-	<0.001	<0.001

Note: Values represent average richness and respectively standard deviation, and results with significant differences after applying the Bonferroni correction

5.4.3. Modelling Bird guilds

We ranked the candidate models for each one of the response variables based on the AICc (ΔAICc<2.00) and also estimated the relative importance of each variable (Table 5.V) (Burnham & Anderson 2002).

Table 5.V – Results from the multi-model inference procedure for the parameters describing species guilds associations to environmental variables: relative variable importance (RVI) and trend of the relationship. The asterisk indicates the variables included in the best models (ΔAICc < 2.00).

	Farmland Species		Edge Species		Forest Generalists		Forest Specialists		Conservation Status		Shannon's Diversity Index		Species Richness	
	RVI	trend	RVI	trend	RVI	trend	RVI	trend	RVI	trend	RVI	trend	RVI	trend
Edge	0.69*	-	0.23	-	0.10	+	0.37*	+	0.89*	-	<0.01	+	0.23	-
Distance to edge	<0.01	+	<0.01	-	<0.01	+	<0.01	+	<0.01	+	<0.01	+	<0.01	-
Sanitary index	0.04	+	0.05	+	0.48*	+	0.05	+	0.06	+	0.99*	+	0.60*	+
Shrubs density	0.11	-	0.01	-	0.01	+	0.33*	+	0.01	-	<0.01	+	0.01	+
Trees density	0.92*	-	0.08	-	0.27*	+	1*	+	0.86*	-	<0.01	+	0.02	+
Woody	0.29*	+	0.17	+	0.42*	+	0.30*	+	0.21	+	0.94*	+	0.96*	+

Farmland Species: three variables - tree density, edge type, and woody species - were included in the set of best models (Table 5.VI - supplementary material). Tree density assumed the greatest importance (0.92), being negatively associated with the richness of Farmland Species. Edge type also had a high relative importance (0.69), with these species being negatively influenced by the presence of non-agricultural edges. Woody species still had some relative importance. Patches with more woody species showed a greater richness of farmland birds.

Edge Species: none of the variables showed an association with this group of species, the top ranked model being the null model (Table VI).

Forest Generalists: although the null model was ranked in the best set of models (in fourth position – Table 5.VI), we found it useful to discuss the variables that enter in the other models. These included three variables – sanitary index, woody species and tree density (table 5.V); all positively associated with this guild.

Forest Specialists: the most relevant variables in the candidate models were tree density, edge type, shrubs density and woody species. Sites with higher tree cover were most important to this species (1.00) being present in all models.

Conservation Status: two variables - edge type and tree density – were included in the models, both influencing negatively the richness of species with conservation status. The types of edge that negatively influenced species with conservation status were forest edges (*e.g.* eucalyptus, pine, orchards) and shrub edges.

Shannon's diversity index: two variables assumed higher importance, and positively influence species diversity: sanitary index (0.95) and woody species (0.88).

Species richness: as in the case of the Shannon's diversity index, the variables included in the models were woody species and sanitary index.

5.5. Discussion

In a first approach we characterized areas and associated bird guilds in order to have a better perception of their similarities and differences, allowing us to distinguish eventual patterns arising from regional influence. The analysis showed the amplitude of *montados* evaluated throughout the country (Table 5.III), and even inside of each area, this is particularly relevant when we try to assess associations between bird guilds and HNV features.

The highest richness for most guilds (except for Farmland Species) was associated with Monfurado (Table 5.IV), this area revealing high amplitude in variables associated with landscape heterogeneity (trees, woody and shrubs; Table 5.III). These results are in line with what has been documented by other authors (*e.g.* Blondel & Aronson 1999, Díaz et al. 2003, Harrop 2007). Actually, the heterogeneous pattern of wooded matrix with open areas, scattered woodlands and undisturbed patches of Mediterranean forest and scrublands, creates a patchwork of habitats which is a trait of *montado* landscape, and induces the highest richness in breeding bird communities in the Iberian Peninsula (*e.g.* Tellería 2001). So, areas that encompass higher densities of shrubs and trees and that are more diverse in woody species have greater potential of being considered good habitats for a large number of species, including species of conservation concern (*e.g.* redstart *Phoenicurus phoenicurus* and crested tit *Lophophanes cristatus*).

Species belonging to the farmland guild, including thekla lark (*Galerida theklae*), stonechat (*Saxicola rubicula*) and corn bunting (*Emberiza calandra*), are tolerant to the presence of trees in their breeding sites. Therefore, they can occur in *montados*, contrarily to what happens to strict farmland species (Moreira et al. 2005). This guild is associated with scattered *montados* and to agricultural edges, decreasing its densities with the proximity of forested edges, like eucalyptus or pine plantations. Such tendency was also recorded by Reino et al. (2009) with the same group of species but in a farmland context. According to such relations between birds and habitat, the Farmland Species occurring in *montados* can be defined as generalist farmland species. Therefore, the diversity of woody vegetation may provide them with more ecological niches; however, shrub coverage must be low since most of these species nests in open ground.

The fuzziness of the *montado* may be the reason for the absence of strong relations between the variables considered and Edge Species. In *montado* these species are associated with the decreasing density of vegetation (*e.g.* trees and shrubs) more than with the abrupt transition between farmland and forestry patches or early-successional habitats as in the case of Central and Northern Europe (*e.g.* Imbeau et al. 2003; Storch et al. 2005). Additionally, inside the guild there are species associated with different kinds of forest interfaces, for example: Turtle dove (*Streptopelia turtur*), melodious warbler (*Hippolais polyglotta*) and cirl bunting (*Emberiza cirlus*) are mainly associated with forest – farmland edges; wood lark (*Lullula arborea*), Iberian grey shrike (*Lanius meridionalis*) and rock sparrow (*Petronia petronia*) are mainly associated with scattered arboreal vegetation such as sparse *montados*, which can be considered transitional habitats between forested and open areas. The diversity of species-habitat associations in this guild is reflected in the uncertainty of the variables considered in the models (Table 5.VII; supplementary material).

Into a more comprehensive view, the forest is the most important component within the cork oak *montados*, and the occurrence of generalist forest species along a wide range of *montado* typologies is to be expected. Our data reveals a preference for diversity of woody vegetation and tree density, although the association with sites with higher pest affectation (reflecting more degraded areas) may indicate the avoidance of sites with higher tree coverage.

The occurrence of forest specialist species was associated with higher densities of trees and shrubs, and with forested edges. These features characterize old and complex *montados*. In a Mediterranean context, species like wren (*Troglodytes troglodytes*), blackcap (*Sylvia atricapilla*) and European robin (*Erithacus rubecula*) use the remaining patches of ancient oak forest with several vegetation strata (*e.g.* Pérez-

Tris et al. 2004) which is a rare feature across *montado*. Besides, these patches allow an increase of niche availability for species and can be used as an important evaluation element of HNV in Europe (Morelli 2013).

The occurrence of priority species for conservation is one of the key points for a site to be recognized as HNV. In our study these species are associated with sparser *montados* and with farmland edge, in other words they tend to avoid more mature and complex sites. This trend is directly influenced by the existing imbalance between the species of this group: 16 out of 19 species (84%) with some criteria of conservation are Farmland or Edge Species associated with the interface forest-farmland. We suggest that this result should be considered with some caution because most of the threatened forest species that nesting in *montado* were not targeted by our study since they have large territories (*e.g.* raptors, black stork) and this could be another factor of bias. The inclusion of other conservation criteria must be considered, such as those proposed by Tavares (2009), based on species of which Portugal hosts significant populations at European level, thus having a responsibility for their conservation (*e.g.* Iberian chiffchaff *Phylloscopus ibericus* or serin *Serinus serinus*).

Species richness and species diversity showed the same trend, being positively associated with areas that have higher diversity of woody vegetation and higher values of sanitary index. The association between these two indices and the sanitary condition may reflect (1) the current state of conservation of *montados* and (2) the influence of the forest generalist species in the species taken as a whole. Most of these species were recorded along several sampling sites (*e.g.* blue tit *Cyanistes caeruleus*, short-toed treecreeper *Certhia brachydactyla*, blackbird *Turdus merula*) which suggests that the global indexes were primarily influenced by the presence of forest generalist species. Cork oak decline has been reported in Southwestern Portugal since the 1890's (Cabral et al. 1992) and therefore, in the light of our results, it seems plausible to state that most of the surveyed areas are under some kind of threat.

5.6. Conclusion

The continuous gradient of land cover and fuzzy boundaries characteristic of *montado* (Pinto-Correia et al. 2011) are well expressed in the variables of density and diversity of vegetation and their association with the bird guilds evaluated. With the exception of the Edge Species, these variables were important to all the other bird groups (Table 5.V). The guilds under consideration mainly characterized a gradient of forest complexity, from the Farmland Species to the Forest Specialists, and perhaps they can be individually used as HNV indicators of a particular typology of *montado*, based on tree coverage: Farmland Species for scattered areas; and, on the opposite side of the range, Forest Specialists for more mature settlements or small well-preserved forest patches. We cannot say if all *montado* typologies can be classified as HNV, but we can define characteristic bird guilds for several typologies, and through the ratio between the species observed and the expected pool of species it should be possible to evaluate if a site may be classified as HNV. At a broader scale the universal measures of species diversity and species richness could also be used as HNV indicators.

The next steps on research should be focused on: (1) the creation and testing of a compound index with farmland, forest generalists and forest specialists species in order to create a reliable indicator of HNV for *montados* applicable to several scales, (2) the assessment of other HNV parameters for *montado* such as stone piles, ponds or fences, and (3) the integration of other species conservation criteria in addition of the traditional red lists.

5.7. Supplementary material

List of analyzed species, common and scientific names (taxonomic order), number of sampling sites where the species was detected (N=117) and area (L - Companhia das Lezírias, G - Serra de Grândola, M - Serra de Monfurado and R - Romeu), and conservation status (BI – Birdlife International, RB – Red Book of Vertebrates of Portugal) (NT - Near Threatened, VU – Vulnerable, DD – Data Deficient)

Common name	Scientific name	N	Area	Conservation status
Red-legged Partridge	*Alectoris rufa*	3	G, M	SPEC 2
Quail	*Coturnix coturnix*	2	L, M	SPEC 3
Wood Pigeon	*Columba palumbus*	18	L, M, R	
Turtle Dove	*Streptopelia turtur*	1	M	SPEC 3
Cuckoo	*Cuculus canorus*	14	L, G, M, R	
Great Spotted Cuckoo	*Clamator glandarius*	1	L	VU (RB)
Hoopoe	*Upupa epops*	10	L, G, M	SPEC 3
Great Spotted Woodpecker	*Dendrocopos major*	24	G, M, R	
Lesser Spotted Woodpecker	*Dendrocopos minor*	11	G, M	
Wryneck	*Jynx torquilla*	2	R	DD (RB) SPEC 3
Thekla Lark	*Galerida theklae*	9	G, M, R	SPEC 3
Wood Lark	*Lullula arborea*	45	L, G, M, R	SPEC 2
Wren	*Troglodytes troglodytes*	48	L, G, M, R	
European Robin	*Erithacus rubecula*	4	R	
Common Nightingale	*Luscinia megarhynchos*	58	L, G, M, R	
Redstart	*Phoenicurus phoenicurus*	8	L, G, M, R	SPEC 2
Black-eared Wheatear	*Oenanthe hispanica*	1	G	VU (RB)
Common Stonechat	*Saxicola rubicula*	14	L, G, M	
Common Blackbird	*Turdus merula*	50	L, G, M, R	
Zitting Cisticola	*Cisticola juncidis*	12	L, G	
Melodious Warbler	*Hippolais polyglotta*	18	L, M	
Blackcap	*Sylvia atricapilla*	14	L, M, R	
Dartford Warbler	*Sylvia undata*	2	G, R	NT (Birdlife)
Subalpine Warbler	*Sylvia cantillans*	5	R	
Sardinian Warbler	*Sylvia melanocephala*	55	L, G, M, R	
Western Bonelli's Warbler	*Phylloscopus bonelli*	9	L	SPEC 2
Iberian Chiffchaff	*Phylloscopus ibericus*	13	G, M	
Long-tailed Tit	*Aegithalos caudatus*	3	R	
Crested Tit	*Lophophanes cristatus*	14	L, G, M	SPEC 2
Blue Tit	*Cyanistes caeruleus*	80	L, G, M, R	
Great Tit	*Parus major*	44	L, G, M, R	
Nuthatch	*Sitta europaea*	46	L, G, M, R	

Short-toed Tree-creeper	*Certhia brachydactyla*	50	L, G, M, R	
Iberian Grey Shrike	*Lanius meridionalis*	1	L	
Woodchat Shrike	*Lanius senator*	6	M	NT (RB)
Jay	*Garrulus glandarius*	12	L, G, M	
Spotless Starling	*Sturnus unicolor*	47	L, G, M, R	
Golden Oriole	*Oriolus oriolus*	3	L, G	
House Sparrow	*Passer domesticus*	5	G, M, R	SPEC 3
Tree Sparrow	*Passer montanus*	4	L, M	SPEC 3
Rock Sparrow	*Petronia petronia*	4	L, G, M, R	
Chaffinch	*Fringilla coelebs*	83	L, G, M, R	
European Serin	*Serinus serinus*	42	L, G, M, R	
European Greenfinch	*Carduelis chloris*	18	L, G, M, R	
Goldfinch	*Carduelis carduelis*	26	L, G, M, R	
Eurasian Linnet	*Carduelis cannabina*	4	M	SPEC 2
Hawfinch	*Coccothraustes coccothraustes*	3	L, M	
Cirl Bunting	*Emberiza cirlus*	7	G, M	
Rock Bunting	*Emberiza cia*	2	R	SPEC 3
Corn Bunting	*Emberiza calandra*	40	L, G, M	SPEC 2

Table 5.VI – Best models (ΔAICc < 2.00) analyzing the effects of environmental variables on species guilds

Variables in the model	df	log-likelihood	AICc	ΔAICc	Akaike weight
Farmland Species					
Edge + Trees density	6	-172.23	357.23	0.00	0.39
Trees density	4	-175.13	358.63	1.39	0.20
Edge + Trees density + Woody species	7	-171.93	358.89	1.66	0.17
Edge species					
Null	3	-156.47	319.15	0.00	0.54
Forest Generalists					
Sanitary index	4	-229.83	468.01	0.00	0.20
Sanitary index + Woody species	5	-229.00	468.55	0.54	0.15
Woody species	4	-230.16	468.68	0.68	0.14
Null	3	-231.24	468.69	0.69	0.14
Trees density	4	-230.35	469.06	1.06	0.12
Forest Specialists					
Trees density	4	-151.50	311.35	0.00	0.24
Edge + Trees density	6	-149.52	311.80	0.45	0.19
Shrubs density + Trees density	5	-150.72	311.97	0.62	0.18
Trees density + Woody species	5	-151.15	312.84	1.49	0.12
Conservation Status					
Edge + Trees density	6	-162.30	337.36	0.00	0.55
Shannon's diversity index					
Sanitary index + Woody species	5	-9.33	29.20	0.00	0.92
Species richness					
Sanitary index + Woody species	5	-236.71	483.97	0.00	0.43
Woody species	4	-238.19	484.74	0.77	0.29

Table 5.VII – Averaging results for the analysis on species guilds

	Model-averaged coefficient	SE	z	p	Relative variable importance
	Farmland Species				
Intercept	2.391	0.633	3.742	0.0001	-
Edge2: shrubs and vineyards	-0.572	0.243	2.325	0.02	0.68
Edge3: eucalyptus, pine plantations, orchards, olive groves	-0.586	0.243	2.391	0.017	0.68
Trees density	-0.031	0.007	4.154	3.27e-05	0.91
Woody species	0.285	0.269	1.047	0.295	0.27
Shrubs density	-0.011	0.004	2.762	0.006	0.11
Sanitary index	0.002	0.058	0.031	0.976	0.05
Distance to edge	0.001	0.001	0.84	0.401	<0.01
	Edge Species				
Intercept	1.122	0.367	3.031	0.002	-
Edge2: shrubs and vineyards	-0.098	0.213	0.457	0.648	0.23
Edge3: eucalyptus, pine plantations, orchards, olive groves	-0.433	0.200	2.139	0.032	0.23
Presence of three or more woody species	0.100	0.230	0.431	0.666	0.17
Trees density	-0.014	0.006	2.470	0.014	0.08
Sanitary index	0.037	0.051	0.726	0.468	0.05
Shrubs density	-0.003	0.003	1.193	0.233	0.01
Distance to edge	-0.001	0.001	1.289	0.198	<0.01
	Forest Generalists				
Intercept	3.530e+00	1.055e+00	3328.00	0.0009	-
Sanitary index	2.165e-01	9.535e-02	2247.00	0.025	0.48
Presence of three or more woody species	5.010e-01	4.400e-01	1127.00	0.260	0.42
Trees density	2.960e-02	1.047e-02	2798.00	0.005	0.27
Edge2: shrubs and vineyards	1.314e-02	4.113e-01	0.03	0.975	0.1
Edge3: eucalyptus, pine plantations, orchards, olive groves	1.383e-01	4.071e-01	0.34	0.736	0.1
Shrubs density	7.624e-03	5.702e-03	1324.00	0.185	0.01
Distance to edge	8.477e-05	1.984e-03	0.04	0.966	<0.01

continue

	Model-averaged coefficient	SE	z	p	Relative variable importance
	Forest Specialists				
Intercept	-0.275	0.343	0.796	0.426	-
Trees density	0.033	0.006	5.466	< 2e-16	1
Edge2: shrubs and vineyards	0.321	0.204	1.558	0.119	0.37
Edge3: eucalyptus, pine plantations, orchards, olive groves	0.467	0.192	2.405	0.016	0.37
Shrubs density	0.009	0.003	3.526	0.001	0.33
Presence of three or more woody species	0.316	0.208	1.503	0.133	0.3
Sanitary index	0.039	0.046	0.828	0.408	0.05
Distance to edge	0.001	0.001	0.701	0.483	<0.01
	Conservation Status				
Intercept	2.432	0.578	4.172	3.02e-05	-
Edge2: shrubs and vineyards	-0.429	0.229	1.853	0.064	0.89
Edge3: eucalyptus, pine plantations, orchards, olive groves	-0.743	0.234	3.150	0.002	0.89
Trees density	-0.025	0.006	3.845	0.0001	0.86
Presence of three or more woody species	0.191	0.248	0.763	0.446	0.21
Sanitary index	0.045	0.053	0.839	0.401	0.06
Shrubs density	-0.004	0.004	1.085	0.278	0.01
Distance to edge	0.0002	0.001	0.162	0.871	<0.01
	Shannon´s Diversity Index				
Intercept	1.285	0.170	7.495	< 2e-16	-
Sanitary index	0.061	0.014	4.381	1.18e-05	0.99
Presence of three or more woody species	0.215	0.062	3.428	0.001	0.94
Edge2: shrubs and vineyards	0.022	0.059	0.369	0.712	<0.01
Edge3: eucalyptus, pine plantations, orchards, olive groves	0.006	0.056	0.111	0.912	<0.01
Trees density	0.002	0.002	0.960	0.337	<0.01
Shrubs density	0.0005	0.001	0.599	0.549	<0.01
Distance to edge	0.0002	0.0003	0.603	0.547	<0.01

continue

	Model-averaged coefficient	SE	z	p	Relative variable importance
	Species richness				
Intercept	5.298	1.376	3.828	0.0001	-
Sanitary index	0.245	0.101	2.402	0.016	0.96
Presence of three or more woody species	1.380	0.465	2.932	0.003	0.6
Edge2: shrubs and vineyards	-0.388	0.433	0.887	0.375	0.23
Edge3: eucalyptus, pine plantations, orchards, olive groves	-0.541	0.407	1.315	0.188	0.23
Trees density	0.013	0.012	0.988	0.323	0.02
Shrubs density	0.002	0.006	0.366	0.714	0.01
Distance to edge	-0.001	0.002	0.237	0.813	<0.01

Chapter

6

Forest bird diversity in native vs non-native forests. Montados, pinewoods or eucalyptus, who wins?

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To be submitted as a short note to Ibis

6.1. Abstract

We have studied, at a very fine scale, how forest bird species and the overall breeding bird community are distributed along the main native (montados and pinewoods) and exotic forests in Portugal.

Forty-five sampling plots were randomly selected, in homogenous forest areas, fifteen in each forest type and surveyed twice during the breeding season. The species-habitat association was evaluated through the species richness by functional guild.

The montado showed significant differences compared to eucalyptus forests for all of variables except *edge species.*

Montados exhibit the highest richness of communities of breeding birds associated with forested areas in the Iberian Peninsula, even on a small scale.

Keywords: species richness, bird communities, ecological guilds

6.2. Introduction

The growing demand of forest products has led to the expansion of tree plantations mainly with fast-growing species (World Bank 2008). The consequence of this worldwide expansion is an increasing pressure on natural and semi-natural forests (*e.g.* Aratrakorn et al. 2006, FAO 2010, Koh & Wilcove 2008, World Bank 2008). Understanding the impact of this changes on biodiversity is crucial to plan appropriate management measures for sustainable forest areas. Studies have been conducted on the similarities between natural forests and tree plantations, and their suitability to maintain forest biodiversity (*e.g.* Calviño-Cancela & Neumann 2015), with some controversial results (Calviño-Cancela et al. 2012, Stephens & Wagner 2007). This is mainly due to the fact that not all tree plantations have the same structure, or the same optimal rotation (it can range between few years and decades), and hence provide distinct habitat and micro-habitat conditions. Exotic species like *Eucalyptus globulus*, with higher growth rates than the native trees, contribute significantly to the regional economy (DAPFVS 2013), but may also be responsible for changes in the natural ecosystems with impact on biodiversity, namely in birds (De La Hera et al. 2013, Pina 1989, Tellería & Galarza 1990).

We have studied, at a very fine scale, how forest bird species and the overall breeding bird community are distributed along the main native (*montado*s and pinewoods) and exotic forests in Portugal. Cork oak *Quercus suber montado*s, pinewoods (maritime pine *Pinus pinaster*) and eucalyptus *Eucalyptus globulus* plantations are responsible for 72% of the Portuguese forested area and therefore were the selected forest habitats in our study. In order to avoid differences on the potential pool of species we sampled forest areas within the same geographical region and under the same landowner.

6.3. Methods

6.3.1. Study area

The study was carried out in central Portugal during the spring of 2009, in a public ownership farm “Companhia das Lezírias S.A.” (8º 48’W and 38º 50’N) (Fig. 6.1) with and area of 11500 ha. The area is mainly occupied by forests, of which 6725 ha are cork oak *montado*s, 971 ha by maritime pine and 476 ha by eucalyptus. In addition to forestry, but with minor extent, also vineyards, olive groves, rice fields, cereal cultures and livestock are present. The slope is soft and altitude ranges between 15 m and 50 m a.s.l.. Climate is typically Mediterranean with hot and dry summers and moderate rainy winters.

Figure 6.1 – Study area in the *Companhia das Lezírias*, maritime pine (dark), cork oak (dark grey) and eucalyptus (light grey).

6.3.2. Sampling sites and bird surveys

Forty-five sampling plots were randomly selected, in homogenous forest areas, fifteen in each forest type and surveyed twice during the breeding season. The first visit occurred in the beginning of April and the second in late May of 2009. Bird surveys were conducted using point counts with limited distance (100 m) and a counting period of 10 minutes (Bibby et al. 2005, Blondel et al. 1981), by two experienced observers with similar identification skills and distance estimation training (CG, PFP). Censuses were carried out in early hours after the sun rise, avoiding days with adverse weather conditions such as moderate rain or strong wind. We excluded aerial-feeders (*e.g.* barn swallow *Hirundo rustica*) from data treatment, as well as species with known large home-ranges (*e.g.* carrion crow *Corvus corone*), or wintering species (*e.g.* song trush *Turdus philomelos*). We selected species that were expected to be breeders in the forest surveyed, based on the Portuguese Breeding Bird Atlas (Equipa Atlas 2008) and our knowledge of the area.

The species-habitat association is based in bird habitat preferences in the Mediterranean part the country during the breeding season; *forest specialist* are species that occur only in certain forest types, *forest generalists* are forest species that occur in any woody area, regardless of the density and height of the plant formations, *edge species* occur at the boundary between two or more habitats and *farmland species* are those that tolerate low tree densities (for a detailed description see Catarino et al. 2016 and Pereira et al. 2015).

6.3.3. Data analysis

For species accumulation curves we used EstimateS 9.1.0 (Colwell 2013), which represents the cumulative number of species as a function of the surveyed sites. We used 1000 runs to randomly drawn species and afterwards add them to the curve until it reached the average species per site. The species-habitat associations were tested using with Poisson distribution for the response variable species richness, and using a linear regression (Gaussian distribution) for response variable species diversity (Shannon diversity index). Habitat was treated as random factor (1 – *Montado*, 2 – Pinewood, 3 – Eucalyptus). With this categorization of variables all the results are in function of the *Montado*. Models were performed in GLM in R V.3.0.2 (RCoreTeam 2013). The composition of bird community was analysed by Bray-Curtis similarity distances with habitat as a factor and a multidimensional scale (MDS) was produced.

6.4. Results

We used 39 species in the analyses, 19 appeared in all forests, 13 in two forests, and 7 in one forest habitat. From those, 6 were *Farmland species*, 10 were *Edge species*, 14 were *Forest generalists,* and 9 were *Forest specialist.*

6.4.1. Species-habitat association

The species accumulation curves showed low slopes towards the end (Fig. 6.2), and appeared to stabilized simultaneously for all habitats, suggesting adequate sample sizes for the estimation of species richness.

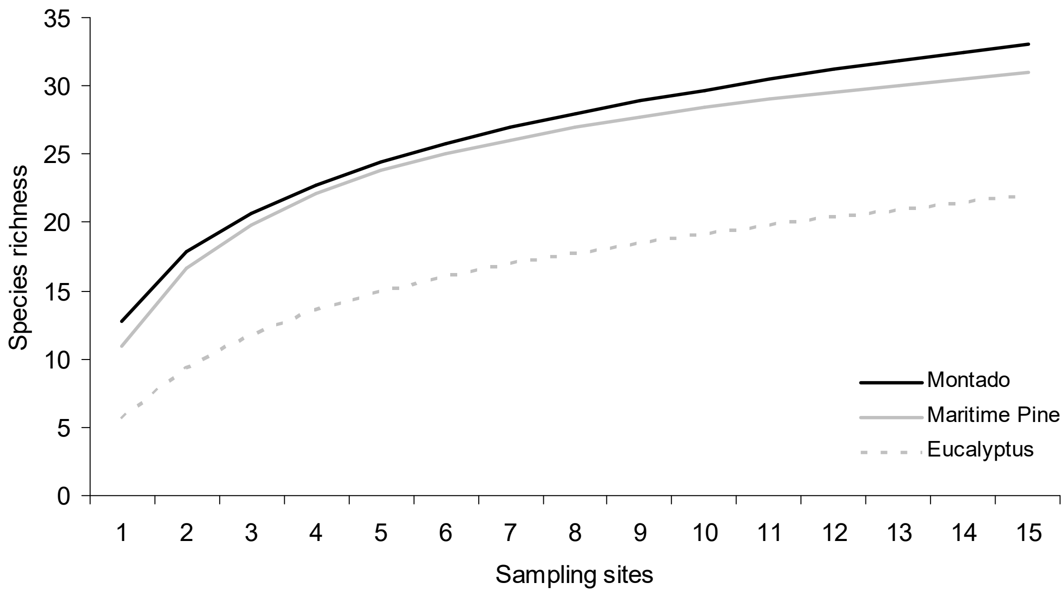

Figure 6.2 – Species accumulation curves representing the cumulative number of bird species observed as a function of the number of plots sampled along the three forest habitats surveyed (*montado*, pinewoods and eucalyptus plantations).

The *montado* showed significant differences compared to eucalyptus forests for all of variables except *edge species.* Eucalyptus forests showed lower species richness and diversity compared to *montado*s. Whereas, there were no significant differences between species richness and diversity in *montado* and pinewood, except in the *farmland species* guild.

Table 6.I - Generalized linear models of ecological bird guilds and species diversity, in relation to forest habitats.

Total Richness	Estimate	SE	z	Pr(>|z|)	
Intercept	2.54945	0.07217	35.326	<0.001	***
Montado: pinewood	-0.15155	0.10616	-1.428	0.153	
Montado: eucalyptus	-0.80315	0.12975	-6.190	<0.001	***
Forest species richness	Estimate	SE	z	Pr(>|z|)	
Intercept	2.17475	0.08704	24.986	<0.001	***
Montado: pinewood	-0.01527	0.12356	-0.124	0.902	
Montado: eucalyptus	-0.99098	0.16728	-5.924	<0.001	***
Forest generalist richness	Estimate	SE	z	Pr(>|z|)	
Intercept	1.92668	0.09853	19.554	<0.001	***
Montado: pinewood	-0.06002	0.14148	-0.424	0.671	
Montado: eucalyptus	-1.02381	0.19166	-5.342	<0.001	***
Forest specialist richness	Estimate	SE	z	Pr(>|z|)	
Intercept	0.6592	0.1857	3.550	<0.001	***
Montado: pinewood	0.1292	0.2545	0.508	0.611701	
Montado: eucalyptus	-0.8824	0.3432	-2.571	0.010148	*
Edge species richness	Estimate	SE	z	Pr(>|z|)	
Intercept	0.6931	0.1826	3.797	<0.001	***
Montado: pinewood	-0.4568	0.2932	-1.558	0.119268	
Montado: eucalyptus	-0.5680	0.3036	-1.871	0.061346	.
Farmland species richness	Estimate	SE	z	Pr(>|z|)	
Intercept	0.6931	0.1826	3.797	<0.001	***
Montado: pinewood	-0.6286	0.3096	-2.031	0.042297	*
Montado: eucalyptus	-0.4055	0.2887	-1.405	0.160148	
Diversity Index (Shannon)	Estimate	SE	z	Pr(>|z|)	
Intercept	2.3612	0.1001	23.595	<0.001	***
Montado: pinewood	-0.1650	0.1415	-1.166	0.25	
Montado: eucalyptus	-0.7299	0.1415	-5.157	<0.001	***

6.4.2. Bird community

The ordination of the bird community revealed differences in structure along the forests habitats. The *montado* as a homogeneous community with most of the sampling sites together; the pinewoods have bird communities more similar to *montado*s, although with higher amplitude; and, the eucalyptus is the forest with less similarities between sampling sites.

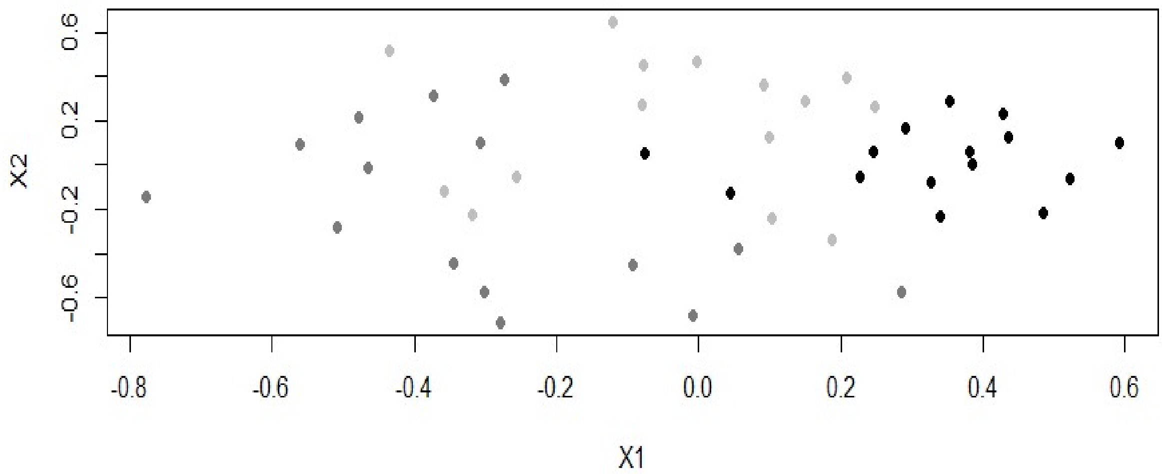

Figure 6.3 – MDS ordination sites based on Bray-Curtis similarities on presence/absences of bird species. Black dots – *montado*, light grey dots - pinewood, dark grey dots – eucalyptus plantations.

6.5. Discussion

We have found that bird communities are differently structured in native versus exotic forests. *Montado*s are a human made system from the native oak forests, and pinewoods have in our days a broader distribution due to wood production. The eucalyptus is the most common exotic forest species used, especially, for paper folder. The richness in bird species recorded in these three forest types highlights these differences. The *montado*s and pinewoods hold the double of species than eucalyptus plantations (Fig. 6.2). The novelty of the study is the geographical proximity between the three forest habitats, which reduce the variability of factors that could influence species distribution (*e.g.* slope, rainfall, temperature), and additionally the forest patches belong to the same owner which reduced differences in management.

One of the potentially short comings of the study could be a limited the number of sampling points per habitat. However, the species accumulation curves (Fig. 6.2) indicate this is not a strong limitation. The species curves followed the same pattern for all the forests types and stabilized after few point counts.

The bird community of the *montado*s is more similar between sampling sites than in pinewoods and eucalyptus, these results may be a consequence of a longer time association between bird species and the management of the *montado* system, compared with the other forest types. On the opposite direction is the bird community from the eucalyptus plantations, which revealed a species turnover from a sampling site to another. These results are in accordance with other studies (*e.g.* Calviño-Cancela 2013), showing that these areas are not suitable habitats for most of the bird species, not only forest species.

Besides the homogeneous structure of the breeding bird communities of the *montado*, one remarkable result is the consistent richness for all the guilds evaluated, even for farmland species. Once more, the fuzzy landscape characteristic of the *montado* promotes the presence of a wide range of species with different ecological requirements (Catarino et al. 2016, Pereira et al. 2014, 2015). The pattern described by Tellería (2001), that *montados* exhibit the highest richness of communities of breeding birds associated with forested areas in the Iberian Peninsula, it is true even on a small scale.

Chapter

7

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

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7.1. 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. In this study we followed 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 where 70% of the area is cork and holm oaks. We used data from 120 10-minute point counts. Using multivariate ordination techniques coupled with variation partitioning, we determined the independent and joint effects of *Forest*, *Management* and *Habitat* variables in bird assemblage. The total variation captured was 65.06%. Most of the explained variation was related to *Habitat* and *Management* variables. All explanatory variables that were highlighted as important predictors reflected tree and shrub density and cork removal. Generalized linear models fitted for each individual forest species emphasized that management plays an important role in 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

7.2. 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 & Mascarenhas 1999; Pinto-Correia 2000) combine the use of woodland products (timber, charcoal and cork) with cereal crops and livestock grazing in the understory (Blondel & 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 (≈737,000ha) 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 & Fonseca 2003). In the Iberian *montados* and *dehesas* the result of an increasing presence of edge and open area birds appears to compensate 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 (Carrion et al. 2000), designated as one of the 25 biodiversity hotspots of the world (Myers et al. 2000), these forest areas are threatened by land abandonment, 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, encompassing as much as possible a wide range of spatial and temporal scales. This knowledge will contribute to implement more effective forest management practices aiming to improve the balance between biodiversity conservation 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. Additionally, for the most common forest species occurring in the study area, we aim to assess the most important forest features in *montado* areas that influence their distribution.

7.3. Methods

7.3.1. Study area

Our study was conducted in the Site of Community Importance of Serra de Monfurado (PTCON0031 - Natura 2000) (Fig. 7.1), whithin an area of 23,878 ha located in the Alentejo province, southern Portugal (38º33'N, 8º09W). The climate is meso-Mediterranean with hot and dry summers and moderate rainy winters (Rivas-Martinez and Loidi 1999). Average monthly temperature varies from 9ºC (January) to 25ºC (July) with an annual average of 12.5ºC, the annual rainfall ranges from 600-1000 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*.

Figure 7.1 - Location of the SCI Serra de Monfurado and forested sampling plots (dark grey). Light grey areas are *montados*.

7.3.2. 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 (CG) always avoiding windy and rainy weather.

7.3.3. 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. Quercu*s 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).

7.3.4. 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 home ranges that go much beyond the census areas (namely birds of prey, crows and insectivorous aerial flyers), or flocks. Analysed 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.* stonechat *Saxicola rubicula*) and shrub understory birds (*e.g.* Sardinian warbler *Sylvia melanocephala*).

In order to assess the relative influence of each set of explanatory variables on bird community, as well as their shared contribution, we used a variation partitioning procedure (*e.g.* Heikkinen et al. 2004, Godinho et al. 2010) based on multivariate canonical ordination techniques.

For forest species (Supplementary material) and for specific richness we developed individual models using Generalized Linear Models (GLM) (Table 7.III). Previously to the construction of the models, the existence of autocorrelation in our bird count data was assessed using Moran's I as a function of spatial distance (Legendre & 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 variable data selection procedures were performed in order to avoid multicollinearity among variables, prior to the statistical modelling phase. All pairwise correlations were assessed by Spearman correlation coefficients (Tabachnik & Fidell 2001). In each pair of highly correlated variables ($r>|0.7|$) (Tabachnik & Fidell 2001), only the most biologically meaningful variable was retained for further analysis. Before the GLM modeling, univariate models were performed and all variables significant estimates (t-test, $p<0.15$) were retained in the subsequent analysis (Hosmer & Lemeshow 2000). All statistical analysis was performed using SPSS 16.0 (SPSS 2007).

Table 7.I - Groups of environmental variables recorded at each one of the sampling stations. Description of the variables associated with the group *Forest*, *Management*, and *Habitat*, as indicated.

Explanatory variables	***Code***
Forest	
Dominant habitat in a 500m buffer from the point count (%)	HDOM
Area of the forested sampling plot (hectares)	AREA
Montado affected by diseases retrieved by percentage of trees affected by at least one biotic agent (%)	MTVIT
Trees affected by Buprestids beetles per forested sampling plot (%)	CORSP
Trees affected by *Numelaria regia* per forested sampling plot (%)	NUMRE
Trees affected by Gypsy moth per forested sampling plot (%)	LYMDI
Management	
Regulated area for small game hunting (ZCT-touristic, ZCM-municipality, ZCA-associative, RG-open) (%)	GAME
Years from the last cork removed (0-removed in the year of the surveys, 2-in the two years prior to surveys, 4- three to four 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 6 classes of high (<0.5; 0.6-1m; 1-2m; 2-4m; 4-8m; >8m) and 6 classes of vegetation density (0%; 0-20%; 21-40%; 41-60%; 61-80%; >80%)	VEG
Dominant plant species (cork oak, holm oak, pines, rockrose, gorse, blackberries, etc.) per stratum (<0.5; 0.6-1m; 1-2m; 2-4m; 4-8m; >8m)	SPE
Shrub ecological succession with 3 classes (1 - shrub absence; 2 - pioneer species; 3 - species of advanced stages of succession	MTS

7.3.5. Partition of variance

The multivariate analysis was performed using the program CANOCO for Windows, version 4.5 (ter Braak & 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 showing weaker species-explanatory correlations were removed. Only 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 & 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.

7.3.6. Generalized Linear Models

We used Generalized Linear Models (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 & 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 is retained is the one with the lowest AICc (Burnham & Anderson 2002). Model fit was evaluated using D2, a measure of the percentage deviance explained according with the formula D2=(null deviance – residual deviance)/null deviance (Guisan & Zimmermann 2000).

7.4. 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 (Supplementary material). 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.

7.4.1. Community analysis - Variation partitioning

Fourteen variables were selected in the community analysis (Table 7.II) 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. 7.2; 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. 7.3. 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 20-40% at 1m high VEG2(20-40) and total stocking (TSTOC) and, in the opposite direction, by the presence of Holm oak (SPEholm), the presence of trees affected by gypsy moth (LYMDI25), vegetation cover between 20-40% 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 the presence of pasture areas herd by pigs (DSWI), and on the negative side, the area of the sampling plot (AREA).

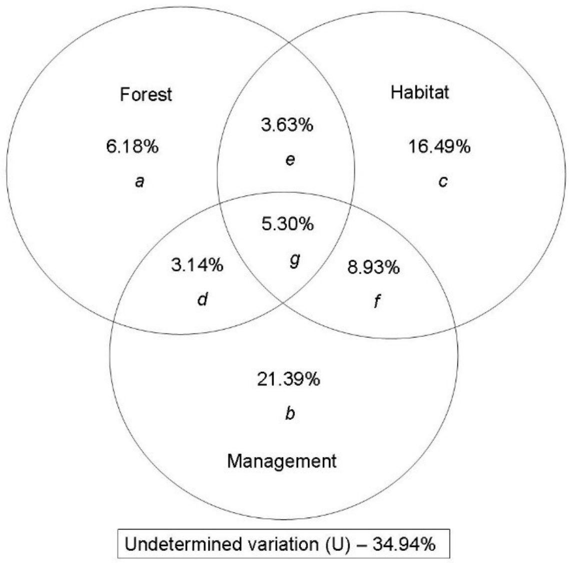

Figure 2 - Results of variation partitioning for bird community in terms of fractions of variation explained. Variation of the species data matrix is explained by three groups of explanatory variables: *Forest*, *Management* and *Habitat*. U is the unexplained variation. *a*, *b* and *c* are unique effects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

Table 7.II - 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*).

	Canonical coefficients				*Intraset correlations*					
Variables	Axis1	Axis2	Axis3	Axis4	Axis1	Axis2	Axis3	Axis4	F	P-value
					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

7.4.2. Modelling Forest species

For 9 forest birds' species and for the species richness, minimal adequate models were calculated using GLM. Modelling was not attempt for 7 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 7.III. From all the set of predicted variables, sixteen occurred in one or more models. Most of the variables selected represent the Management group (12 variables), 3 variables belong to the Forest group and only one to the Habitat group. The most commonly identified predictor variables were the cork removed at the same year of the census (TDES0) and grazing by cattle (COWS) occurring respectively in 9 and 3 of the species models and deviance captured by models ranged between 17% and 55%.

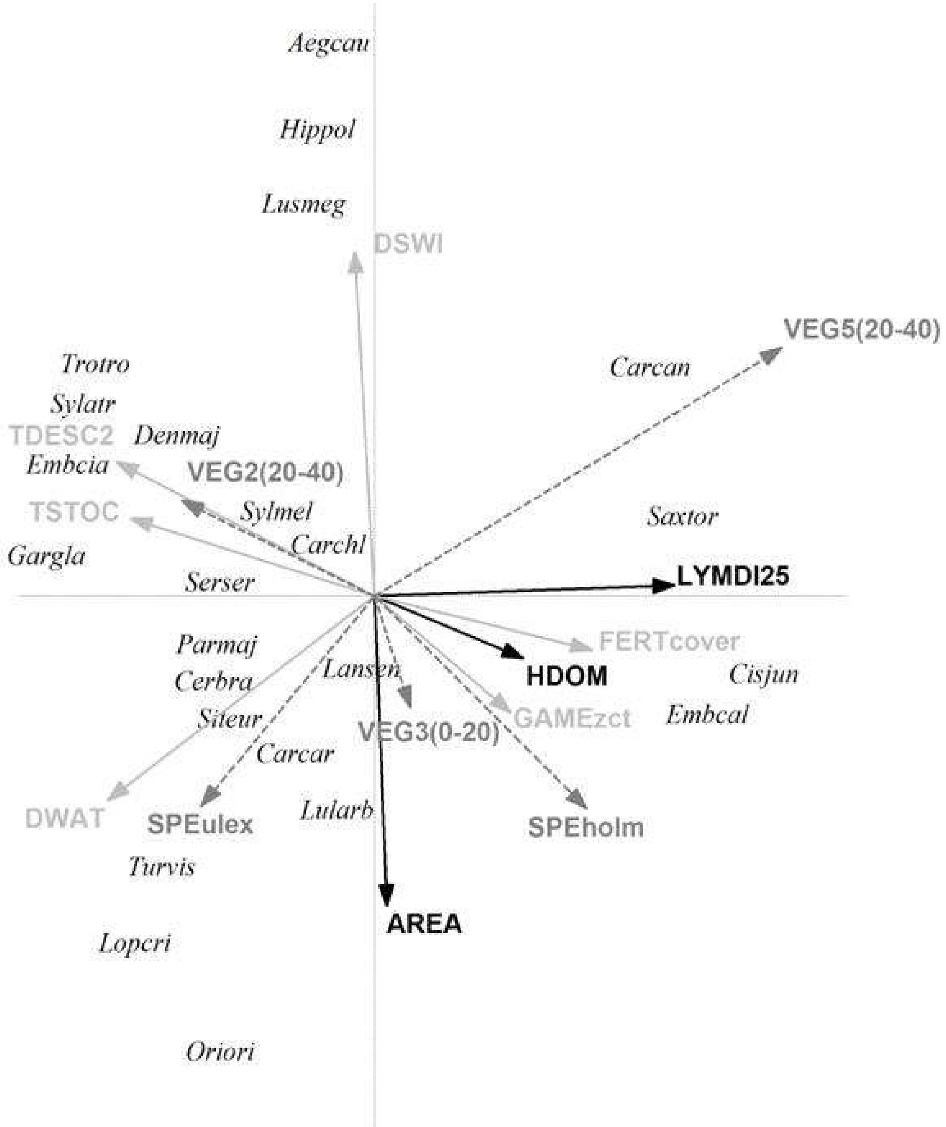

Figure 7.III - Ordination biplot of the first two axes of the CCA for bird community. **Forest** variables are represented in black, **Management** variables in grey and **Habitat** variables in dashed grey (see table 1 for variables names and appendix for species codes).

Table 7.III - Generalized linear models of forest species and species richness, in relation to environmental predictors. Values for *B,* standard error, deviance explained D^2 and AICc.

Species	B	SE	Sig	*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 dominant 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.	
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 two 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; *** p<0.001, ** p<0.01, * p<0.05, non-significant (n.s.).

7.5. Discussion

7.5.1. Bird community

The 3 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 rubicula*, zitting cisticola *Cisticola juncidis* and *Emberiza calandra*. This group pulls together species often associated to open area habitats (*e.g. Cisticola juncidis*, *Emberiza calandra*) and edge habitats (*e.g. Saxicola rubicula*). 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 analyzed 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 of these species with areas pastured by pigs can be driven from an association between variables that were not totally 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).

7.5.2. Forest species modelling

With GLM modelling we identified habitat associations for forest species (Table 7.III). As in community approach, variables that appeared to be more important to predict 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 ten 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, 8 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 exploitation 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.

7.6. Conclusion

Our results are consistent with the findings of Tellería (2001), showing that *montados* (and *dehesas*) act as an ecotone 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 show the ability to recover in short time even after extensive to cork removal activities.

7.7. Supplementary material

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

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Chapter

8

General discussion

8.1. General discussion

The maintenance of the species diversity in *montados* is only possible, and sustainable in a long term, if we understand how management influences the bird communities. Such complex research topic involves several approaches at different scales in order to achieve more accurate results. In this thesis we had focus our research on the structure of the communities (chapter 6) and the effect of the main management actions at species level (chapter 7); we identified the elements whose presence might increase the number of species in the system (chapter 3), and evaluated more deeply the impact of riparian galleries, as a singular element, in the bird communities (chapter 4); additionally, the background provided by the concept of *montado* (chapter 2) together with the identification of singular elements, allowed to evaluate the potential of birds as indicators of High Nature Value *montados* (chapter 5).

This chapter aims to highlight the main results and conclusions obtain in chapters 2 to 7, and to stress the innovative character of the research developed and the results obtained. Although in each one of the previous chapters a discussion is present, in here we intent to frame those discussions into a broader scale based of the current knowledge on the interactions among management, birds and habitat features of *montado*.

8.2. Summary of main results and conclusions

The chapters 2 and 3 are theoretical chapter's and provide an important background to a better understanding of the *montado*. They result from our field experience and from reviewing the information available. One of the contributions from this thesis is to propose a definition of *montado*, that encompasses all the multiplicity of the system.

Most of the characteristics associated to the *montado* are consensual and broadly accepted: the diversity of productive activities, the main tree species, the fuzziness landscape and human intervention. On the other hand, the lower and upper limits of tree cover are not well defined, which may lead to misclassification of some areas. Despite all man-made changes, the *montado* is based on a forest matrix, meaning that the tree is the core of the system. Therefore, we suggest a 10% of tree cover of mature oaks as the lower limit to consider an area as *montado*. This will separate sparse *montados* from open areas with scattered trees. On the other hand, should we consider the existence of limit between a dense *montado* and a dense oak dominated forest? In our opinion, the answer should be no; it should not be established a limit based exclusively on the tree cover. Regardless of the tree cover, if there is human management, even occasionally, it should be considered as *montado*. This is a key factor in the *montado*, the dependency of human management, which is quite well expressed in the typologies suggested by Pereira et al. (2015). The knowledge of the bird species representative of each typology allows two main achievements (Pereira et al. 2015); (1) the establishment of biological indicators, based on observed versus expected species, and (2) the improvement of species diversity through the promotion of singular elements that provide different ecological conditions for birds (see chapter 3). These singular elements can promote a higher bird species diversity, during all the annual cycle (*e.g.* small clearings in dense *montado* promote the presence of farmland species like corn bunting *Emberiza calandra*) or at particular times of the year, such has migration periods (*e.g.* riparian galleries as stopover sites for migratory birds such as willow warbler *Phylloscopus trochillus*) and autumn-winter season (*e.g.* robins *Erithacus rubecula* and blackcaps *Sylvia atricapilla* in the olive groves).

With this approach we excluded important areas for birds such as rice fields and large dams, these land uses create a marked interruption on the *montado* matrix. By definition, areas classified as singular elements, can be disproportionately important for birds considering the small area they occupy (c. 1 ha). One of the best examples is showed by riparian galleries (chapter 4).

We have evaluated the influence of the matrix in the bird communities of the riparian galleries, through a gradient of tree cover. In the context of this thesis, our results provide information on the use of this habitat by forest birds in two different typologies of *montado* (sparse and dense). One of the findings, addressed in more detail in chapter 6, is the similarity in bird community composition among sampling stations set on the matrix. This is consistent in each *montado* (sparse and dense), revealing continuity of suitable habitat in the matrix. The increase in vegetation complexity provided by riparian galleries improves the species diversity, especially in sparse *montado*. Since these montados are dominated by edge species, riparian galleries provide suitable habitat for forest species (*e.g.* great tit *Parus major* and short-toed treecreeper *Certhia brachydactyla*).

Watecourses are also one of the High Nature Value (HNV) features, together with rows of trees, complex elements composed of shrubs, unpaved roads, ponds, orchards (Aue et al. 2014). These are common elements in the *montado* and were also classified as singular elements (chapter 3). An important part of the system is depended from farmland practices, which is the reason to be considered under the HNV classification, whose concept involves low intensity farming, presence of semi-natural vegetation and diversity of land cover (Andersen et al. 2003, Hoffmann & Greef 2003, Kleijn et al. 2009).

In order to evaluated if birds can be reliable indicators of HNV *montados*, we conducted this study along a gradient of altitude and tree covert at the country scale. As indicators we used the species richness of four ecological guilds (Farmland Species, Edge Species, Forest Generalists and Forest Specialists), and Shannon's diversity index, total species richness and the richness of species with conservation status. Of all the study areas, the one with high amplitude of landscape heterogeneity (trees, woody vegetation and shrubs) was simultaneously the one with the higher richness for most of the guilds considered.

Our results do not support that all *montados* can be classified as HNV, but we can define bird as indicators for several typologies, and through the ratio between observed species and the expected pool of species it should be possible to evaluate if a site might be classified as HNV. At a broader scale the general measures of species diversity and species richness could also be used as HNV indicators.

In chapters 2, 3 and 5 we demonstrated the association between bird ecological guilds and *montado*. In chapter 6 the homogeneity of the bird communities in *montado* is suggested, and is broadly mentioned that *montados* host higher values of bird diversity than other forests. We evaluated species preferences in habitat selection among the three most important forested areas – *montado*, maritime pine and eucalyptus plantations. The overall results revealed that bird communities in the *montado* are more similar between sampling sites than in pinewoods and eucalyptus, suggesting the existence of a more stable community. The *montado* also presents higher number of species, although very close to the pine forest. The eucalyptus plantations have half of the species richness. *Montado* is the selected forest for all the bird guilds considered, including farmland species, highlighting the importance of *montado* for a wide range of species, not only forest ones.

Finally, in chapter 7 we assess if management is really determinant for bird species of the *montado*, comparing it with habitat and forest features. Results suggest that species are mainly influenced by management activities in the forest and by singular habitat features at a more detailed scale. Two of the main activities (chapter 2), cork harvesting and cattle grazing were studied, and the *montados* with higher species richness and diversity are characterized by lower intensity of grazing with livestock species turnover, and trees where the cork was removed at least 2 years ago. Results suggest an abandonment of debarked areas by the forest species (generalists and specialists), mainly due to disturbance and lack of nesting and feeding sites. With the dynamic of the *montado* and the cork growth the bird community seems to attain the previous diversity level after one-two breeding seasons.

8.3. Contribution to existent knowledge

In the last years the research on birds and *montados* has increased, and since 2011 it was the subject of three PhD thesis (Ceia 2016, Correia 2014, Leal 2011). Several issues were addressed in these studies: the impact of cork extraction on birds (Leal et al. 2011a), forest management (Ceia & Ramos 2016a, Correia et a. 2015), Leal et al. 2013, Leal et al. 2016), influence of habitat fragments (Leal et al. 2011b), and the role of birds as pest predators (Ceia & Ramos 2016b, Ceia et al. 2016).

Our results are in accordance with Leal et al. (2011a) on the effect of cork removal on bird communities. The definition of the singular elements occurring in *montados* (chapter 3), and the study on the importance of the riparian galleries to promote higher species diversity (Pereira et al. 2014) add important information to the studies of Leal et al. (2011b, 2016). By the first time, the role of birds as indicators of High Nature Values was assessed for *montado* (Catarino et al. 2016), which will contribute to conciliate HNV and High Conservation Value Forest concepts (Bugalho et al. 2016). The review of the concept of montado, and the pattern of the bird communities among different management forests, brings novelty to the previous knowledge.

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Chapter

9

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