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Habitat fragmentation influences nestling growth in Mediterranean blue and great tits

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ABSTRACT

In patchy forest areas, the size of the forest patch where birds breed has a strong influence on their breeding success. However, the proximate effects contributing to lowering the breeding success in small forest patches remain unclear; and a shortage of crucial resources in those forest patches has been suggested to account in some degree for this failure. With the aim to further investigate this issue, we have monitored the breeding cycle of blue and great tits in three 'large' forest patches (ranging between 26.5 and 29.6 ha) and twelve 'small' forest patches (ranging between 1.1 and 2.1 ha) in a Mediterranean area in central Spain, during three years (2011–2013). We also recorded the nestling diet inside the nest-boxes with the aid of handy-cams. Only males significantly differed between forest patch size categories; being on average younger and with better body condition in small patches for great and blue tits respectively. Reproductive traits did not vary between forest patch size categories, but the body condition of blue tit nestlings and the size of great tit nestlings did, being significantly better and larger respectively in large forest patches. The recruitment rate of blue tit nestlings was also higher in large patches. Regarding nestling diet, blue tits did not differ but great tits did, delivering a larger amount of caterpillars in large forest patches. Most variation in the reproductive traits occurred between years, probably due to annual differences in environmental conditions. This study suggests that food supply could be limiting the breeding success of birds above all in small patches, but also in large patches under particular environmental conditions.

1. Introduction

Habitat fragmentation is one of the major threats that forest biodiversity faces (Laurance, 2010; Amos et al., 2013; Bregman et al., 2014), and its effects have been widely studied in forest birds (Fahrig, 2003). The ultimate effect of habitat fragmentation is the decline of bird species richness and population abundances (Moller, 1987; Debinski and Holt, 2000; Boulinier et al., 2001). These numerical responses may stem, at least in part, in demographic changes, i.e. proximate effects given at a regional-scale (Lampila et al., 2005). However, the mechanisms underlying these proximate effects remain unclear, and it is of vital importance to light them in the sake of conservation biology (Boulinier et al., 2001; Le Tortorec et al., 2012). One feature that affects the breeding success of birds, is the size of the forest patch where they breed (Paton, 1995; Hinsley et al., 1999, 2009; Shochat et al., 2001; Loman, 2003; Zitsque et al., 2011; but see Nour et al., 1998), and a reduction of crucial resources in small forest patches has been suggested to be a responsible cause (Kuitunen and Makinen, 1993; Tremblay et al., 2005; Hinam and Clair, 2008).

In this regard, food supply could be a crucial resource limiting the breeding success of birds in small forest patches, as it is one of the most important limiting factors affecting life-history in birds (Lack, 1968; Martin, 1987; but see Martin, 1995). Food supply could be compromised in small forest patches just because their small

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surface area (Moller, 1991); but also because in small forest patches the proportion of forest edges increases (Helzer and Jelinski, 1999), which harsh the environmental conditions (Zanette et al., 2000) and may drive to a decrease in the amount of invertebrates (Didham et al., 1996; Burke and Nol, 1998). Furthermore, the process of habitat fragmentation typically implies degradation, which changes the structure of the remaining habitat (Hinsley et al., 1999; Fahrig, 2003). These changes in the vegetation structure usually involve microclimate alterations too; which apart from its direct effects on the abundance of invertebrates, it could promote a change in the composition of the vegetation which could also alter the composition of invertebrates (Cramp and Perrins, 1993; Laurance et al., 2002). In addition, for altricial bird species, breed in a small forest patch could be challenging due to they are 'central-place foragers', as they are attached to a fixed point when they breed, their nests (Tremblay et al., 2005). If they are not able to cope with the food demand of their broods within the patch, they will be forced to travel longer distances to reach other foraging patches, crossing unsuitable foraging habitats, which will limit their feeding rate (Bruun and Smith, 2003). In other cases, in landscapes containing little habitat, the distance between forest patches may exceed a species gap-crossing tolerance, constraining the size of the home ranges and limiting the availability of resources (Desrochers and Hannon, 1997). The ultimate effect of both scenarios is a reduction of the breeding success (Frey-Roos et al., 1995; Hinsley, 2000).

The aim of the present study was to test whether there is an effect of the forest patch size on the breeding performance of two populations of blue (*Cyanistes caeruleus*) and great tits (*Parus major*). To do this, we studied the breeding performance of these two species of tits in a fragmented landscape in central Spain during three years. Both species are ideal to study this topic as they need an enormous supply of food when they breed. For example great tits while feeding their chicks made up to 700 feeding visits per day, and blue tits even more (Perrins, 1991). Because of this, it is crucial for tits to match the maximum food demand period of their chicks with the food peak in the forest (Naef-Daenzer and Keller, 1999; Matthysen et al., 2011); when they do not achieve this match, their reproductive success can decrease (Svensson and Nilsson, 1995; Naef-Daenzer et al., 2001; Tremblay et al., 2003). We hypothesized that in small patches the breeding performance will be worse (Moller, 1991; Riddington and Gosler, 1995), and predict that the lack of resources in small patches will be an important responsible factor, concretely food supply (Burke and Nol, 1998; Zanette et al., 2000; Razeng and Watson, 2014).

2. Material and methods

2.1. Study area

The present study was conducted in the locality of San Pablo de los Montes situated in Montes de Toledo (39°32′44″N, 4°19′41″W; Toledo, central Spain). This region presents continental Mediterranean climate, characterized by pronounced summer droughts and a high daily thermal oscillation, with mean annual rainfall of 700–800 mm. The landscape of this area has suffered an intense fragmentation due to human activities, mainly agriculture and deforestation for raising cattle, as occurs in other regions of the Mediterranean basin (Blondel and Aronson, 1999). As a consequence, deciduous woodlands, considered the most suitable breeding habitat for tits in this region (Atiénzar et al., 2012), are scattered and patched in a matrix of less suitable habitat, mainly Mediterranean scrubland with low tree cover and pastureland. Our study area consisted of fifteen oak (*Quercus pyrenaica*) forest patches: three '*large*' patches ranging between 26.5 and 29.6 ha, and twelve '*small*' patches ranging between 1.1 and 2.1 ha, separated from each other by a mean distance of 4.23 km (range 0.53–9.84 km). Both oak forest patch size categories present a similar habitat structure, with the oak as dominant plant accompanied by its typical shrub courtship: common hawthorn (*Crataegus monogyna*), elmleaf blackberry (*Rubus ulmifolius*), terebinth (*Pistacia terebinthus*), and common broom (*Cytisus scoparius*). Large patches were provided with 80 wood nest-boxes (internal dimensions: 12 × 11.5 × 16.5 cm) and small ones with 5 wood nest-boxes; separated from each other by at least 30 m. All nestboxes were hung on the branches of oak trees at a height of 2.5–3 m and oriented towards the south. They were protected from predators (mustelids, woodpeckers) with wire mesh and a polyvinyl chloride (PVC) pipe (length: 50–70 mm, diameter: 40 mm) fixed to the hole-entrance. Because of this protection, the main predator in our study area was the ladder snake (*Rhinechis scalaris*), a very common species in the area (Salvador and Pleguezuelos, 2002).

2.2. Field work

During the 2011–2013 breeding seasons (day 1 = April 1), nest-boxes were frequently inspected to obtain the basic reproductive parameters of our tit population, such as laying date (the day of laying the first egg of the clutch), clutch size, hatching date and brood size. Body condition, size and age of parents were compared between patch size categories because these variables are indicators of status and thus of dominance over resources (Gosler, 1997; Stahl et al., 2001). To do this, parents were trapped and ringed while feeding their nestlings (8–9 days old). The tarsus length of birds was measured with a digital calliper to the nearest 0.01 mm; the body weight was measured with an electronic balance (0.01 g) and the age of parents (yearling or older) was noted according to plumage characteristics. Due to technical difficulties, adult great tits in 2011 were not trapped. Nestlings were ringed, measured and weighted when they were 13 days old, and mean values per brood were taken in the analyses. Tarsus length was employed as a surrogate of body size, and the weight analyses were corrected by the tarsus length (added as a covariate) to consider the body condition of birds. Nest-boxes were also visited on day 22 to assess the number of chicks fledged. We assumed that all chicks have fledged when we did not find any chick dead inside the nest-boxes. Hatching success was calculated as the ratio between the number of nestlings hatched and the clutch size; and fledgling success was calculated as the ratio between nestlings fledged and hatched. To assess the breeding performance of each tit pair, seven variables were used (laying date, clutch size, hatching success, fledgling success, nestling body condition, nestling size and fledgling recruitment). Fledgling recruitment was estimated by noting, for each yearling that we recaptured (i.e. that was born in the study area); the forest patch ID where it was breeding and the forest patch ID where it was born. Through this way, we could estimate the percentage of recruitments that were born in large or small patches and the percentage of them that achieved to breed in large or small patches the next year. Apart from the seven breeding variables mentioned above, we also estimated the nest-box occupation rate and the breeding density to increase the comprehensive approach of this study. Nest-box occupation rate was obtained for each species and year as the ratio between occupied nest-boxes and total availability of them in each forest patch. We also calculated the density of great and blue tits in each breeding territory as the number of tit breeding pairs in a radius of 75 m around each occupied nest-box with the aid of Quantum GIS 2.0.1, as it is an important trait influencing breeding performance and recruitment rate (Both, 1998; Both et al., 1999).