Universidade de Aveiro Departamento de Biologia
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Impacto da gestão florestal na reprodução de chapins

Forest's management impact on tits reproduction

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Dissertação apresentada à Universidade de Aveiro para cumprimento dos requisitos necessários à obtenção do grau de Mestre em Biologia Aplicada no ramo de Ecologia, Biodiversidade e Gestão de Ecossistemas, realizada sob a orientação científica do Professor Doutor Carlos Manuel Martins Santos Fonseca, Professor Auxiliar com Agregação do Departamento de Biologia da Universidade de Aveiro.

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Palavras-chave Chapim, parâmetros reprodutores, ocupação de caixas ninho, florestas, gestão florestal, competição alimentar, Bussaco

Resumo

Actualmente existe uma grande reflorestação do território nacional, em que as florestas de monoculturas substituem aos poucos as florestas mais diversificadas e complexas. Neste estudo, um dos principais objectivos foi comparar os parâmetros reprodutores do Chapim-real *Parus major* e do Chapim-azul *Cyanistes caeruleus* entre uma floresta nativa de folhosas, uma floresta mista dominada por espécies exóticas e duas florestas de monocultura – pinhal e eucaliptal, bem como a influência da orla florestal. O estudo teve por base caixas ninhos para monitorização dos parâmetros reprodutores das duas espécies e das variáveis que podem influenciar a ocupação das mesmas. Os resultados demonstraram que as características dos diferentes tipos de florestas influenciam o uso das caixas ninhos, assim como a localização geográfica das mesmas. Demonstraram ainda que a floresta nativa não é a que melhores condições oferece para as duas espécies em estudo, mas sim a floresta que possui maior complexidade e diversidade vegetal, ou seja a floresta mista. As elevadas densidades e a competição pelo alimento nas florestas mais complexas, levam a uma diminuição do sucesso reprodutor dos chapins. Assim, os eucaliptais apresentam capacidade de suportar a avifauna, desde que algumas medidas simples sejam aplicadas, como por exemplo a colocação de caixas ninho, podendo mesmo adquirir maior potencialidade e adequabilidade para estas espécies do que os pinhais. À semelhança do que acontece em muitas outras espécies da fauna, a orla florestal, pela sua peculiaridade e heterogeneidade de espécies e espaços, confere algumas vantagens aos indivíduos que as utilizam, traduzindo-se por vezes num aumento do seu sucesso reprodutor.

Keywords Tit, reproductive parameters, nest box occupancy, forests, forest management, food competition, Bussaco

Abstract Nowadays, there's a high part of the national territory, where monoculture forest replaces gradually the more complex and diversified forests. In this study, one of the main objectives was to compare the reproductive parameters of the great tit *Parus major* and the blue tit *Cyanistes caeruleus* among the native broadleaf forest, the mixed forest dominated by exotic species and two monoculture forests - pine and eucalyptus forests, as well as the influence of forest edge. The study involved the use of nest boxes to monitor the breeding parameters of both species and of the variables that can influence its occupancy. The results show that the characteristics of different forest types influence the nest boxes use, as well as its geographical location. It was also demonstrated that the native forest isn't the forest which offers the best conditions for the two studied species, instead was the forest that has a greater plant complexity and diversity, i.e. the mixed forest. The high densities and the food competition in the more complex forests, decreases the breeding success of the tits. Thus, eucalyptus forests have the capacity to withstand the avifauna, since some simple measures are applied, such as the nest box placement, and may even acquire more capability and suitability for these species than the pine forest. As in the case of many other fauna species', the forest edge, due to its uniqueness and diversity of species and spaces, gives some advantages to individuals which use it, sometimes leading to an increase in its reproductive success.

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1 Introduction

1.1 Why?

Around the world, there is a big heterogeneity of habitats due to natural and anthropogenic factors. Natural factors as climate, altitude, solar exposure and others are obvious to us. However human pressure has changed many of the natural habitats, particularly through politics of forest management and land use (Blondel and Aronson 1999). In the Iberian Peninsula, as in all Europe, most habitats have been changed by human activity (Amo *et al.* 2007 *in* Hawksworth and Bull 2008).

The introduction of a large number of plant species through Iberia Peninsula, and its plantation in monocultures, has been occurring throughout the centuries. These plantations are made in order to provide food or raw material in a more profitable way. Monocultures plantations of eucalyptus (*Eucalyptus globulus* Labill) and several pine species, mainly maritime pine (*Pinus pinaster* Aiton), are very common.

The eucalyptus is a tree native from Australia, and its large introduction began in 1960 with the appearance of the paper industry (Catry *et al.* 2010). The eucalyptus forests are common in the northern and central Portugal, occupying about 21% of the total forest area of the country and are still expanding (DGRF 2007). In Spain, the eucalyptus is also spreading and is very common throughout the autonomous regions of Galicia, Asturias and Basque Country. Eucalyptus forests have a low diversity, richness and density of birds (Catry *et al.* 2010; Proença *et al.* 2010), and perhaps that's the reason why there are almost no studies done with birds in this type of habitat.

The maritime pine exists in the Iberia for at least 55 000 years, and has survived the last glaciation (Figueiral 1995), being well distributed through all the Iberian Peninsula. In Portugal, it suffered a great expansion during the XIV and XX century, due to the forest politics of that time (DGF 1999; Catry *et al.* 2010) and represents 23% of the Portuguese continental forest (DGRF 2007). Pine forests usually have a low bird diversity and richness (Catry *et al.* 2010), which is higher though than in eucalyptus forests (Pina 1989; Proença *et al.* 2010), but some birds species seem to have their highest densities in this kind of forests (Catry *et al.* 2010).

These two tree species have a significant importance for the economy due to their high productivity. The eucalyptus trees are the preferred raw material to pulp and all its products (Rocha and Santos 2007), while the pine tree plantations represent an important source of good quality timber and resin supply (DFG 1999).

The exotic flora in Portugal represents already 15% of all flora species (Domingues de Almeida and Freitas 2001), and with all the developments concerning to the introduction and invasion of different species, it is becoming increasingly difficult to find native forest. The human pressure, mainly due to timber and real estate industry, has left only small fragments of native forest, and even these are at risk of disappearing. Some of the most important and representative native forests from Iberia Peninsula are the ones with predominance of *Quercus* sp.. However, nowadays less than 10% of the area with high conditions for its existence has such specimens (Plieninger *et al.* 2004) due to human activity (Plieninger *et al.* 2004; Castro *et al.* 2006).

The reforestation carried out by man raises some questions over the animals' communities. Generally, the native animals' populations are not favored with plantation of exotic plants, despite some exceptions (Stephens and Wagner 2007). The plant complexity and biodiversity have a straight relation with the animal communities (Chace and Walce 2006), occurring a clear decrease of the floristic complexity and biodiversity in the monoculture plantations.

Birds are the vertebrates most used to study the man made forest's alterations (Stephens and Wagner 2007). Tits are one of the most studied birds and an optimal choice for those trying to understand this subject. There are several reasons for its choice (them to be so studied), such as tits are important elements and good representatives of the forest bird community, have a wide distribution, reach sexual maturity at their first year, readily use nest boxes (Fidalgo 1988; Costa *et al.* 2005), and they don't need only food but also suitable nest place, and this factors are affect by forest composition and structure (van Balen 1982). The nest box use is of extreme importance because it allows an easy data collection and so, tits are used in short, medium and long time studies. The long time studies are crucial for making a follow-up to evaluate effects that otherwise would be difficult to estimate, as rare phenomenon (*e.g.* inbreeding) (Szulkin and Sheldon 2008), or even the effects of global climate change (Charmantier *et al.* 2008; Husby *et al.* 2009). The studies of short and medium term with tits are also very important and common, in order to understand the different aspects of birds' life and reproduction, like understand the importance of distinct kinds of habitats and its influence in tits' life traits (van Balen 1973; Blondel 2007; Atiénzar *et al.* 2010).

Several studies, with the main focus on tits' reproduction, have been done in various habitat types, such as deciduous forests (*e.g.* van Balen 1973, Moreno *et al.* 1996), evergreen forests (*e.g.* Lambrechts and Dias 1993; Martins 1999), parks and gardens (*e.g.* Minelli and Spampanato 1993), monoculture plantations (*e.g.* Belda *et al.* 1998) and coniferous forests (*e.g.* Fidalgo 1988; Brotons and Herrando 2001; Costa *et al.* 2005; Pimentel and Nilsson 2007),

among others. One of the main objectives of the works on tits is to compare the reproductive parameters of this species in different habitat types (*e.g*. van Balen 1973; Belda *et al.* 1998). The quality of various habitats can be estimated by the breeding success (van Balen 1973), or by taking into account the size of the broods and time of laying (Belda *et al.* 1998), or even the chicks' body condition (Lambrechts *et al.* 2008). The results of many of the studies done so far using breeding parameters indicate that depending on the habitat type under study the breeding success changes, proving that some of them provide superior conditions than the others. Since van Balen (1973), several other authors have obtained better breeding results and higher bird densities in deciduous forests than in pinewoods, concluding that these habitats are most appropriate for tits. However, Magi *et al.* (2009) and Mand *et al.* (2009) didn't get the same results in their studies, showing that the preferred habitats didn't have superior breeding success. Despite the greater abundance of resources in that types of habitat (van Balen 1973), the food availability is probably lower (Magi *et al.* 2009), due to the higher bird density (Mand *et al.* 2009), not allowing to increase the reproductive performance of these species, because of interspecific and intraspecific competition (Mand *et al.* 2009).
Two generalist tit species were chosen to this work, the blue tit and the great Tit, in order to avoid a monospecific comparison. The blue tit is more specialized than the great tit, and feed mainly on leaves, while the great tit feed more on twigs and branches (Cramp 2000).

1.2 Objectives

The main objective of this study is to understand how different types of forest affect the reproductive performance of great and blue tits. The several types of forest evaluated, include native forest (broadleaf forest) and artificial forest, planted by man, with different degrees of plant diversity and complexity, in order to know how its influence tits. The pine and eucalyptus forests were chose because were the dominant forest of the regions, and the first represent a monoculture of a native species and the second from an exotic. The broadleaf and the mixed forest are old forest with a high complex composition and structure, despite their differences the broadleaved represent a native forest and the mixed forest a non native forest with a high flora diversification. This study also attempts to increase the general knowledge about a particular forest type, the eucalyptus forest, about which almost no ornithological information is available, beyond the knowledge of low bird diversity and densities, in spite of it great expanding and where the worst results were expected. Considering that this study required the use of nest boxes, the factors which might have influenced the boxes' occupation by tits

were also evaluated. Finally, this study aims to understand the effect of forest edge on tits reproduction, where human activity is higher.

1.3 Thesis structure

The present thesis is organized in five parts. The first part is an introduction to the work, where it is explained the reasons behind it and the main methodology used, as well as the main objectives of the study. *Study species*' part, the second one of this thesis, includes an overview about the blue and great tits, concerning their taxonomy, characteristics, habitat selection, and reproductive parameters, among others. At the *Study area*, and as the name suggests, the most relevant information about location, climate, flora and fauna is described. The fourth part is a chapter like paper, entitled *Forest's management impact on tits reproduction*. Here, beyond an introduction and the methodology, are presented the results, discussion and main conclusions of this study. Lastly, the thesis ends with *The Final Remarks* that contains advices about forest management in order to prevent loss of biodiversity.

2 Study Species

Tits, chickadees and titmice are the most used vernacular terms to refer to a family of birds that in the Portuguese language has a wide variety of names (Costa *et al.* 2000). The local populations call these birds "Majengras". The two study species are the blue tit *Cyanistes caeruleus* Linnaeus 1758 and the great tit *Parus major* Linnaeus 1758.

2.1 Taxonomy, Field characteristics and Distributions

The tits' taxonomy has been in constant alteration. They belong to the class Aves, order Passeriforme and family Paridae. Nowadays, the blue tit belongs to the genus *Cyanistes* and the great tit to the genus *Parus*, for most of the authors and institutions. In the mid 90's, only five genus were recognized in the Paridae family, *i.e. Pseudopodoces*, *Baeolophus*, *Melanochlora*, *Sylviparus* and *Parus* (Harrap and Quinn 1996). However, recent works (*e.g.* Gill *et al.* in 2005) that have access to new sources of data, such as genetic data, led to the recognition of more groups as genus, like the *Cyanistes*.

Although, the new genus are recognized by most ornithology experts, the results from the works done by Kvist *et al.* (2003) and Päckert *et al.* (2005), that recognise some groups of great tits as species, are far from being widely accepted. Even the taxonomy used in some of the most appraised and updated books (Gosler and Clement 2007) have been criticized (Packert and Martens 2008).

The blue tit is a very active bird and easy to distinguish (Figure 1). It has between 10.5 and 12 cm in length, a short neck and a small and rounded head, black eyes and a little blue cap on top. The upper parts of the bird are yellow with a central and strict grayish-black list. The wings are bluish with bright blue on the covers. The distinction between sexes is very slight, being the males brighter than females (Harrap and Quinn 1996; Cramp 1998; Svensson *et al.* 2009). In Iberia Peninsula, the existing subspecie is *Cyanistes caeruleus ogliastrae* that has a large white supercilious list and a white wing bar (Harrap and Quinn 1996; Cramp 1998). Although there are almost no differences in plumage between sexes in this subspecie, some males are bigger than females (Cramp 1998). The blue tit is distributed over Europe, from Iberia Peninsula to the center of Scandinavia and thence to the Caucasus, North Africa and Asia Minor (Equipa Atlas 2008).

The great tit is the biggest tit, about 20% bigger than blue tit, with 13.5 to 15 cm in length (Harrap and Quinn 1996; Cramp 1998; Svensson *et al.* 2009). To the majority of the actual

authors there are three groups of subspecies of great tit. The group *major* dwells in Europe, North Africa, North Asia, going east to the Pacific and south to Israel, North of Iran, Mongolia and Northern China, the group *cinereus*, that exists in northeastern Iran, southern Afghanistan, the Indian subcontinent, Southeast Asia and Indonesia and the *minor* group, that lies in the southeast of Russia, Japan, and the distribution limited to South by South Tibet and north across Southeast Asia (Harrap and Quinn 1996; Birdlife International 2010). The group that exists in Europe has yellow under parts, with a black central band, bright head and neck, in a tone between blue and black, connected to the throat area always in the same tones, completely encircling the white cheeks, moss-green back, narrow white wing bar on blue-gray wings and strong bill and legs (Figure 2). The distinction between genders is seen by the dimensions of the black list located in the under parts (Harrap and Quinn 1996; Cramp 1998; Svensson *et al.* 2009). In Portugal, there are two subspecies, *Parus major ma*jor and *Parus major corsus*, and the best way to distinct them is through the amount of white color in the tail (Harrap and Quinn 1996). In both subspecies, as in the blue tit, the males are usually slightly bigger than the females (Harrap and Quinn 1996; Cramp 1998).

Both species are resident in Portugal (Catry *et al.* 2010), even though some populations from their Northern distribution make movements to South, in order to avoid the rigorous Winter season (Harrap and Quinn 1996; Cramp 1998) and also the altitudinal migrations made by the populations with breeding areas at high altitudes (Cramp 1998).

Figure 1. Blue tit (Photo by Luis Pascoal da Silva).

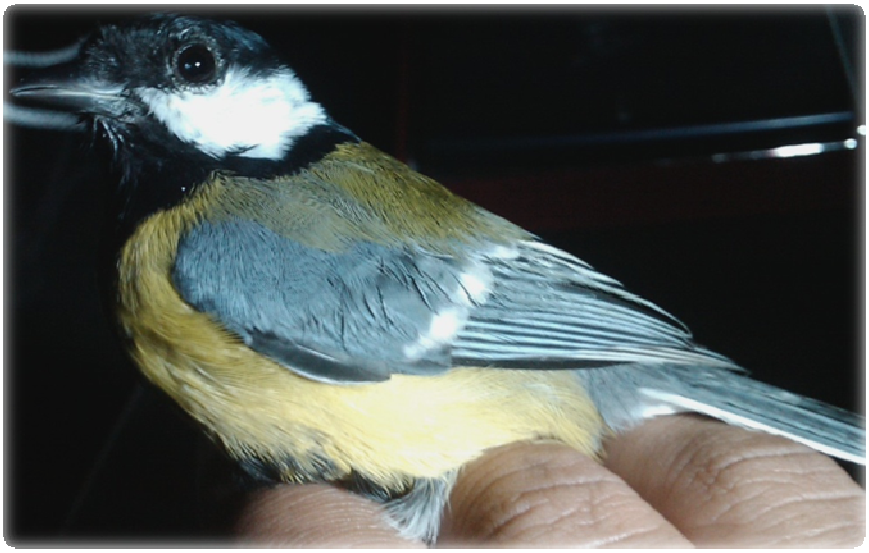

Figure 2. Great tit (Photo by Luis Pascoal da Silva).).

2.2 Conservation status, Population and Legislation

The blue tit and the great tit have both the same conservation status at a national and international level, which is Least Concern (Cabral *et al.* 2006; IUCN 2010). Birdlife International attributes the status of Non-SPEC^{E} to the blue tit, which means it is concentrated in Europe with a favorable conservation status and of Non-SPEC to the great tit, meaning it is not concentrated in Europe but has a favorable conservation status in this continent (Birdlife International 2010).

Both species have an unset population trend according to Birdlife International (2010), and blue tit has a population estimate of 10 million birds and great tit between 300 million and 110 million birds.

These two species are also in the annex II of the Berne Convention (Cabral *et al.* 2006).

2.3 Habitat and Feeding

The blue tit is essentially a bird of broadleaf woodland, which also inhabits parks, gardens, riparian galleries, olive groves, farmland with some trees, etc. (Harrap and Quinn 1996; Cramp 1998; Equipa Atlas 2008). In Portugal, despite being present all over the country, its density is lower in the Center and North Coast due to the strong presence of pine trees and eucalyptus plantations (Equipa Atlas 2008). Usually, it only breeds in altitudes below 1250 m.a.s.l., there are some exceptions through the higher Caucasus (Cramp 1998).

The great tit prefers mixed types and open forest, or even fragmented and scattered trees, to dense pure deciduous forest, disliking pure coniferous forest (Cramp 1998). Despite their preference, it can be found in almost all habitats with trees, including all variety of woods (including dense coniferous forest) and developed scrubs, all kinds of fruit trees, gardens and parks and even graveyards (Harrap and Quinn 1996; Equipa Atlas 2008). In Portugal, it's only sparse in the big and continuous eucalyptus plantations (Equipa Atlas 2008). In terms of altitude, it is also more of lowland specie but might be present up to 1900 meters high (Cramp 1998).

The feeding of both species is similar, chiefly insects and spiders in the breeding season and fruit and seeds in the winter. The diet reflects seasonal and year abundance (Banbura *et al.* 1994; Cramps 1998) and is influenced by the habitat type (Barba and Gil-Delgado 1990). The main difference between the diets of the two tits is related to the place where they look for food. The blue tit feeds primarily high in the trees, on twigs and buds, and the great tit mostly on the ground or on the trunks and thicker branches of trees, eating more vegetable elements (Cramp 1998; Slagsvold and Wiebe 2007). The main size of the preys is also related to the size of the tit (Park *et al.* 2005). Both species use bird feeders, especially in winter and show a general preference to feed the nestling with caterpillars (van Balen 1973; Cramp 1998).

2.4 Behavior and Reproduction

The blue and great tits have also similar behaviors. Both species form mixed foraging flocks (it isn't unusual to see the great tit and the blue tit together in these flocks) from late Summer to Winter and during the rest of the year they establish territories. The main song period is when they have territorial behavior, until the end of the nesting season. Furthermore, both species are usually monogamous despite some bigamy (Cramps 1998). The percentage of extra-pair was estimated slightly over 10% for both species (Kempenaers *et al.* 1992; Blakey 1994).

The blue tit typically starts its clutches from early April to mid May. However, the beginning date depends on the local (latitude, altitude, etc) and its conditions (weather, habitat type, etc.). The clutch size depends of the same factors, as well as the laying date, and regularly the clutch has commonly between 6 and 16 eggs, being slightly smaller in Mediterranean areas. The incubation time is between 13 and 16 days, and the fledging period among 16 and 23 days. The eggs are sub-elliptical, smooth without gloss and white, generally with some spots concentrated at the base. The nest is built in tree holes and nest boxes (or other kinds of artificial holes), being rare the use of other birds' nest (open nest), the base of large birds' nest

or even on ground. Commonly blue tit lays only one clutch, but through Central Europe two clutches are common (Harrap and Quinn 1996; Cramp 1998).

The breeding ecology of the great tit is like the blue tit. The place where the nest is built is the same, the eggs are only slightly larger (Figure 3), the time of the incubation and fledging period is also similar between the two species, and even the conditions that affect reproduction are identical. The main differences between the reproduction of these two tits are the number of eggs laid and the number of clutches. The great tit usually lays two clutches, sometimes even three, but the number of eggs is lower than in blue tits (Gibb 1950; Harrap and Quinn 1996; Cramp 1998).

The breeding success is highly variable in all tit species, and there are many important factors, as predation, but the most important one is food availability (Cramp 1998).

Figure 3. Great tit eggs in a nest box (Photo by Luis Pascoal da Silva).).

3 Study area

3.1 Localization

This study was conducted in the North of Central Portugal, about 40 km from the coast in the Northwest of Bussaco Mountain Range (Figure 4). It's mainly situated in the Northeast of Mealhada municipally, Aveiro district and a small part in Penacova municipally, Coimbra district.

In order to have the less unbiased data due to climate and geographical variations, all the studied forests are within a radius of 1500 meters from a central point (40º22'02''N, 8º21'45''W) (Figure 4).

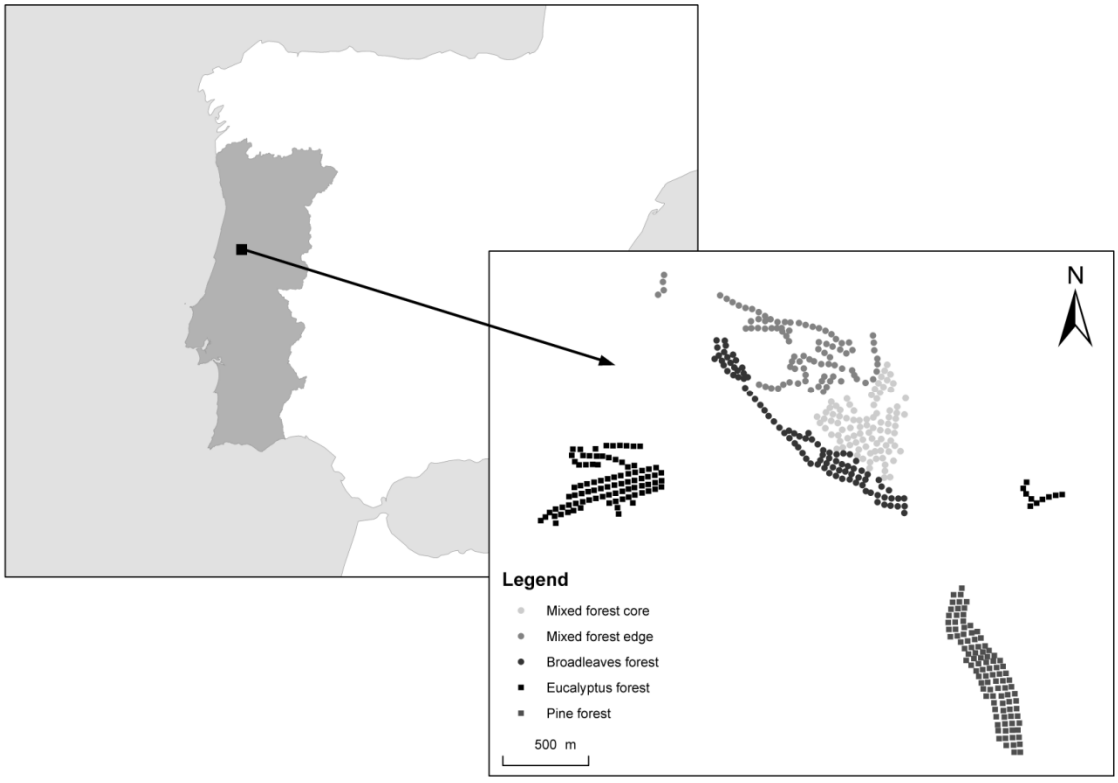

Figure 4. Location of the study area in Portugal and distribution of the study forests.

3.2 Topography, Geology and Hydrology

The study area has a range of altitudes between 160 and 459 m.a.s.l. The highest spot is located in a plateau of the Bussaco mountain range, and the remaining study area is distributed through its northern hills.

Sedimentary and metamorphic rocks are present, being the majority of them quartzite and some sandstones, conglomerate and clay.

The study place has several streams, but only one is permanent. The main sources of water are the seasonal watercourses and the several ponds formed during the rain periods which remain until the middle of summer. The water courses belong to the hydrographic basin of the Vouga (Administração da Região Hidrográfica do Centro 1999).

3.3 Climate

The climate has a strong Atlantic influence, yet is located biogeographically in the Mediterranean Region (Lopes *et al.* 2008). According to Rivas-Martínez *et al.* (2004) it's located in the transition between the bioclimatic areas of mediterranean pluviseasonal oceanic and temperate oceanic submediterranean, and between the thermoclimatic belts of mesomediterranean and meso-submediterranean.

The weather is mild. There are some short frosts (not more than 21 days per year) and virtually no snow. The insulation is higher in July and reaches its minimum values in December. The average temperature in summer is around 21ºC (maximum near 40ºC) and around 8ºC during the winter (minimum around -3ºC).The rainfall regime is a bit irregular, with the driest months in the summer. The annual precipitation is around 1530 mm, which indicates a very rainy microclimate. The relative humidity is near 80% and the total evaporation around 580mm per year. The dominant winds are northwestern and periodical, lasting for several days, with strong bursts. Dense fogs are common, especially in summer, only vanishing in the end of the morning (Ferreira 1946 *in* Coimbra 1993).

3.4 Flora

The choice of this area to do this work links with its high heterogeneity of habitats with different kinds of forest. There are four main forest types in the study area, two of monoculture plantations and two of mixed forests. The monocultures are mainly made up of maritime pine (*Pinus pinaster*) and eucalyptus (*Eucalyptus globulus*), while one of the mixed forests is a sample of native forest (the most part composed by evergreen broadleaf species) and the other is a mixed exotic forest, where coniferous species are mixed with deciduous and evergreen species. This last one was originally planted as a meditation site, representing nowadays one of the most important dendrology collections of Europe, according to Paiva

(1987). The different types of forest were used as distinctive sampling sites in order to try to understand a little more of the impact of the forest management.

The pine forest has several shrubs, mainly sallow wattle (*Acacia longifolia*) and silver wattle (*A. dealbata*) that are invasive species, creating small woods. There are also various species from the Poaceae family, and several others plants with small size like heathers (mainly *Erica lusitanica*), gorse (*Ulex europaeus*), winged-brooms (*Pterospartum tridentatum*), blackberries (*Rubus* sp.), and scarce holly (*Ilex aquifolium*) and oaks (*Quercus* sp.). The pine trees are about 14 m. tall and the majority of them have more than 50 years.

The eucalyptus plantation has also a lot of wattles (*Acacia dealbata* and *A. longifolia*), as well as large numbers of heathers (mainly *Erica lusitanica*), gorse and winged-brooms forming a dense bush in the majority of the patches. Despite its presence only occur in small areas in the eucalyptus plantation, the blackberries (*Rubus* sp.) can create condensed shrubs. In areas without high densities of shrubs, the presence of some bracken (*Pteridium aquilinum*) and grass (family Poaceae) is noted. The eucalyptuses have in most of the study area about seven meters tall, but some of them reach already about 20 m..

Native forest is a relic of the primeval forest in the Atlantic region of the country (Paiva 2004). This mixed native forest is mainly dominated by *Phillyrea latifolia* and oaks (mainly *Quercus faginea*). These trees are highly variable in tall, where some specimens reached more than 20 m., while the majority of them has around 10 m.. There are also other common trees or big shrubs, like bay laurel (*Laurus nobilis*), holly (*Ilex aquifolium*), cork oak (*Quercus suber*), Portugal laurel (*Prunus lusitanica*), laurustinus (*Viburnum tinus*), strawberry tree (*Arbutus unedo*), and in a lowest number, tree heath (*Erica arborea*) with a considerable size. The herbaceous plant more common is the butcher's broom *Ruscus aculeatus* but there are many others as *Narcissus bulbocodium*, *Neotinea maculata*, *Serapias cordigera*, *Orchis mascula*, *O. morio*, *Ophrys apifera*, *Epipactis palustris*, *Neothia nidus-avis*, *Polygonatum odoratum*, *Fragaria vesca*, *Viola riviniana*, *V. canina*, *Sanicula europaea* and the Iberian endemisms, *Fritillaria lusitanica* and *Crocus serotinus* (Paiva 1987, Paiva 1992, Paiva 2004). Despite the dominance of native species, there are also some invasive species, such as sweet pittosporum (*Pittosporum undulatum*) and several wattle species (*Acacia* sp.).

For last, the mixed exotic forest is dominated by the mexican cypress (*Cupressus lusitanica*). There are dozens of exotic tree species across this forest, some of them with a considerable size or other characteristic that makes them notable trees. The bigger tree diversity is usually near paths. Although this forest type is mainly constituted by exotic species, also occurs there are some native trees, like oaks, holly and bay laurel (Paiva 1987, Paiva 1992, Paiva 2004). At a

lower level stands out butcher's broom, blackberries and ivies (*Hedera* sp.). This forest has the bigger trees, a few with more than 60 meters, and the majority of them with more than 20 m. tall.

3.5 Fauna

A lot of animals are present in the study area, belonging to several classes. However only a small amount of them will be referenced, especially the tit's predators and most direct competitors.

The main predators are medium size mammals, birds of prey and woodpeckers (Harrap and Quinn 1996; Cramp 1998), and the main competitors are other tits (Dhondt and Eyckerman 1980) and other small passerines (Krist 2004).

The mixed forest has more species and greater densities of the majority of the animals than the monocultures (Matos *et al.* 2007).

The mammals present in the study area that can hunt tits are mainly the red squirrel (*Sciurus vulgaris*), common genet (*Genetta genetta*), stone marten (*Martes foina*) and mouse weasel (*Mustela nivalis*). These mammals are present in all forests, with the exception of the red squirrel that seems to avoid eucalyptus forests, and all are far more common in the mixed forest.

There is wide diversity of bird species through the entire study area, around 100, with higher number of species and densities in the mixed forest. The forest with more birds is the exotic, but is also the one with more space (considering the vegetation volume, and not only area) and the forest with less bird species is the eucalyptus forest. The woodpeckers (mainly *Dendrocopus major*) are present in all the study area and have caused damage in the nest boxes during all year. However no nests of woodpeckers has been found in the eucalyptus forest, and they probably only raided the area to search for food. There are also four common birds of prey, the common buzzard (*Buteo buteo*), the Eurasian sparrowhawk (*Accipiter nisus*), the northern goshawk (*Accipiter gentilis)* and the tawny owl (*Strix aluco*). The densities of the common buzzard appear to be similar in all the forests, but the presence of the *Accipiter* species seems more regular in the native forest. The tawny owl, although a nocturnal bird, can also capture tits and has higher densities in the two mixed forests.

3.6 Human activity

The human activity is very heterogeneous at the study site. The different forest types also have different levels of human perturbation. For example, the pine forest is often used by sheep and goats for pasture. On the road that crosses this area, the presence of cars passing by is common, and in some of the paths, there are occasionally all-terrain vehicles. During this study, about half of the initial area was cut down in order to try to stop a nematode infestation.

In the eucalyptus area, there is less human perturbation, only a few people pass through the paths weekly, however due to the fast grow of this tree and the difference in age between some parcels of land, some of the area has been also cut down during the study.

The mixed forest has similar human perturbation; both are used as a recreational space. The roads are used by a lot of cars and people, especially in the weekends. There are some parking and other recreational spots, mainly in the exotic forest, where people eat and spend their free time. Away from roads and main paths, only a very few tourists pass, so there are some areas without human disturbance.

4 Forest's management impact on tits reproduction

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4.1 Abstract

Man has progressively replaced natural forests by others, mainly monoculture forests. Great tit *Parus major* and blue tit *Cyanistes caeruleus* are some of the most used animals to understand the impact of this forest management. In this study, these two species were used in order to compare its breeding parameters in several forest types (native broadleaf, mixed, and pine and eucalyptus plantations). Furthermore, we evaluated the edge effect in the mixed forest as well as the factors that may influence nest box occupancy. Our results suggest that the edge brings benefits to both species and that the nest box occupancy is affected by the dominated trees present in each forest type, as well as by its geographical location. The results suggest that the proper forest for tits is not the native broadleaf forest but the mixed forest. Moreover, the eucalyptus forest, the most cost-effective of the studied forests, may have a good potential for tits since simple proceedings are implemented.

4.2 Keywords

Management's forest, nest box occupancy, food competition, breeding success, great tit, blue tit

4.3 Introduction

Due to many factors, mainly economic, man has changed the natural habitats, and the forests are no exception. Native forest has been replaced through all Europe. In the Iberian Peninsula plantations of eucalyptus (*Eucalyptus globulus*) and several pine species, mainly maritime pine (*Pinus pinaster*), have replaced the native forests of oaks (*Quercus sp.*) (DGRF 2007). These plantations are forests with a low floristic complexity and consequently, have low bird diversity and richness (Catry *et al.* 2010; Proença *et al.* 2010). However, the area occupied by monocultures of maritime pine and eucalyptus in the Portuguese forest is 23% and 21%, respectively, and the last one is still expanding (DGRF 2007).

Blue tit *Cyanistes caeruleus* and great tit *Parus major* are birds that occupied a wide range of habitats (van Balen 1973; Blondel 2007) and during the last decades, there are numerous studies comparing the habitat quality using their breeding parameters (van Balen 1973;

Blondel *et al.* 1987; Dias *et al.* 1994; Mand 2005; Atiénzar *et al*. 2010, Sanz *et al.* 2010). The tits are usually used as a way of evaluate the adequacy of broadleaf forest, evergreen and deciduous, and pine forests (van Balen 1973; Belda *et al.* 1998; Sanz *et al.* 2010) in the breeding season. As so, and given the habitat used by each species, the great tit is useful to compare all of these forests, while with the blue tit is generally only possible compare broadleaf forests and mixed forests (Blondel *et al.* 1987; Dias et al. 1994), since its scarcity in pine forests (Sanz *et al.* 2010). Usually broadleaf deciduous forests have a better breeding performance and higher breeding densities of blue and great tits than broadleaf evergreen forests (Dias *et al.* 1994; Blondel 1987), while in pine forests great tits have the worst reproductive performance and the lowest densities (van Balen 1973). However, the better breeding performance isn't always obtained in the preferred habitats (Magi *et al.* 2009; Mand *et al.* 2009).

The tits' reproduction is mainly limited by food abundance and availability (Blondel 1985; Dias *et al.* 1994; Mand *et al.* 2009), as well as the availability of holes where tits can build their nests (van Balen *et al.* 1982; Mand *et al.* 2005; Pimentel and Nilsson 2007 a). The preferred habitats usually have more food but also more available holes than the not-preferred ones, and therefore, higher tit densities (van Balen 1973). Nevertheless, these factors may lead to lower food availability due to competition (Mand *et al.* 2009). Pine forests and other managed forests of quick growth are places that typically have a low number of available cavities (van Balen *et al.* 1982), and a way of increasing the tits' population is by placing nest boxes (van Balen *et al.* 1982; Mand *et al.* 2005; Pimentel and Nilsson 2007 b). The addiction of nest boxes in the preferred habitats also increases tits' densities, but in this case, their densities increase to such an extent that density dependent effects, like competition, become more apparent (Mand *et al.* 2009). The placement of nest boxes is an important measure, especially in man-made forests of fast growth, because they increase the biodiversity in these habitats and are a way of fighting unwanted pests (*e.g.* Pimentel and Nilsson 2007 b). In these not preferred habitats, density increases but doesn't reach too high values, so that breeding performance becomes better than in the most suitable habitats (Mand *et al.* 2005).

In this work, we intend to compare different forest types, some of which also studied by other authors (*e.g.* van Balen 1973; Pimentel and Nilsson 2007 a), broadleaf forests and mixed forests with forests of single species, like pine forests and eucalyptus forest, that differ in the degree of plant diversity and complexity. The expansion of the eucalyptus forest occur throughout Europe, and almost no ornithological work exist, being only known that they have a very low bird diversity, richness and densities (Pina 1989; Proença *et al.* 2010), make crucial

to evaluate the adequacy of this forest type for these species. Ultimately, as nest boxes were used to perform this study, the factors which might have influenced the boxes' occupation by tits were also studied, together with the edge effect.

4.4 Methods

4.4.1 Study area

The study area is located in the Northwest of Bussaco Mountain Range, at the Centre of Portugal.

In order to have the less unbiased data due to climate and geographical variation all the study area is within a radius of 1500 meters from a central point (40° 22' 02'' N, 8° 21'45'' W).

Five distinct patches of forest were considered in this work, the mixed forest core and edge, the broadleaf forest, the eucalyptus forest and the pine forest. The mixed forest is a forest dominated by the Mexican cypress *Cupressus lusitanica,* with many other tree species like Sweet pittosporum *Pittosporum undulatum*. It has several arboreal substrates and is the tallest and diversified forest in this study, with native and exotic species of both coniferous and broadleaf trees. This forest was divided in two areas, the core and the edge, to assess the effect of edge. The edge is near of human constructions as picnic parks, wide and busy roads, and paths on the other hand the core has only small pathways and is at least 50 meters away from the structures that characterize the edge. The broadleaf forest is the native forest of the study area, with dominance of Phillyrea *latifolia* and several oaks *Quercus* sp. The eucalyptus forest is a monoculture forest of blue gum *Eucalyptus globulus* with a dense understory of shrubs, mainly heather *Erica lusitanica* and gorse *Ulex europaeus*. Finally, the pine forest is also a monoculture of maritime pine *Pinus pinaster*, almost without understory.

A total of 470 nest boxes were placed between the end of 2008 and January of 2009. These were distributed among the different habitats with 90 boxes in the mixed forest core, mixed forest edge and broadleaf forest, and 100 boxes in the pine and eucalyptus forest. All the nest boxes had the same size and appearance, and were placed 40 meters away from each other in order to avoid inter and intraspecific competition between nest hole breeders, based in previous census data (Matos, unpub. data) of the study area. The nest boxes were placed in a height between 2.5 and 5 meters, depending on the tree characteristics.

4.4.2 Census data

During the early breeding season of 2009, 12 point counts per forest type were performed (mixed forest core and edge were considered as only one type during the census), performing a total of 48 point counts. The censuses were carried by two operators, during 15 minutes in each point and all birds seen or heard in a 30 meters radius were recorded. The census was done during the first hours of the morning and only with favorable conditions, according to Bibby *et al.* (1992).

To estimate a continuous surface of values of density of the great tit, blue tit and great spotted woodpecker *Dendrocopos major* in the study area, we applied an Inverse Distance Weighting interpolator on the census data. We extract the values for each nest box from the obtained rasters creating three different variables (densities of tits and woodpecker). The great spotted woodpecker densities were also estimated because this is the main predator of the tit's nest boxes.

4.4.3 Breeding parameters

The breeding parameters were recorded during 2009 and 2010. All nest boxes were visited at least once a week since March until the end of the breeding season (beginning of August). When a nest was found, inside a nest box, it was visited as frequently as necessary to know the laying date (assuming that one egg was laid per day, even though in some cases it wasn't completely true; 1st March was considered as day 1), the clutch size, the number of hatchlings and the number of fledglings. The eggs were measured with a calliper (0.1 mm accuracy), and the egg volume was calculated from the formula $V=(\pi/6)LB^2$, where V is egg volume (in mm^3). L is egg length and B is egg breadth (both in mm). (Preston 1974). The chick body mass was weighted with a digital balance (0.1 g precision) after they had at least 14 days old (hatching date = day 0), that is when chick weight stabilizes (van Balen 1973). Unfortunately, the individual ringing of females was impossible of do it in this study, so there wasn't an absolute certainty of second broods. However, due to laying synchronisation and bird territoriality it was possible to distinguish between the first and second broods.

4.4.4 Topography parameters

To obtain the topographic variables, like altitude (m), slope (degree) and aspect, a digital terrain model of the study area was constructed using ArcGis 9.3®. In order to use *aspect* in linear regressions, we converted this measure into two separate continuous variables (Zar 1999), eastness [sen (aspect in degrees)] and northness [cos (aspect in degrees)]. Northness

quantifies the degree to which an aspect is north, and the eastness measure the degree to which it is east. The distance (m) of each nest box to the nearest road and water course was also measured.

4.4.5 Data analysis

We used multinomial logistic regressions to model the nest box occupancy, including all the topography parameters plus the density of great tit, of blue tit and of great spotted woodpecker, year and habitat type as independent variables. The multinomial regression was chose because nest boxes can be only occupied by single specie at a time. The model that best predicted nest box occupancy was selected through stepwise logistic regression procedures.
In order to evaluate the effect of the forest type, year and their interaction (independent variables) in the timing of reproduction, clutch size, number of hatchlings, number of fledglings, egg volume and chick body mass (dependent variables), general linear models were run for each species. Models were controlled for brood, except for the timing of reproduction, where only the first brood was used. Whenever relevant, we performed multiple pair wise comparisons using Bonferroni adjustments for the confidence intervals and significance. In all statistical analysis values of $P<0.05$ were considered significant. The results are expressed as mean ($\bar{x}$) ± standard error (SE) and respective 95% confidence intervals (CI). All analyses were performed using R 2.10.0 (R Development Core Team 2009).

4.5 Results

4.5.1 Great and blue tits densities

The densities obtained have a very high deviation, even though it's notable that the higher densities of tits were in the mixed and the broadleaf forest (Table 1). The highest densities of great tits were found in the mixed forest followed by the broadleaf forest, while the eucalyptus and the pine forests arises with the lower densities, with a mean density of about two individuals per hectare. The blue tits were only detected in the mixed and broadleaf forests, with higher densities in the last one.

Table 1. Population density (mean number of birds ha^{-1} ± standard deviation) of great tit (*Parus major*) and blue tit (*Cyanistes caeruleus*) in the different forest types.

	Great tit			Blue tit		
	Mean	±	SD	Mean	±	SD
Mixed forest	7.96	±	9.31	6.19	±	6.05
Broadleaf forest	4.72	±	4.85	9.14	±	6.12
Eucalyptus forest	2.06	±	3.18	0	±	0
Pine forest	1.79	±	4.40	0	±	0

4.5.2 Nest box occupancy

A total of 135 nest boxes were occupied during the study period, 88 by great tit and 47 by blue tit. The nest box occupancy ratio has not changed much between the two years of the study (Table 2), despite the considerable increase in the number of nest boxes used by great tits in the Eucalyptus forest and by blue tits in both mixed forests. Although, blue tit has not been detected during the point census in the monoculture forests (pine and eucalyptus), some nest boxes were used by this species.

Table 2. Number of nest box occupied per species and year.

	Total nest box	Great tit		Blue tit	
		2009	2010	2009	2010
Mixed forest core	90	5	5	5	9
Mixed forest edge	90	9	8	8	12
Broadleaf forest	90	14	15	3	4
Eucalyptus forest	100	7	11	2	2
Pine forest	100	7	7	1	1
All forest	470	42	46	19	28

The factors that best explain the nest boxes use are summarized in table 3. Comparing with the mixed forest core, almost all forest types influence significantly the nest boxes occupation by both species. Comparatively, with the core of mixed forest, the great tit seems to occupy preferentially all the other habitats, except the pine forest where no significantly differences were found. For blue tit, the nest boxes present at the broadleaf and pine forest were avoided, while the edge of the mixed forest was positively preferred, when compared with the mixed forest core.

The altitude doesn't affect the occupancy of the great tit in the nest boxes on the other hand, it influences the blue tit. Although, the northness hasn't affected the use of the nest boxes, the eastness influenced positively its use by the great tit.

Table 3. Parameter estimates of the variables included in the model that best explains nest box (n=470) occupancy by great tit (*Parus major*) and blue tit (*Cyanistes caeruleus*) in the studied years, using multinomial logistic regressions.

	Great tit			Blue tit		
	β (SE)	χ^2_{Wald}	*P*	β (SE)	χ^2_{Wald}	*P*
Intercept	-4.010 (1.028)	15.200	**<0.001**	-5.976 (1.730)	11.938	**0.001**
Forest type						
Mixed forest core	0[a]	-	-	0[a]	-	-
Mixed forest edge	0.977 (0.479)	4.165	**0.041**	1.406 (0.542)	6.738	**0.009**
Broadleaf forest	1.021 (0.389)	6.880	**0.009**	-1.053 (0.526)	4.005	**0.045**
Eucalyptus forest	1.186 (0.601)	3.890	**0.049**	0.362 (0.891)	0.165	0.684
Pine forest	-0.182 (0.452)	0.163	0.687	-2.784 (0.801)	12.087	**0.001**
Altitude	0.003 (0.002)	2.130	0.144	0.008 (0.004)	4.819	**0.028**
Eastness	0.563 (0.232)	5.892	**0.015**	0.447 (0.332)	1.811	0.178

[a] comparison term.

4.5.3 Breeding success

Relatively, to a great part of the breeding parameters studied, all forest types show a similar performance for both tit' species (Table 4). Likewise, the results didn't show significant differences among the years, except for the number of hatchlings of blue tit (Table 4), that was higher in 2010. With respect to reproductive timing of both species, no differences were found for forest type or year and the estimated marginal mean for the laying date was the 54th day for great tits and for blue tits the 58th. The number of fledglings, as well as the clutch size, didn't also reveals statistical differences among forest types, years and no significant interactions between these two factors. The number of hatchlings of great tits differs significantly between forest types (Table 4).

Table 4. Effects of forest type, year and their interaction on breeding parameters of great tit (*Parus major)* and blue tit (*Cyanistes caeruleus)*.

	Great tit			Blue tit		
	df	*F*	*P*	*df*	*F*	*P*
Timing of reproduction						
Forest type	4	1.632	0.182	3	1.152	0.345
Year	1	0.297	0.588	1	0.664	0.422
Forest type x Year	4	1.106	0.365	3	2.504	0.079
Clutch size						
Forest type	4	2.123	0.086	3	1.458	0.242
Year	1	0.113	0.738	1	0.363	0.551
Forest type x Year	4	0.243	0.913	3	1.032	0.390
Number of hatchlings						
Forest type	4	3.535	**0.011**	3	0.425	0.736
Year	1	0.830	0.366	1	5.966	**0.020**
Forest type x Year	4	0.449	0.773	3	1.190	0.329
Number of fledglings						
Forest type	4	1.217	0.311	3	1.297	0.292
Year	1	0.109	0.742	1	0.255	0.617
Forest type x Year	4	1.577	0.190	3	1.242	0.310

Models were controlled for brood (1^{st} and 2^{nd}), except for the timing of reproduction where only the 1^{st} brood was used.

Due to residual occupancy of nest boxes by blue tit in the Pine forest no comparisons were performed with this specie in this forest type. The comparisons between forests are present in Figure 5. The estimated marginal means showed no differences in the clutch size for the both species in the different habitat types, as previous referred, but there seems to be a trend, where bigger clutches were laid in the monoculture forest and smallest ones in the mixed forest core. The number of hatchlings of the great tit was significantly higher in both monoculture forests when compared with the mixed forest core. At last, despite the lack of significant differences, the broadleaf forest seems one of the worst forests for the great tit while the eucalyptus forest is surprisingly a forest with tendency to more fledglings. For the blue tit, the number of fledglings is very similar in all forests, with the mixed forest edge achieving the highest values, and again the broadleaf forest with the lowest numbers

(estimated marginal mean of 2.548), with a value very similar to the one obtained in the eucalyptus forest (estimated marginal mean of 2.599).

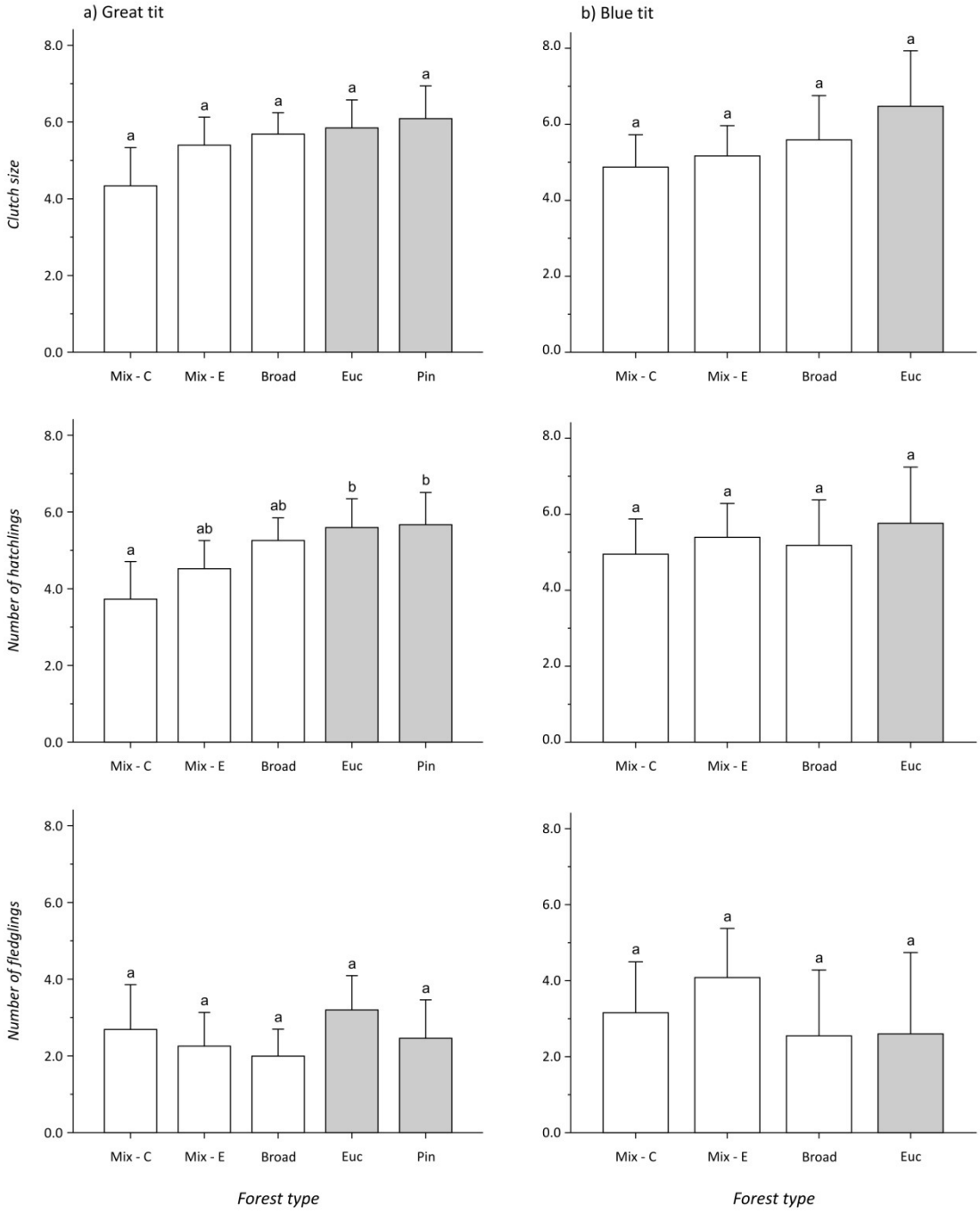

Figure 5. Comparison between the several forest types of the clutch size, number of hatchings and fledglings of great tit (*Parus major*) and blue tit (*Cyanistes caeruleus*). The bars represent the estimated marginal means and the error bars are the 95% confidence intervals.

4.5.4 Egg and chick traits

The eggs of great tits differ significantly between forest types, and there is also a significant interaction between forest type and year. In relation to blue tit, no differences were found in eggs' volume. The weight of both tits exhibited significant differences depending on the forest type (Table 5).

Table 5. Effects of forest type, year and their interaction on egg and chick traits of great tit (*Parus major*) and blue tit (*Cyanistes caeruleus*).

	Great tit			Blue tit		
	df	*F*	*P*	*df*	*F*	*P*
Egg volume						
Forest type	4	5.809	**<0.001**	3	0.513	0.677
Year	1	0.324	0.571	1	0.056	0.815
Forest type x Year	4	2.874	**0.029**	3	0.515	0.676
Chick body mass						
Forest type	4	3.172	**0.021**	3	3.488	**0.029**
Year	1	0.270	0.606	1	0.065	0.800
Forest type x Year	4	1.446	0.233	3	1.873	0.158

Models were controlled for brood (1^{st} and 2^{nd}).

The comparisons between the forest types showed that the eggs of great tits in the pine forest are significantly more voluminous when compared to eggs of the broadleaf and eucalyptus forests (Figure 6).

The fledgling's weight of great tits in the broadleaf and pines forests was the lowest, and with significant differences from those analysed in the mixed forest core (Figure 6). Furthermore, in figure 6 it is possible to see the differences of weight in blue tits chicks, where the lightest ones appear in the eucalyptus forest, which is significantly different from the chicks of the mixed forest edge.

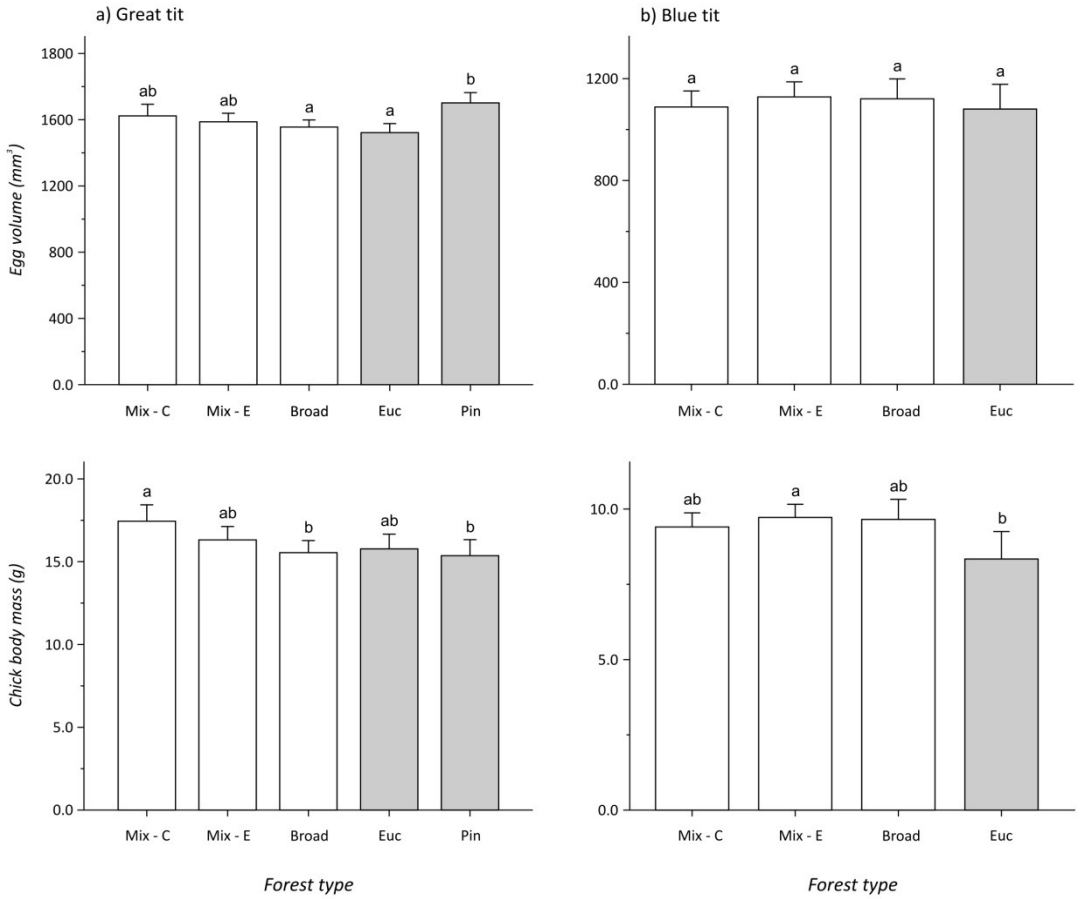

Figure 6. Comparison between the several forest types of the egg volume and chick body mass of great tit (*Parus major*) and blue tit (*Cyanistes caeruleus*). The bars represent the estimated marginal means and the error bars are the 95% confidence intervals.

4.6 Discussion

4.6.1 Great and blue tits densities

The relative mean densities of the great tit were, in a general way, as expected, and the high standard deviation values are an effect of the edge and clearings in all type of forests. The mean densities in the broadleaf forest were similar with the ones found in other forests with similar characteristics (*e.g.* van Balen 1973), those being some of the preferred habitats for this tit. The densities found in the pine forest were equivalent with densities described in others Maritime pine forests (Pina 1989; Pimentel and Nilsson 2007 a; Pimentel and Nilsson 2007 b). The higher mean density obtained in the mixed forest was also expected due to the higher volume of vegetation, which reaches more than twice the volume of the broadleaf forest for the same area. The density in the eucalyptus forest is much higher than the described by Pina

(1989), but as the census was conducted after the nest box placement, which occurred during the tit's dispersion and territory establishment period, mainly of first time breeders (Krebs 1971), what may have increased the density values. The usual cutting age of eucalyptus forests is around 10-12 years, and rarely exceeds 15 years (Pina 1989), so no natural holes exist in the trees, and not even woodpeckers seem to make them. Therefore, the presence of nest boxes is a great improvement for the eucalyptus forest quality to some nest hollers, including great tits. The breeding great tit density in the pine forest is similar to the obtained by Pimentel and Nilsson (2007a) in a near and identical study area.

The density of blue tits breeding pairs in oak woodlands in Spain (3.5 pairs ha^{-1}) (Sanz *et al.* 2010) is in the range of the estimated density value for the broadleaf forest in this study. The lower density verified in the mixed forest seems to be an effect of this species' habitat preference. The absence of blue tits during the census in the eucalyptus and pine forests, are a result of their extreme low densities and very restricted presence, because the census covers a very small area of the total area occupied by these types of forests in the study area. Almost no detections of this species occurred when large areas of these two forest types were surveyed by Pina (1989), and not even the nest boxes presence seems to be enough for this species, ecological more demanding than the great tit and more specialized (Nour *et al.* 1998), collecting almost all its food in broadleaf trees (Gibb and Betts 1963).

4.6.2 Nest box occupancy

The abundance of suitable natural holes is higher in the mixed and broadleaf forest than in both managed forests. Possibly, the high number of suitable natural holes in the mixed and broadleaf forest led to an occupation of the nest boxes, mainly by first year breeders during the first year of study. The same happened in the eucalyptus forest where the densities found are only justified by the placement of the nest boxes. On the other hand, in the pine forest older tits have also occupied the nest boxes due to their previous existence in this forest with almost no suitable holes, as in others similar forests (van Balen 1973; van Balen *et al.* 1982).

The density of tits and of its main nest predator don't seem to influence the nest box occupation, and neither does the distance to water source, roads, or the year of the study.

The tits densities may not affect the nest box occupancy, since the places with higher densities are also the ones with apparently better breeding conditions, as suitable natural holes. The great spotted woodpeckers, despite being predators of nest holes' species, may contribute to create the necessary conditions for the tits reproduction, having contradictories influences on tits populations.

Even though the distance to roads seemed not to affect the nest use, the mixed forest edge had a significantly higher occupancy of boxes by both tit species, which can reflect a preference for edges by them, as previous described for the great tit (Hanson 1994).

The number of nest boxes used by tits in the broadleaf forest, when compared with the mixed forest core, isn't proportionally related to their densities. The main trees in the mixed forest, the Mexican cypress, are generally thicker than the trees in the broadleaf forest, and also hollow inside, so cavities in the mixed forest are usually larger and with a bigger entrance than the holes that occur in the broadleaf forests. The natural holes in the mixed forest are more adequate for great tits, while the natural holes in the broadleaf forest are small for this specie, but more appropriate for blue tits, according to the preferences described for these two species by van Balen *et al*. (1982). This probably led to the higher number of boxes occupied by blue tits in the mixed forest, and by great tits in the broadleaf ones.

The altitude isn't a determining factor of the nest box occupancy by great tits and the result obtained for the blue tit, which preferred the nest boxes in an interval between the 400 and the 500 m. a.s.l. , can be a consequence of the low number of nest boxes used by this specie and due to the experimental design that wasn't the most appropriate to perform this kind of spatial analysis. The geographical position of the nest boxes affects their use, so the nests positioned to East were more occupied than those positioned otherwise. This could be explained by the uprising of sun at morning that helps tits to recover from the temperature fall occurred during the night. Although the results only confirm this theory for the great tit, the blue tit might have the same preference, but due to the facts previous mentioned for the altitude, no statistical differences were found.

Despite the fact that the year isn't a significant variable in the nest box occupation, if, as earlier suggested, in the first year the majority of breeders, in all forests except the pine forest, were first time breeders, in the second year an increase of the nest boxes should occur in all forests, except in the pine forest, even without a density increase, as we expected (van Balen *et al.* 1982; Mand *et al.* 2005; Mand *et al.* 2009). Even though not quite evident in table 2, the number of breeding pairs relying on nest boxes increase, because the number of second clutches laid in 2010 was only half of the ones in 2009. However, the increase of blue tits' breeding pairs in nest boxes of both mixed forests, and of great tits' in eucalyptus forest, cannot be explained exclusively by the number of second clutches, so probably the densities of blue tits in the mixed forest and of great tits in the eucalyptus forest also suffered a significant increase. The maritime pine forest too suffered an increase in the breeding pairs of great tits, as established by Pimentel and Nilsson (2007 a).

4.6.3 Breeding success

The laying date is known to be affected by some forest types, in the deciduous forest the laying date is earlier than in the evergreen forests for the great tit (Mand *et al.* 2005) and for the blue tit (Blondel *et al.* 1987; Dias *et al.* 1994; Blondel 2007), despite the absence of significant differences in several works (van Balen 1973; Sanz *et al.* 2010). In this study, all the forests are mainly evergreen, despite a noteworthy presence of deciduous trees in the broadleaf forest. The estimated dates in this study area for both species are similar with others of the Iberian Peninsula (*e.g.* Sanz *et al.* 2010), regardless of a small delay for the closer studies (Pimentel and Nilsson 2007 a; Norte *et al.* 2010).

The breeding results (number of eggs, hatchlings and fledglings) are lower than the usual in the Iberian Peninsula for the great tit (Belda *et al.* 1998; Atienzar *et al.* 2010; Sanz *et al.* 2010) and the blue tit (Blondel *et al.* 1987; Sanz *et al.* 2010). Even in a study situated 80km away from this one (Pimentel and Nilsson 2007 a; Pimentel and Nilsson 2007 b), and only exist a similarity on clutch size with the closest study, at less than 20Km (Norte *et al.* 2010). However, the existent differences can be explained by the availability of food, which affects the breeding parameters (van Balen 1973; Dias *et al.* 1994; Mand *et al.* 2009), and by other factors like bird densities (Blondel 1985; Pimentel and Nilsson 2007 a) and year (van Balen 1973).

The number of eggs, hatchlings and fledglings of the great tit should be a consequence of the amount of existent food and the competition to get it (Mand *et al.* 2009). The mixed and broadleaf forests have higher vegetation diversity and complexity, therefore, should provide more food, but the competition for it is also stronger. The tendency of the mixed forest, which has superior great tit densities, is to have the lowest clutches, while in the monoculture forests (pine and eucalyptus) is to have the bigger ones, which corroborates with it. In the pine forest, where larger clutches were present, it's also known that the laying of the first clutch matches with the stage where the Pine Processionary Moth *Thaumetopoea pityocampa* is more vulnerable (Pimentel and Nilsson 2007 b). The number of great tit hatchlings follows the tendency of the clutch size, with significant differences between the mixed forest core and the monoculture forests. The mixed forest should have the highest competition, so females have to spend more time feeding, and a high number of embryos die during the not totally adequate incubation (Atiénzar *et al*. 2010). However, the nest female in the edge of the forest seems to avoid this problem, because the open spaces allow a quick movement between various locations (Naef-Daenzar 2000), as well as benefiting from the human food wastes (Cowie and Hinsley 1988). Despite no significant differences were obtained in the number of fledgling, there are several observations that can be withheld. After the hatching, the number

of birds that each area has to support change, because where the birds' densities were high and the number of hatchlings was high too. So the competition for food increases more than in the forest where the number of hatchlings is inferior, leading to a lower survival rate of chicks (i.e. birds that can leave the nest).The number of fledglings in the pine forest suffered a great decrease compared to the number of the hatchlings, probably because the source of food that leads to a superior clutch finished. The eucalyptus forest is the habitat which tends to have more fledglings, due to the absent (or almost absence) of competition for food and by the presence of a strong shrub layer that can be an extra source of food to the great tit (Atiénzar *et al*. 2010).

The numbers of eggs laid by blue tit follow a similar trend to the one observed for the great tit, where the clutch tends to be bigger in the monoculture forest, in this case only in the eucalyptus forest (due to the lack information obtain for this specie in the pine forest). However, in the blue tit case, the habitat with higher density doesn't have the lower clutch size, probably pursuant to the differences in the feeding habits, that comparing with great tit have a higher dependence to the broadleaf trees (Gibb and Betts 1963) and even with greater densities, the blue tits can get more food. Nevertheless, when the eggs hatch, the food competition became apparent, and once again the edge seems to benefit the tits. At last the number of fledglings, show a lesser number of fledglings in the broadleaf forest, probably due to the higher food competition in this forest, while the edge effect seems to bring a little more benefit for the blue tit than for the great tit, because of the higher distance that this specie usually travels (Matthysen *et al.* 2005). However, caused by the feeding differences the blue tit cannot take the same advantages from the shrubs as the great tit (Gibb and Betts 1963), so their number of fledglings tends to be low.

4.6.4 Egg and chick traits

The egg size differences in the great tit can be explained by several factors as the size of the female, ambient temperature during egg formation (Nager and Zandt 1994) and by the clutch size (Encabo *et al.* 2001; Encabo *et al.* 2002). The differences obtained in the size of the great tit eggs between the several forests can hardly be explained by differences in the habitats, because of the proximity of them in terms of environmental conditions. Furthermore, Encabo *et al.* (2002) didn't find influences of the habitat type on the egg size. Previous was suggested that the breeding population in the nest boxes in the pine forest, during the first year of the study, was older than the population in the other forests, which can explain the differences in the egg size, because bird eggs can increase with female age (Christians 2002). Additionally,

this reason can explain the differences found in the interaction between forest type and years, since the breeding population age in the nest boxes increase in the remaining forest types, so the eggs should also suffer a slight increase, despite no significant differences were found between years.

Finally, the chicks' weight corroborates with the tendencies that other breeding data provide. The heavier great tits chicks, from the mixed forest core have significant differences from the ones who survived in the two forests with lower numbers of chicks, which confirms the worst breeding conditions in these forests. The blue tits chicks were heavier in the habitat that exhibit more fledglings per nest. The blue tits fledglings' weight confirms the lack of adequate food in the eucalyptus forest, while in the broadleaf forest regardless of the tendency to heavier chicks, regardless of the absence of significant differences between these two forests.

4.7 Conclusion

Both species show an adaptation to the non native forests, being able to reproduce in these forests with a better performance than in the native ones. In this study, the results shown a better balance between the number of eggs laid, the number of fledgling, and the chicks' weight in the mixed forest, which represents the habitat more diversity and complex in terms of vegetation. Notwithstanding the breeding results, the natural broadleaf forest should be preserved since it has high densities and can act as a species' source. However, the mixed forest and the broadleaf forest aren't as productive as the monocultures forests. The nest box placement is an effective way of increase bird densities in the monocultures. The general idea, that eucalyptus forest is less suitable for bird species doesn't seem true, at least compared with other commons monoculture forests. However, the high frequency of cutting doesn't allow natural sites for the breeding but the nest box placement can minimize it. In order to obtain the best possible results, should be taken into account the edge presence (Paton 1994) and the geographic placement of the nest boxes. The shrubs' layer cuts should also be done more carefully, in order to have a lower biological impact, due to its importance to the fauna.

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5 Final Remarks

5.1 Advices on the forest management

Higher bird densities were present in the more complex and diverse forests (Chace and Walce 2006), being these the natural broadleaf forest or mixed forest. The mixed forest showed a better breeding performance than the broadleaf in this work, probably due to the higher complexity in the vegetation. However, these two forest types aren't profitable when compared to the monoculture forests' plantations, but at least some of this "no" profitable forest should be maintained or even planted, because they can act as a species source, preventing the loss of biodiversity.

Nowadays, the expansion of eucalyptus forest isn't welcomed for most nature defenders, because it is seen as a poor forest (Catry *et al.* 2010; Proença *et al.* 2010). However, our results suggest that a correct nest box placement, as many times proved (van Balen 1973; Pimentel and Nilsson 2007; Mand *et al.* 2009), will make this forest much more suitable for birds, than the majority of forests that exist in Portugal, due to the elimination of one of the most important limiting factors to birds, an appropriate nest place.

The presence of patches showed advantages for the two study species of this work. However, it is important to remember that other species are harmed by their presence (Hansson 1994; Imbeau *et al.* 2003).

A different politics should also be taken for the cuts of shrubs. Although, its cut in the forests usually occurs in order to prevent large wild fires, the shrubs at the understory level are crucial to the fauna, and almost always forgotten. This vegetation can be essential for many animals, including passerines, and even to species with an unfavorable global status (IUCN 2010).

The small landholding areas that occur in the study area benefits the birds, because there are always places where trees are cut down, and others nearby to where birds can easily move to it. This may take place even in the breeding season when the nest is already started in a tree that will be cut, leading the tits to use another tree near its territory. If large areas are cut, as happened in the majority of cases, the birds and other fauna will die or forced to move to distant places.

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