

Nesting habitat requirements and nestling diet in the Mediterranean populations of Crested Tits *Lophophanes cristatus*

Francisco ATIÉNZAR¹, Emilio BARBA¹, Leonard J. M. HOLLEMAN² & Eduardo J. BELDA³

¹„Cavanilles” Institute of Biodiversity and Evolutionary Biology, University of Valencia, PO Box 22085, E-46071 Valencia, SPAIN, e-mail: Francisco.Atiénzar@uv.es

²Netherlands Institute of Ecology (NIOO-KNAW), PO Box 40, 6666 ZG Heteren, THE NETHERLANDS

³IGIC, Universidad Politécnica de Valencia, C/ Paranimf n° 1, E-46730 Gandía, SPAIN

Atiénzar E, Barba E., Holleman L. J. M., Belda E. J. 2009. Nesting habitat requirements and nestling diet in the Mediterranean populations of Crested Tits *Lophophanes cristatus*. *Acta Ornithol.* 44: 101–108. DOI 10.3161/000164509X482678

Abstract. Most bird species show specific habitat requirements for breeding and feeding. We studied the pattern of habitat occupation, nestling diet and breeding performance of Crested Tits *Lophophanes cristatus* in a “typical” (coniferous) and an “atypical” (Holm Oak *Quercus ilex*) forest in eastern Spain during 2005–2007. We aimed to determine which microhabitat characteristics in the Holm Oak forest could account for the presence of Crested Tits, and checked whether the nestling diet in the Holm Oak forest resembled that obtained in the pine forest. Vegetation maps were produced using GIS from observations made in the field (tree species, tree and shrub cover). Nestling diet was recorded through video surveillance. Crested Tits bred in mature, low-density areas in the pine forest. Those breeding in the Holm Oak forest built their nests in areas including pine trees and avoided densely forested areas. Birds breeding in the pine forest started laying by mid-April and the average clutch size was 5 eggs. In the Holm Oak forest, birds started laying by the end of April and average clutch size was also 5 eggs. Fledglings weighed around 12 g in both forests. Nestling diet, prey size and feeding frequency by the parents did not vary between the forests. The main prey types consumed were Lepidoptera larvae and Diptera.

Key words: *Lophophanes cristatus*, Crested Tit, nest site selection, habitat requirements, Holm Oak forest, nestling diet

Received — March 2009, accepted — Oct. 2009

INTRODUCTION

Most bird species have specific habitat requirements for breeding (see Cody 1981, Holmes & Robinson 1981, Avery & Leslie 1990, Jones 2001, Mörtberg 2001). For instance, Crested Tits *Lophophanes cristatus* are adapted to coniferous forests (Cramp & Perrins 1993). In spite of this, Crested Tits also breed in other habitats, such as mixed (Perrins 1979, Díaz et al. 1998), Holm Oak *Quercus ilex* (Herrera 1978, Maicas & Fernández 2004) or even pure deciduous forests (Perrins 1979, Blondel 1985), though densities are generally low in these habitats (Díaz et al. 1998). Nevertheless, the conditions required for this species to occur in forest types other than coniferous ones remain unknown.

Tree species composition and vegetation structure may be important habitat traits for nest site selection (Avery & Leslie 1990, Denny & Summers 1996). Thus, a way to answer the above question

might be studying the characteristics of the specific sites where birds are breeding within the uncommon habitat, and see whether those places resemble the characteristics of their preferred habitat. For instance, Pied Flycatchers *Ficedula hypoleuca*, typical deciduous forest birds (Lundberg & Alatalo 1992, Martí & Del Moral 2003), have been found nesting in coniferous plantations, but only in patches including a few broadleaved trees (e.g. Avery & Leslie 1990). This type of studies gives the most useful information on tree-species preferences by birds, though they are relatively scarce (see Avery & Leslie 1990).

Floristic composition determines the dominant food type and food abundance for birds (Blondel et al. 1991, Lundberg & Alatalo 1992). Since the quality and quantity of food supply are crucial in determining breeding traits (see Martin 1987, Blondel et al. 1993), it is of interest to find out how bird species adapted to a specific habitat cope with the food resources available in different

“atypical” habitats (e.g. Barba et al. 2004). Little is known on the nestling diet of Crested Tits, and most studies have been carried out in pine or spruce forests (Cramp & Perrins 1993, and references therein). Therefore, apart from how the birds consider the physical characteristics of the habitat for nesting in a non-coniferous habitat, it is of interest to know which prey types and sizes the adults bring to their nestlings in those “atypical” forests.

The original forests in the Mediterranean Basin were composed of different oak species, with Holm Oaks being the dominant evergreen tree species within altitudes ranging 500–1000 m a.s.l. (Blondel & Aronson 1999). However, Holm Oak forests have been largely replaced by pine plantations, which were virtually non-existent until a few decades ago in the south of the Iberian Peninsula (Maícas & Fernández 2004). In the Mediterranean area, Crested Tits mainly occur in pine forests, though they have also been found in Holm Oak forests (see Tellería et al. 1999).

We studied Crested Tits in two forests in eastern Spain: a Holm Oak forest, which was an example of the ancient forests of the Mediterranean region, and a pine forest, an example of relatively new reforested areas, both placed at the same latitude. Our aim was to describe the nesting habitat, the nestling diet and the breeding performance of Crested Tits in a “typical” (coniferous) and an “atypical” (Holm Oak) forest. This will give insights into the microhabitat that Crested Tits use in these forests.

STUDY AREA AND METHODS

Study area

The study was performed in two natural parks, Sierra Mariola (38°44'N, 0°33'W, 900 m a.s.l.) and Font Roja (38°39'N, 0°32'W, 1090 m a.s.l.) in eastern Spain. The distance between these areas was about 8 km. Sierra Mariola (SM hereafter) consists mostly of Aleppo Pine trees *Pinus halepensis*, and Font Roja (FR hereafter) of Holm Oaks. Despite that short distance, the vegetation composition and climate were different because of differences in altitude, orography and orientation. In both areas, human activity (e.g. silvicultural practices for preventing forest fires) has created a vegetation structure mainly characterized by regeneration of stands of even age. During three breeding seasons (2005 to 2007), a total of 110–121 nestboxes in SM and 118–140 in FR were checked.

Nestboxes occupied a surface of ca. 442 ha in SM and of ca. 355 ha in FR. All nestboxes were located using a geographic positioning system (GPS; Garmin 12). They were similar in size, were hung at a similar height (around 2 m) near pathways about 75–100 m away from each other, and were cleaned before each breeding season.

Breeding parameters and vegetation sampling procedure

Nestboxes were visited once a week, and active nests were visited with a pattern which allowed us to assess laying date (assuming that one egg was laid per day; 1 = 1 April), clutch size and hatching date. After hatching, nests were checked till fledging or failure, and the number of fledglings registered. Nestlings were weighed at day 14 (day of hatching = 0). Weight measurements of nestlings from the same nest were averaged to obtain a single value per nest (Eddison 2000), so the statistical unit was the brood. Only first clutches were used, and sample size varied according to the breeding trait analyzed due to nest losses along the nesting period.

Vegetation cover and species composition were quantified by performing three 50 m line intercept transects starting from each nestbox. For each transect, we measured the cover of trees (more than 3 m in height) and shrubs (range 0.5–3 m) through the intercept of each shrub and tree species along the line (Elzinga et al. 2001, Hill et al. 2005). Vegetation shorter than 0.5 m was not considered. The directions of transects from the nestbox were chosen at random, through fixing a minimum distance of 45° among transects; these bearings were measured with a compass. Transects were performed throughout the year (2006–2007), but in FR the sampling was done in spring and summer to allow easy identification of deciduous species. We considered that vegetation structure did not differ appreciably during the study period.

Additionally, sampling plots of 25 m radius centered on each nestbox were established. Within these plots we measured the average diameter at breast height (DBH) of the five thickest trunks (using a 1-m metric tape), and the number of young (5–10 cm DBH) and old trees (> 30 cm DBH; Arriero et al. 2006) classified by eye after previous training. To increase the accuracy of the count of the trees, the 25 m radius circle around each nestbox was split into four sections. The shrub layer, composed by 17 (FR) to 19 (SM) species, was included, since Crested Tits were

observed foraging on it (pers. obs.), and because shrubs may be considered as a secondary micro-habitat for this species when food availability is scarce (Díaz et al. 1998).

We included in the sample all nestboxes placed in SM, but only 116 (83% of the maximum number present) in FR. The remaining FR boxes were excluded for safety reasons, since the slope was too steep for vegetation sampling. All vegetation measurements were made by the same author (FA).

The software ARCGIS spatial analyst version 9.1 was used for processing vegetation data. Transect data were georeferenced in a Transverse Mercator Complex WG1984, Complex UTM-Zone 30 N coordinate system. From each transect, we calculated the spatial distribution of several tree species and shrubs with an interpolation technique called Inverse Distance Weighted (IDW). This method estimates cell values by averaging the values of sample data points in the vicinity of each cell. The closer a point was to the centre of the cell being estimated, the more influence, or weight, it had in the averaging process. Thus, a complete vegetation map of each study area was generated. Finally, we created three different buffers around each nestbox (25, 50 and 75 m radius), all within the normal foraging area for Crested Tits (Karlsson 1994). For each nestbox and buffer, we estimated different vegetation parameters (tree species, tree and shrub cover) with a specially written program which uses an overlapping zonal statistical technique (PythonWin 2.1). This program allows calculating average vegetation cover within a layer and for overlapping layers (buffer).

Principal component analyses (PCA) were carried out to reduce the number of habitat variables. Since we were interested in knowing the incidence of Aleppo Pine trees on nest placement in

FR, we used two measures of tree cover, one taking into account only the Aleppo Pine cover, and the second taking into account tree cover excluding Aleppo Pines. Based on broken stick analyses (Jackson 1993), PC1 and PC2 should be taken into account in further analyses for both study areas (see Table 1). Therefore, all the analyses were performed with PC1 and PC2, but none of the results including PC2 were significant and they are not presented here. An increase of PC1 values in the pine forest meant more mature vegetation patches, with low shrub cover and few number of young trees. On the other hand, as the value of PC1 in the Holm Oak forest decreased, the Aleppo Pine cover increased.

We also repeated PCAs for the three buffers. Analyses were then performed with data of the three buffers, but results obtained for 50 m and 75 m were either not significant or redundant with those for 25 m, so they are not presented here.

Diet sampling procedure

Diet was studied by videotaping (Currie et al. 1996) using digital video cameras (Sony DCR-DVD 203). Feeding visits were recorded during one hour per nest when nestlings were around 10 days old (10.66 ± 0.17 , range 10–13 days old). Afterwards, DVDs were played and, for each visit, we recorded prey type and length. To identify prey types more easily, we placed wire cages (see Atiénzar et al. 2009) onto the front of the nestbox before filming, so that birds entered the nestbox slowly. Prey were assigned to several categories (see Table 3) by the same author (FA). Nestling diet was studied during the three years in SM and only during the two first ones in FR, since all nests failed in 2007.

Prey body length was estimated for all identified prey items, ignoring legs and other appendages. It was estimated by comparison with the bill

Table 1. Summary of the two first components extracted from the principal component analyses for habitat measured in 25 m buffer around nests in both forests. Tree cover — total amount of cover around the nest; Tree cover_b — total amount of cover excluding Aleppo Pine cover. * — $p < 0.05$.

	Pine forest (SM)		Holm Oak forest (FR)	
	PC1	PC2	PC1	PC2
N° trunks 5–10 cm	-0.50*	0.04	-0.13	0.13
N° trunks > 30 cm	0.88*	0.17*	0.91*	0.27*
Mean diameter 5 thickest trees	0.88*	0.26*	0.92*	0.14
Shrub cover (%)	-0.61*	0.53*	0.22*	0.66*
Aleppo Pine cover (%)			-0.27*	0.58*
Tree cover (%)	0.04	-0.89*		
Tree cover_b (%)			0.48*	-0.72
Eigenvalue	2.17	1.16	2.05	1.38
% variance accounted for	43.45	22.92	34.2	23.05

length of the bird, both measured over the computer screen by placing graph paper. Actual mean bill length was measured on adult birds mist-netted in both forests when they were bringing food to their nestlings (mean bill length for FR: 10.85 ± 0.31 mm, $n = 6$; for SM: 11.20 ± 0.20 mm, $n = 18$). To estimate prey length we used the appropriate mean bill length depending on the forest.

Samples collected in SM belonged to 20 different nests (19 first and one second clutch) obtained between 14 April and 8 June. For FR, data were obtained from 6 first clutches, 5 from nestboxes and one from a natural nest, between 12 May and 8 June.

Statistical analyses

To remove the possible non independence of data among years, only one data point was used for analyses concerning habitat characteristics when the same nestbox was chosen for breeding more than one year. Thus, a total of 48 nests in which at least one Crested Tit egg was laid were used (SM = 35 nests, FR = 13 nests).

To analyze the likelihood of a nestbox being occupied by Crested Tits we considered nestboxes occupied by this species (scored as 1) and those which remained empty (scored as 0). We excluded from this analysis nestboxes occupied by other putative competitors like Great Tits *Parus major*, Coal Tits *Periparus ater*, Short-toed Treecreepers *Certhia brachydactyla* and House Wrens *Troglodytes troglodytes* (see Díaz et al. 1998) and therefore not available for Crested Tits. The best model was found using stepwise logistic regression. The effect of habitat type on breeding parameters (only for laying date and clutch size, as for number of fledglings and their condition sample sizes were too small) and on prey sizes were analyzed using GLM (SPSS 15.0 statistical package) showing the mean \pm SE when needed. Those nests in which chicks were predated were excluded from the analyses where the number of fledglings was involved.

RESULTS

Habitat structure, nestbox occupancy and breeding parameters

In their typical pine forest habitat (SM), Crested Tits chose open mature areas including trees with a mean diameter greater than 30 cm immediately around the nest (Wald Statistic = 4.28,

$p = 0.039$). The probability of nestbox occupancy by Crested Tits in the pine forest increased with the vegetation maturity of the territory within 25 m around the nest (regression equation: $y = 1/(1 + e^{-(0.30 + (3.36 \text{ PC1}))})$). Areas composed of young trees with a developed shrub layer were avoided (Fig. 1).

In the "atypical" Holm Oak forest habitat (FR), the likelihood of a nestbox to be occupied by Crested Tits increased with Aleppo Pine cover (Wald Statistic = 7.80, $p = 0.005$, regression equation: $y = 1/(1 + e^{-(2.73 + (-1.18 \text{ PC1}))})$, Fig. 2). Mean Aleppo Pine cover around nestboxes where Crested Tits bred was $6.5 \pm 1.8\%$, being of $3.8 \pm 0.7\%$ the cover of Aleppo Pine where the species was absent (see more in Table 2 for other vegetation traits). Instead, they avoided nestboxes located in mature and dense areas, and lacking pines.

Mean laying date of Crested Tits was 16.43 ± 2.07 ($n = 42$ nests) in the pine forest (SM) and 27.09 ± 2.71 ($n = 11$ nests) in the Holm Oak forest (FR) ($F_{1,51} = 6.15$, $d = 0.35$, $p = 0.02$). Mean clutch size was around 5 eggs in both forests (SM: 5.1 ± 0.2 eggs, $n = 39$; FR: 4.9 ± 0.4 eggs, $n = 9$; $F_{1,46} = 0.51$, $d = 0.37$, $p = 0.48$). The number of fledglings was approximately 4 (SM: 4.4 ± 0.2 , $n = 24$) and nestling weighed about 12 g in both forests (SM: 11.5 ± 0.2 g, $n = 21$; FR: 11.7 ± 0.3 g, $n = 4$).

Nestling diet, prey size and feeding frequency

A total of 362 prey items were registered. We removed from this sample 68 flying ants recorded in one nest in one sampling session (in SM), so sample size for further analyses was 294 prey items.

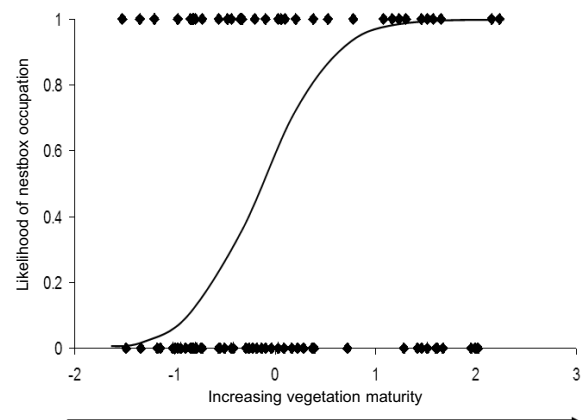


Fig. 1. The probability of nestbox occupancy by Crested Tits in the pine forest in relation to the vegetation maturity (PC1) of the territory within 25 m around the nest.

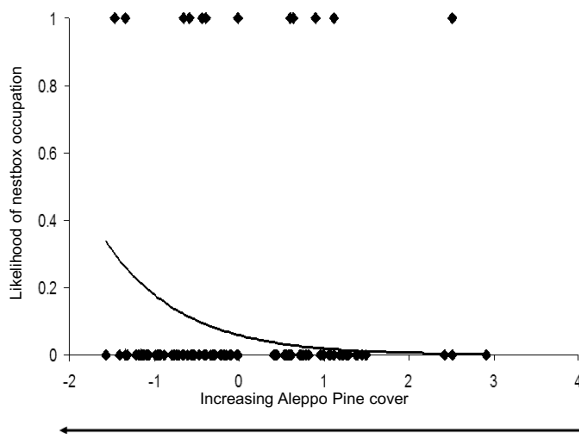


Fig. 2. The probability of nestbox occupancy by Crested Tits in the Holm Oak forest in relation to the Aleppo Pine cover within 25 m around the nest.

Considering the three main prey types (caterpillars, Diptera and spiders), diet composition of Crested Tit nestlings did not show differences between forests ($\chi^2_2 = 1.63$, $p = 0.44$). Thus, nestling diet was mainly composed by Lepidoptera larvae (64%) and Diptera (16%, mainly tipulids; see Table 3 for more details). Crested Tits nestlings consumed 11 different prey types in the pine forest, though 9 of them accounted for less than 4% of the items. The percentage of unidentified prey was high in FR, though excluding data from the natural nest, where prey identification was more difficult, it decreased to 9.8%, a similar level than in SM.

Mean prey length did not vary significantly between study areas (SM: 1.89 ± 0.07 cm, $n = 229$; FR: 2.05 ± 0.16 cm, $n = 37$; $F_{1,264} = 0.76$, $p = 0.39$). The same result was obtained when only caterpillars were considered (SM: 2.13 ± 0.10 , $n = 149$; FR: 2.06 ± 0.19 cm, $n = 28$; $F_{1,175} = 0.12$, $p = 0.74$). Prey length mostly ranged 1–2 cm in both areas. Prey above 3 cm were scarce (Fig. 3).

Finally, adults visited nests at a rate of 11.99 ± 0.86 visits/h in pine forest (SM, $n = 18$ nests) and of 12.29 ± 1.60 visits/h in Holm Oak forest (FR, $n = 4$ nests). Each nestling received, on average, between 3 and 4 visits per hour (SM: 3.06 ± 0.26 ; FR: 3.85 ± 0.26 visits per hour per nestling).

DISCUSSION

Habitat requirements of Crested Tits in their typical habitat are poorly known. They excavate cavities in large dead trees in open forests to build their nests (Denny & Summers 1996, Mörtberg 2001). In the cases where artificial nestboxes were used, the species preferred areas which provided high vegetation cover created by a high density of thin trees (Summers et al. 1993). Our results showed that Crested Tits breeding in nestboxes in the pine forest selected open areas with trees with a large girth. It is difficult to explain the differences between our results and those presented by Summers et al. (1993) and Denny & Summers (1996), but differences in the overall forest structure could have contributed. One plausible explanation would be that dominant Great Tits selected dense areas and thin trees (own unpubl. data) forcing Crested Tits to occupy open areas composed by thick trees. However, the probability of nest occupancy by Great Tits was the same for those nestboxes located either in mature or in immature areas (own unpubl. data; $p > 0.05$).

Crested Tits have their life history mainly adapted to coniferous forests, but they also appear in other habitats, including those dominated by Holm Oaks (Herrera 1978, Maicas & Fernández 2004, present study). Some studies have reported that birds may use certain tree species within the forest (see Hartley 1953, Franzreb 1978, Holmes & Robinson 1981, Avery & Leslie 1990). For instance, Coal Tits preferred mostly coniferous trees for

Table 2. Vegetation characteristics (mean \pm SE) in buffer 25 m around nestboxes occupied or not by Crested Tits for both studied forests. N — sample size.

	Pine forest (SM) Nestboxes		Holm Oak forest (FR) Nestboxes	
	occupied (N = 35)	not occupied (N = 60)	occupied (N = 13)	not occupied (N = 127)
N° trunks 5–10 cm	12.3 ± 7.6	14.3 ± 1.4	41.9 ± 7.6	27.5 ± 1.3
N° trunks > 30 cm	4.2 ± 0.5	3.6 ± 0.5	0.9 ± 0.5	2.0 ± 0.2
Mean diameter 5 thickest trees	33.6 ± 1.2	31.3 ± 0.8	24.9 ± 1.2	29.1 ± 0.5
Shrub cover (%)	6.8 ± 4.3	7.4 ± 1.1	25.1 ± 4.3	26.5 ± 1.5
Tree cover (%)	51.4 ± 5.8	46.7 ± 2.2	41.7 ± 5.8	54.2 ± 1.9
Aleppo Pine cover (%)			6.5 ± 1.8	3.8 ± 0.7

Table 3. Diet of Crested Tit nestlings in the pine forest (SM) and in the Holm Oak forest (FR), expressed as frequencies of appearance of the different food categories in the samples.

	Pine forest		Holm Oak forest	
	% prey	% nests	% prey	% nests
Lepidoptera adult	2.0	20.5	0	0.0
Lepidoptera larvae	60.1	95.0	68.3	100.0
Diptera	12.6	55.0	19.5	40.0
Spiders	5.9	55.0	2.4	20.0
Hymenoptera	3.2	25.0	0.0	0.0
Pupae	3.6	40.0	0.0	0.0
Homoptera	1.1	10.0	0.0	0.0
Coleoptera	0.8	10.0	0.0	0.0
Miriapoda	0.4	5.0	0.0	0.0
Odonata	0.4	5.0	0.0	0.0
Seeds	0.4	5.0	0.0	0.0
Not identified	9.5	50.0	9.8	60.0
Total number of prey/nests	253.0	20.0	41.0	6.0

feeding in mixed forests (Hartley 1953). Similarly, Wood Warblers *Phylloscopus sibilatrix* occur mainly in deciduous forests, and they select patches of deciduous trees when they are breeding in coniferous forests (Avery & Leslie 1990). In the present study, we have shown that Crested Tits preferred breeding in territories including pines within the Holm Oak forest. Birds may select trees because they provide different nesting opportunities, but since we used nestboxes, this explanation could be dismissed. On the other hand, choosing certain tree species may be a useful strategy to further segregate the habitat among other competitors (Balda 1969). However, only 45% of the nestboxes placed in the Holm Oak forest were used for nesting by putative competitors, so competition for nesting sites should be low. Finally, differences in food availability (Díaz et al. 1998, Tremblay et al. 2003) and type (Blondel et al. 1991) that trees may

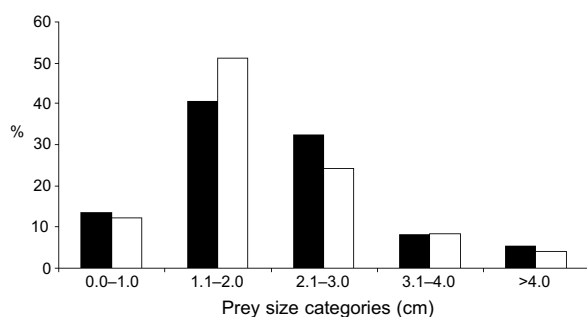


Fig. 3. Range of prey sizes (cm) consumed by Crested Tit nestlings according to the percentage of occurrence for Holm Oak forest (FR, black bars) and for pine forest (SM, white bars).

contain may account for our results. It probably was not an issue of food quantity, since Holm Oaks hold more food than pines (Tremblay et al. 2003). A most suitable explanation is that Crested Tits searched for pine trees because birds might find in pines some prey types and prey species not present in Holm Oak trees. Actually, we did not find any difference in the nestling diet between nests in pine and Holm Oak forests, though we are aware that we did not identify the prey to species level and differences might arise at this level. Finally, we can not reject the idea that birds just chose for nesting microhabitats more familiar to them, selecting then those nestboxes with some pines around. In any case, it is clear from our results that Crested Tit distribution within the Holm Oak forest was affected by pine tree distribution.

Crested Tits started to breed around 10 days later in the Holm Oak forest. A similar difference was found by Maícas & Fernández (2004) when comparing two Crested Tit populations occupying similar habitats, though the structure of the Holm Oak habitat was that of a "dehesa", not a forest. Several factors may be behind these differences. First, there is a general pattern of delaying reproduction as altitude increases, mainly due to delays in vegetation phenology associated to a decrease in temperatures (Sanz 1998). Indeed, the peak of caterpillar abundance was later in the Holm Oak forest (own unpubl. data). Hence, this might contribute to the observed difference in our study. Second, competition with other tit species for nestboxes, along with low food availability in coniferous forests (Tremblay et al. 2003) could force Crested Tits to breed earlier (Maícas & Fernández 2004). Indeed, 75% of the nestboxes were occupied in the pine forest, compared with the 45% in the Holm Oak forest.

Food availability depends on the floristic composition of the habitat (Díaz et al. 1998). Considering the positive relationship between food availability and clutch size (Klomp 1970), differences reported by Tremblay et al. (2003) in food availability among forests should result in larger clutches in the Holm Oak forest. However, no differences in clutch size between forests were detected. Also, nestling diet composition, prey size, and feeding frequency did not differ between forests, suggesting that Crested Tits experienced similar food conditions in both areas. Indeed, no differences in fledgling weight were detected. Thus, our results suggest that Crested Tits breeding within the Holm Oak forest

managed relatively well, though we are aware that sample sizes for the Holm Oak forests were low, and more data should be collected to be conclusive. Breeding traits observed in the pine forest were similar to those previously obtained in this habitat type (Denny & Summers 1996, Maícas & Fernández 2004). To the best of our knowledge, no previous breeding data from Holm Oak forests are available.

Not surprisingly, the few available studies on Crested Tit nestling diet have been mostly performed in coniferous forests. In these habitats, spiders and caterpillars were reported to be the main prey types consumed, although pine seeds were also found in significant quantities (Cramp & Perrins 1993 and references therein). In our study areas, Crested Tit nestlings were fed mainly with insects, and occasionally with vegetable matter. Caterpillars and Diptera amounted to 72% of total animal prey types. Contrasting with most previous studies, spiders were not the main prey type consumed. On the other hand, based on the effect of tree species over food types present (Blondel et al. 1991), one would expect to find differences in chick diet among types of forests. However, adult Crested Tits fed their chicks with similar main prey types and prey sizes in Holm Oak and pine forests. The facts that Crested Tits in the Holm Oak forests selected mainly nearby pines to find food, and that our level of precision in the determination of prey was too rough, might have contributed to this result.

Summing up, the present study has shown that those Crested Tits inhabiting in a Holm Oak forest bred successfully despite being an unusual breeding habitat for the species. Clutch size, number of fledglings, nestling diet (prey type and size) and feeding frequency did not differ from those observed in a pine forest. We found that, within the Holm Oak forest, Crested Tits selected patches including pine trees for placing the nest, so the presence of pine trees around the nests might have favoured the similarity of the breeding traits between the two populations. We are certainly aware that sample sizes are low for some parameters, and further studies on these Mediterranean habitats would be desirable.

ACKNOWLEDGEMENTS

We wish to thank to V. Cortés, J. L. Greño, E. Marco, E. Álvarez, J. Andreu, M. Domínguez and D. Martínez for their help in the field and lab. We

also thank to R. Summers for useful comments on a previous draft. T. Durmaz kindly revised and improved the English of this manuscript. Vegetation data used in the present study was processed at the Netherlands Institute of Ecology (NIOO-KNAW) according to suggestions given by M. E. Visser. The study was financed by the Ministerio de Educación y Ciencia (MEC, projects CGL2004-00787 and CGL2007-61395). F. Atiénzar had a FPU grant from the Ministerio de Educación y Ciencia (AP2004-0907), and enjoyed a short stay at the NIOO thanks to a grant awarded by the Ministerio de Educación y Ciencia (2007).

REFERENCES

- Arriero E., Sanz J. J., Romero-Pujante M. 2006. Habitat structure in Mediterranean deciduous oak forests in relation to reproductive success in the Blue Tit *Parus caeruleus*. *Bird Study* 53: 12–19.
- Atiénzar F., Andreu J., Álvarez E., Barba E. 2009. An improved wire cage for the study of parental feeding behaviour of hole-nesting passerines. *Catalan J. Ornithol.* 25: 26–31.
- Avery M., Leslie R. 1990. *Birds and forestry*. T & A D Poyser, London.
- Balda R. P. 1969. Foliage use by birds of the oak-juniper woodland and ponderosa pine forest in South-eastern Arizona. *Condor* 71: 399–412.
- Barba E., Gil-Delgado J. A., Monrós J. S. 2004. Relationship between nestling diet and breeding performance of Great Tits in a caterpillar-poor environment. In: van Emden H. F., Rothschild M. (eds). *Insect and bird interactions*. Intercept, Cambridge, UK, pp. 233–238.
- Blondel J. 1985. Breeding strategies of the Blue Tit and Coal Tit *Parus* in mainland and island Mediterranean habitats: a comparison. *J. Anim. Ecol.* 54: 531–556.
- Blondel J., Aronson J. 1999. *Biology and wildlife in the Mediterranean region*. Oxford Univ. Press, Oxford.
- Blondel J., Dervieux A., Maistre M., Perret P. 1991. Feeding ecology and life history variation of the Blue Tit in Mediterranean deciduous and sclerophyllous habitats. *Oecologia* 88: 9–14.
- Blondel J., Dias P. C., Maistre M. C., Perret P. 1993. Habitat heterogeneity and life-history variation of Mediterranean Blue Tits *Parus caeruleus*. *Auk* 110: 511–520.
- Cody M. L. 1981. Habitat selection in birds: the roles of vegetation structure, competitors, and productivity. *Bioscience* 31: 107–113.
- Cramp S., Perrins C. M. 1993. *The birds of the Western Palearctic*. Vol. VII. Oxford Univ. Press, Oxford.
- Currie D., Nour N., Adriaensen F. 1996. A new technique for filming prey delivered to nestlings, making minimal alterations to the nestbox. *Bird Study* 43: 380–382.
- Denny R. E., Summers R. W. 1996. Nest site selection, management and breeding success of Crested Tits *Parus cristatus* at Abernethy Forest, Strathspey. *Bird Study* 43: 371–379.
- Díaz M., Illera J. C., Atienza J. C. 1998. Food resource matching by foraging tits *Parus* spp. during spring-summer in a Mediterranean mixed forest; evidence for an ideal free distribution. *Ibis* 140: 654–660.
- Eddison J. C. 2000. *Quantitative investigations in the Biosciences using MINITAB™*. Chapman & Hall/CRC, Boca Raton, USA.

- Elzinga C. L., Salzer D. W., Willoughby J. W., Gibbs J. P. 2001. Monitoring plant and animal populations. Blackwell Science, Inc. USA.
- Franzreb K. E. 1978. Tree species used by birds in logged and unlogged mixed coniferous forests. *Wilson Bull.* 90: 221–238.
- Hartley P. H. T. 1953. An ecological study of the feeding habits of the English titmice. *J. Anim. Ecol.* 22: 261–288.
- Hartley P. H. T. 1987. Ecological aspects of the foraging behaviour of Crested Tits *Parus cristatus*. *Bird Study* 34: 107–111.
- Herrera C. M. 1978. Niche-shifts in the genus *Parus* in southern Spain. *Ibis* 120: 236–240.
- Hill D., Fasham M., Tucker G., Sherry M., Shaw P. 2005. Handbook of biodiversity methods. Survey, evaluation and monitoring. Cambridge Univ. Press, UK.
- Holmes R. T., Robinson S. K. 1981. Tree species preferences of foraging insectivorous birds in a northern hardwoods forest. *Oecologia* 48: 31–35.
- Jackson D. A. 1993. Stopping rules in principal components analysis: a comparison of heuristical and statistical approaches. *Ecology* 74: 2204–2214.
- Jones J. 2001. Habitat selection studies in avian ecology: a critical review. *Auk* 118: 557–562.
- Karlsson S. 1994. Foraging area and feeding frequency of the Crested Tit *Parus cristatus* during the nestling period. *Ornis Fennica* 71: 72–74.
- Lundberg A., Alatalo R. V. 1992. The Pied Flycatcher. T & A D Poyser, London.
- Klomp H. 1970. The determination of clutch size in birds: a review. *Ardea* 58: 1–124.
- Maicas R., Fernández J. 2004. Pine plantations as a breeding habitat for a hole-nesting bird species Crested Tit *Parus cristatus* in southern Spain. *Forest Ecol. Manage.* 195: 267–278.
- Marti R., Del Moral J. C. 2003. [Atlas of breeding birds of Spain]. Dirección General de Conservación de la Naturaleza-Sociedad Española de Ornitología. Madrid.
- Martin T. E. 1987. Food as a limit on breeding birds: a life history perspective. *Ann. Rev. Ecol. Syst.* 18: 453–487.
- Mörtberg U. M. 2001. Resident bird species in urban forest remnants; landscape and habitat perspectives. *Land. Ecol.* 16: 193–203.
- Perrins C. M. 1979. British tits. Collins, London.
- Sanz J. J. 1998. Effects of geographic location and habitat on breeding parameters of Great Tits. *Auk* 115: 1034–1051.
- Summers R. W., Taylor W., Underhill L. G. 1993. Nesting habitat selection by Crested Tits *Parus cristatus* in a pine plantation. *Forestry* 66: 147–151.
- Tellería J. L., Asensio B., Díaz M. 1999. [Iberian Birds. II. Passerines]. J. M. Reyero Ed. Madrid.
- Tremblay I., Thomas D. W., Lambrechts M. M., Blondel J., Perret P. 2003. Variation in Blue Tit breeding performance across gradients in habitat richness. *Ecology* 84: 3022–3043.

STRESZCZENIE

[Wymagania środowiskowe i pokarm piskląt czubatki we wschodniej Hiszpanii]

W pracy porównano wybiórczość środowiskową, biologię lęgów i pokarm przynoszony pisklątom przez czubatki gniazdujące w dwóch środowiskach — typowym dla gatunku lesie iglastym z sosną alepską *Pinus halepensis* oraz dąbrowach z dębem ostrolistnym *Quercus ilex*. Celem badań było określenie, które z czynników środowiskowych wpływają na występowanie tego gatunku w dąbrowach, oraz czy pokarm przynoszony pisklątom w obu tych środowiskach jest podobny.

Na obu terenach ptaki gniazdowały w skrzynkach lęgowych, ich kontrole prowadzono tak, aby określić elementy biologię lęgów. Dane o pokarmie przynoszonym młodym zbierano przy pomocy nagrań wideo. Od każdej skrzynki prowadzono 3 transekty długości 50 m, określając gatunki drzew, oraz pokrycie drzewami i krzewami. Prócz tego wokół każdej skrzynki w promieniu 25 m mierzono grubość pięciu najgrubszych drzew i określano liczbę młodych (pierśnica 5–10 cm) i starych drzew (o pierśnicy > 30 cm). Na tej podstawie stworzono mapy roślinności badanych terenów. Aby zredukować liczbę zmienionych środowiskowych użyto analizę składowych głównych (Tab. 1).

W lesie sosnowym czubatka gniazdowała w prześwietlonych starszych drzewostanach, unikając terenów z młodymi drzewami i rozwiniętą warstwą krzewów (Fig. 1, Tab. 2). W dąbrowie zajmowanie skrzynek lęgowych zależało od występowania w ich okolicy sosen (Fig. 2, Tab. 2). W lesie sosnowym ptaki zaczynały składać jaja w połowie, zaś w dąbrowie — pod koniec kwietnia. Wielkość zniesienia, liczba piskląt i ich kondycja były podobne w obu lasach, jednak w dąbrowach zbadano zaledwie kilka lęgów. Częstość, rodzaj przyniesionego pokarmu jak i wielkość zdobyczy były podobna między badanymi lasami (Tab. 3, Fig. 3). Młode karmione były głównie gąsienicami i muchówkami.