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Nesting habitat requirements of two species of North African woodpeckers in native oak forest

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Capsule Nests of Levaillant's Woodpecker *Picus vaillantii* and Great Spotted Woodpecker *Dendrocopos major* were associated with higher densities of snags and downed wood than foraging locations.

Aims To quantify the nesting requirements of two sympatric woodpecker species in Tunisian oak forests.

Methods We compared habitat structure around nests and foraging locations for both woodpecker species using logistic regression. We examined evidence for preferences in nesting substrates using resource selection indices. Then, we used discriminant function analysis to identify variables separating nesting, foraging, and unused habitat of each species.

Results The probability of presence of nests of both species was significantly related to densities of downed wood and snags. Nests of Levaillant's Woodpecker were located in areas with slightly higher snag densities. Habitat structure differed between nesting and foraging locations of Great Spotted, but not Levaillant's Woodpecker

Conclusion Both Levaillant's and Great Spotted Woodpecker showed high requirements for large-diameter trees and snags, which provide substrates for both nesting and foraging. Nesting habitat requirements may not always be higher than those associated with foraging, but the fact that they were for the Great Spotted Woodpecker calls for caution when planning for woodpecker conservation.

In many forest ecosystems worldwide, conservation targets for woodpeckers have been proposed on the basis of habitat features present at and around nests, or where individuals are detected (Bütler *et al.* 2004a, 2004b, Kosinski *et al.* 2006, King *et al.* 2007, Pasinelli 2007, Poulin *et al.* 2008, Roberge *et al.* 2008, Hebda 2009). Primary cavity nesters such as woodpeckers have very specific requirements for habitat structures such as snags of a certain diameter, decay stage, or height for foraging and nesting (Conner *et al.* 2001). Among forest birds associated with conifers, MacKay *et al.* (2014) found that primary cavity nesters were the most sensitive to the conversion of naturally regenerated stands into spruce plantations. Woodpeckers are often considered as biodiversity indicators because they play a keystone role by providing breeding sites for many secondary cavity users (Pasinelli 2000, Mikusinski *et al.* 2001, Angelstam *et al.* 2004, Martin *et al.* 2004, Roberge & Angelstam 2006, Wesolowski 2007). On that basis,

and because woodpeckers are found in most forest regions of the world (except Australia, Madagascar, and New Zealand), quantitative knowledge of woodpecker nesting requirements is a critical step in forest conservation planning (Kosinski & Winiecki 2004, Hebda 2009).

Most studies aiming to quantify the nesting habitat requirements of woodpeckers have been conducted either in North America or in Europe. Few studies have quantified woodpecker nesting habitat requirements on other continents, especially Africa. A particularly striking example for lack of basic ecological data is Levaillant's Woodpecker *Picus vaillantii*. Touihri *et al.* (2014) surveyed Oak forests of northwestern Tunisia and detected thresholds in the probability of detection of three woodpecker species, including Levaillant's, along gradients in forest structure. High (≥ 0.9) probabilities of detection of Great Spotted Woodpecker *Dendrocopos major* and Levaillant's Woodpecker corresponded to high densities of large-diameter trees and snags. However, habitat requirements for nesting have been shown to

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differ from those associated with other activities in several species of cavity nesters (e.g. Red-cockaded Woodpecker, *Picoides borealis*, Jackson 2003; Brown Creeper, *Certhia americana*, Poulin *et al.* 2008) and open nesters (Angelstam 2004). Thus, the development of conservation targets may require the quantification of habitat requirements at and around nests.

This study aimed to quantify nesting habitat used by Great Spotted Woodpecker and Levaillant's Woodpecker in North African native oak forests. Specifically, we compared stand structure at the local scale (80 m radius) around nests of the two species, as well as between nests and foraging locations of each species separately. Then, we compared microhabitat features at nest trees to determine whether nesting substrates differed from vertical structures available.

METHODS

The study was conducted in Feija National Park (8° 15' E, 36° 29' N) (hereafter Feija NP), a Tunisian native oak forest located in Kroumirie Mountains. Feija NP has an area of 26 km², 75% of which is covered by woodland dominated by Zen Oak *Quercus fagenia* and Cork Oak *Quercus suber*. The structure of stands dominated by either oak species exhibit sharp contrasts (see Touihri *et al.* 2014 for details). Intensive silviculture and hunting are strictly prohibited within Park boundaries. However, the 40 resident families graze livestock and collect firewood. These activities have resulted in patchy openings in the forest and in a severe reduction of natural regeneration in portions of the Park.

We surveyed woodpeckers using the point count method. Survey locations were randomly placed along wildlife trails, with the constraint that they were at least 300 m apart. At each location, we performed three 15-minute point counts (10–25 April; 10–25 May; 1–15 June). Each count was divided into three 5-minute periods: 0–5 minute (silent observation); 5–10 minute (playback broadcasting); and 10–15 minute (silent observation). Playbacks consisted of recordings of focal woodpeckers' drummings and vocalizations. During the 2009 and 2010 breeding seasons, Great Spotted Woodpeckers were detected at 67 stations and Levaillant's Woodpeckers at 59. We searched for nests at all point count locations where either focal species was detected. Nest searches were conducted immediately after point counts by three observers within a 2-ha plot (140 × 140 m) around each point count location. Each observer inspected all

trees within a band of ca. 50 × 140 m to search for evidence of a nest, either from the presence of wood chips on the ground or through direct observation of bird activities around tree cavities.

To minimize false negatives, we calculated nest detectability using Presence (Hines 2006). For Great Spotted and Levaillant's Woodpeckers, nests found during the first visit ($n = 12$, $n = 15$, respectively) were coded (111), those found during second visit ($n = 5$, $n = 7$, respectively) were coded (011), and nests recorded during third visit ($n = 2$, $n = 3$, respectively) were coded (001). Sites where individuals were detected but no nest was found ($n = 20$, $n = 21$, respectively) were coded (000). Nest detectability was similar between the two species, i.e. 0.83 (se = 0.05, 95% CI [0.71–0.91]) for Levaillant's Woodpecker and 0.82 (se = 0.04, 95% CI [0.71–0.95]) for Great Spotted Woodpecker. All nests found were monitored during subsequent visits to determine whether they were active, except those found at the third visit.

Sites where a focal species had been detected at least once but no nest was found were classified as 'foraging locations'. If neither species was detected after three visits, we considered the site as 'unused'. For each nest, we recorded tree species, diameter at breast height (dbh), entrance height, microhabitat of the cavity (in dead limb, in the trunk, or in live limb), and decay stage (alive; declining, i.e. a live tree with many dead branches; dead).

We collected habitat data in July 2009 and 2010 using the following protocol. Around each nest or point count location (if no nest found), we quantified parameters of vegetation structure along three transects (80 × 4 m) oriented to the north, southeast, and southwest. Along each transect, we recorded tree species and we measured dbh of all trees (≥ 30 cm) and snags (≥ 10 cm) and we counted all fallen trees (≥ 10 cm at mid-length). Every 25 m, we measured canopy height with a clinometer and we estimated canopy closure by counting the squares covered (even partially) by canopy foliage through a 5 × 5 grid traced on a transparent sheet of plexiglass (50 × 50 cm) held overhead.

We calculated seven variables reflecting habitat structure: density of trees 30–40, 40–50, >50 cm dbh; density of snags ≥ 10 cm; density of dead trees lying on the ground (downed wood) (>10 cm at midpoint); density of saplings (<10 cm dbh); and canopy closure. We verified that all variables were normally distributed and we selected one variable of each pair whose correlation coefficient was >0.7. For that reason, density of saplings was excluded due to its high

negative correlation with density of large trees (40–50 and >50 cm dbh).

To compare nest sites between the two woodpecker species, we used logistic regression models contrasting nest sites versus foraging sites. Presence–absence of a nest was entered as the dependent variable. Woodpecker species was entered as factor, along with the six habitat variables mentioned above. The best model was identified using a backward stepwise procedure, with probabilities set at 0.05 for entry and 0.1 for removal. We included all habitat structure variables in the initial model, as well as species \times habitat first-order interaction terms. The final model was not improved when reinserting each previously removed variable separately.

For each focal bird species separately, we calculated selection ratios for nest tree species, dbh class, and decay stage using a resource selection index (Manly *et al.* 2002). Selection ratios were calculated by dividing the proportion of a used resource by its proportional availability. Substrates considered available for nesting were trees and snags sampled along the three 80 m transects used to characterize surrounding vegetation (see above). A substrate type was considered to be selected when the selection ratio was >1 and the 95% confidence interval did not include 1. Selection ratios <1 with confidence intervals that did not include 1 indicated avoidance. Finally, the substrate was considered to be selected in proportion to its availability when the confidence interval included 1 (Manly *et al.* 2002).

We performed a discriminant function analysis to determine whether habitat structure differed among nesting, foraging, and unused sites. Statistical analyses were performed using SPSS 18.0 and graphics were drawn using SigmaPlot 11.0.

RESULTS

Among the six habitat variables considered, only densities of snags and downed woody material had a significant positive effect on nest presence (Table 1, Fig. 1a). We found a significant interaction between woodpecker species and snag density (Table 1), the latter being slightly higher around Levillant's Woodpecker nest sites (Fig. 1b).

Both woodpecker species mainly built their nests in live trees, which were much more abundant than dead or declining trees. However, the selection ratio indicated strong preference for dead and declining trees and an avoidance of live trees. Great

Table 1. Parameters of a backward stepwise logistic regression model relating the probability of presence of a nest of either Woodpecker species to parameters of habitat structure.

	Estimate	se	Wald	P-value
Intercept	-2.84	1.63	17.5	0.001
Species	-6.23	6.42	20.1	0.098
Density of snags (stems ha ⁻¹)	0.047	0.01	15.4	0.001
Density of downed wood (stems ha ⁻¹)	0.023	0.01	10.5	0.001
Species * Density of snags	0.059	0.01	12.0	0.001

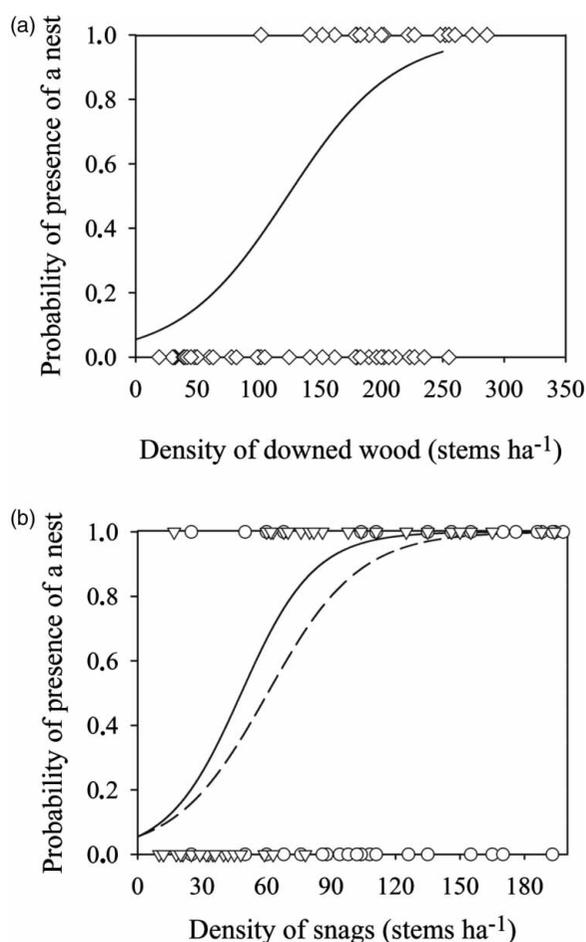


Figure 1. Logistic regressions showing the relationship between the probability of presence of a nest of both woodpecker species ($n = 85$, diamonds) and the density of downed wood (a) and snags (b). Levillant's Woodpecker (dashed line, circles) had higher snag requirements than Great Spotted Woodpecker (solid line, triangles).

Spotted Woodpeckers seemed to prefer declining trees ($\chi^2 = 6.4$, $df = 2$, $P = 0.03$) and Levillant's Woodpeckers preferred snags as nesting substrates ($\chi^2 = 6.7$, $df = 2$, $P = 0.031$) (Fig. 2a).

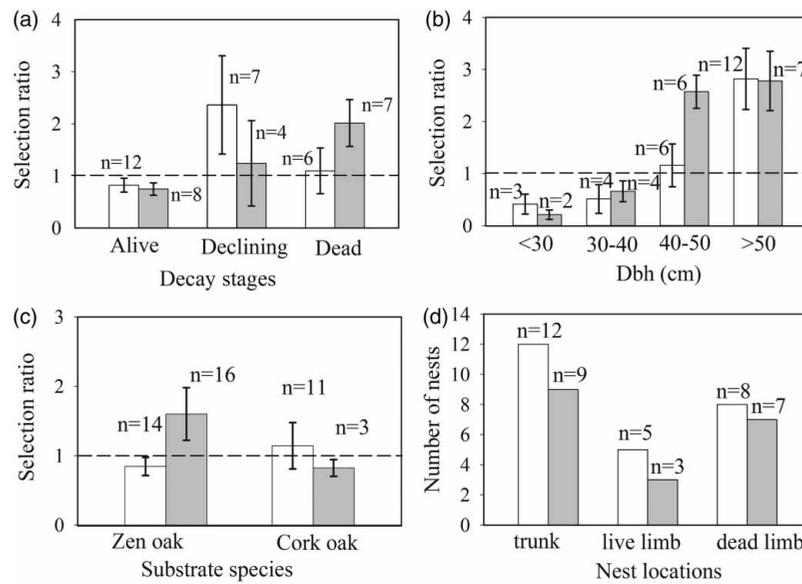


Figure 2. Selection ratios and their 95% confidence intervals for (a) decay stage and (b) diameter at breast height, and (c) tree species used as nesting substrates, as well as microhabitat of cavity (d) for Great Spotted Woodpecker (white bars) and Levillant's Woodpecker (grey bars). The dashed line represents the selection threshold (see Methods for details) and *n* indicates the number of substrates used in each category.

With respect to tree diameter, both woodpecker species preferred to nest in large-diameter trees (>40 cm dbh) (Fig. 2b). The Great Spotted Woodpecker showed a clear preference for trees >50 cm dbh ($\chi^2 = 15.0$, *df* = 3, *P* = 0.001). In contrast, Levillant's Woodpecker had a very similar selection index for trees 40–50 and >50 cm dbh ($\chi^2 = 13$, *df* = 3, *P* = 0.004), whereas smaller trees (dbh <40 cm) were avoided.

In our study area, the dominant tree species is Zen Oak. In spite of this, the Great Spotted Woodpecker showed a preference for Cork Oak ($\chi^2 = 4.1$, *df* = 1, *P* = 0.04). Zen Oak was highly selected by Levillant's Woodpecker ($\chi^2 = 5.1$, *df* = 1, *P* = 0.022) (Fig. 2c). About half of the nesting cavities of each woodpecker species were located in the trunk (Fig. 2d), and another 30% in dead limbs. The remaining nests were

excavated in live limbs. Nests of Levillant's Woodpecker were slightly higher (7.1 ± 2.1 m) than those of Great Spotted Woodpecker (6.7 ± 3.0 m), but this difference was not significant ($t = -0.3$, *P* = 0.071).

For Great Spotted Woodpecker, the discriminant function analysis produced two significant axes (Wilk's $\lambda = 0.25$, $r = 0.79$, *P* < 0.001, *n* = 67) (Table 2) and correctly classified 92% of sites. We found significant differences in vegetation structure between nesting, foraging, and unused sites. The first axis (DF1) explained 67.4% of the variance and separated unused sites from others (Fig. 2b). In decreasing order of importance, density of trees 30–40 cm dbh and canopy closure were the most significant discriminant variables positively correlated with DF1. Sapling density was negatively correlated with DF1 (Table 3). Unused sites

Table 2. Global parameters of discriminant function analyses contrasting nest sites, foraging sites, and unused sites in the two focal species of woodpeckers. Only significant discriminant functions are shown.

Function	Eigenvalues	Variance explained (%)	Canonical correlation	Wilk's lambda	Chi-square	df	<i>P</i> -value
<i>Great Spotted Woodpecker</i>							
DF1	6.14	67.4	0.92	0.02	200.6	14	0.001
DF2	2.96	32.6	0.78	0.25	82.6	6	0.001
<i>Levillant's Woodpecker</i>							
DF1	7.74	98.4	0.94	0.1	123.3	14	0.001

Table 3. Standardized discriminant coefficients and canonical correlations from a discriminant function analysis contrasting nest sites, foraging sites, and unused sites, as well as descriptive statistics.

Variables	Standardized coefficients		Canonical coefficients		Mean (sd)		
	DF1	DF2	DF1	DF2	Nest sites (n = 25)	Foraging sites (n = 21)	Unused sites (n = 21)
<i>Great Spotted Woodpecker</i>							
Density of trees 30–40 cm dbh (stems ha ⁻¹)	0.65	-0.14	0.63 ^a	-0.19	317.4 (66.0)	298.4 (67.8)	91 (59.9)
Canopy closure (%)	0.09	-1.12	0.44 ^a	0.30	59.7 (9.1)	48.7 (7.7)	19.5 (17.1)
Sapling density (stems ha ⁻¹)	-0.63	0.24	-0.53 ^a	0.13	2.5 (1.0)	9.6 (5.0)	98.2 (55.1)
Density of downed wood (stems ha ⁻¹)	0.17	0.62	0.25	0.52 ^a	198.4 (46.2)	142.9 (31.18)	88.1 (35.8)
Density of snags ≥10 cm (stems ha ⁻¹)	0.20	0.25	0.38	0.41 ^a	108.1 (48.4)	35.4 (21.2)	34.6 (28.4)
Density of trees >50 cm dbh (stems ha ⁻¹)	-0.01	0.60	0.45	0.53 ^a	96.8 (39.4)	25.8 (15.2)	25.2 (22.2)
Density of trees 40–50 cm dbh (stems ha ⁻¹)	0.14	0.55	0.41	0.45 ^a	136.6 (56.0)	44.8 (25.3)	34.3 (24.9)
<i>Levaillant's Woodpecker</i>							
Density of trees 30–40 cm dbh (stems ha ⁻¹)	0.29	-0.15	0.619 ^a	-0.17	290.7 (46.9)	268.5 (55.7)	86.5 (32.2)
Canopy closure (%)	0.39	0.11	0.61 ^a	-0.31	75.0 (10.2)	67.6 (14.5)	21.8 (10.2)
Sapling density (stems ha ⁻¹)	-0.48	0.38	-0.54 ^a	0.20	4.9 (2.1)	14.0 (8.9)	102.5 (32.2)
Density of downed wood (stems ha ⁻¹)	0.32	0.38	0.42 ^a	0.12	205.1 (49.2)	182.3 (44.6)	80.2 (48.6)
Density of snags ≥10 cm (stems ha ⁻¹)	0.12	1.01	0.20	0.84 ^a	148.3 (63.3)	104.7 (41.1)	66.3 (36.7)
Density of trees >50 cm dbh (stems ha ⁻¹)	0.19	-0.16	0.52 ^a	0.14	150.3 (34.7)	129.2 (41.3)	32.4 (19.1)
Density of trees 40–50 cm dbh (stems ha ⁻¹)	0.13	-0.24	0.43 ^a	-0.15	171.6 (47.3)	158 (47.6)	52.8 (32.0)

^aLargest absolute correlation between variable and discriminant function.

differed from nests and foraging sites by their higher density of saplings (98.2 ± 55.1 vs. 2.5 ± 1.0 and 9.6 ± 5.0 , respectively) and lower density of trees 30–40 cm dbh (91 ± 59.9 vs. 317.4 ± 65.9 and 298.4 ± 67.8 , respectively). Nest sites had a mean density of trees 30–40 cm dbh and a canopy closure almost three times higher than those of unused sites (Table 3). Unused sites corresponded to disturbed or transition zones where tree densities were probably insufficient to host woodpeckers despite the presence of some critical resources such as dead wood (mean density of snags: 34.6 ± 28.4 and downed wood 88.1 ± 35.8 , $n = 21$) and large trees (Table 3).

The second axis (DF2) explained 32.6% of variance and contrasted nest sites and foraging sites (Fig. 3b). Four variables were significantly and positively

correlated with DF2. In decreasing order of correlation, they were: density of downed wood, density of trees >50 cm dbh, density of trees 40–50 cm dbh, and density of snags ≥10 cm.

For Levaillant's Woodpecker, the discriminant function analysis produced only one significant axis (Table 2), which explained 98.4% of the variance and correctly classified 76.7% of sites. Six variables were significantly correlated with this axis. Among them, only sapling density had a negative coefficient, all other variables being positively associated (Table 3). In decreasing order, they were: density of trees 30–40 cm dbh, canopy closure, density of trees >50 cm dbh, density of trees 40–50 cm dbh, and density of downed woody material. This discriminant function separated unused sites from nests and foraging sites (Fig. 3a).

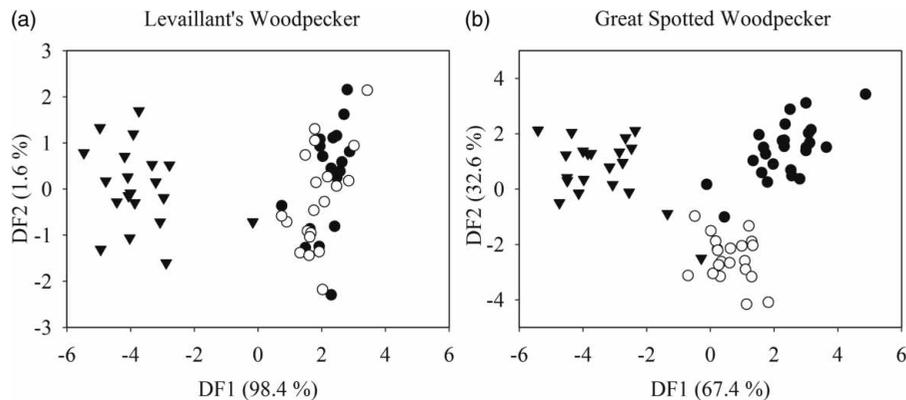


Figure 3. Discriminant function (DF) scores for (a) Levaiillant's Woodpecker; unused sites (black triangles) ($n = 20$); nest sites (black circles) ($n = 19$); and foraging sites (white circles) ($n = 20$) and (b) Great Spotted Woodpecker; unused sites (black triangles) ($n = 21$); nest sites (black circles) ($n = 25$); foraging sites (white circles) ($n = 21$).

Unused sites had low densities of large trees, snags, and downed wood (Table 3). However, there was no significant distinction between foraging and nest sites. Only the density of snags around nest sites was slightly higher than around foraging sites (148.3 ± 63.3 vs. 104.7 ± 41.1).

DISCUSSION

A fine-filter conservation approach requires detailed information on the ecology of focal species. To our knowledge, this study is the first to quantify habitat parameters around nest sites of Levaiillant's Woodpecker, a species endemic to North Africa (Isenmann *et al.* 2005). Touihri *et al.* (2014) reported that the occurrence of Levaiillant's Woodpecker was related to high densities of trees, snags, and downed wood. Levaiillant's Woodpeckers selected snags >40 cm dbh as nesting substrates. Although vegetation structure differed around foraging and nest sites compared to unused sites, there was no clear discrimination between nests and foraging sites in this species. This may reflect the particular foraging behaviour of Levaiillant's Woodpeckers, which often feed on ants and termites on the ground (Cramp *et al.* 1998). In Tunisian oak forests, Madon (1930) counted approximately 300 ants *Camponotus nylanderi* in one stomach of a Levaiillant's Woodpecker. Otherwise, there is a paucity of knowledge on the ecology of this species and we must extrapolate from data on Green Woodpecker *Picus viridis* (Cramp *et al.* 1998). Green Woodpecker foraging sites are significantly influenced by ant abundance and availability (Alder & Marsden 2010). During the winter in Scandinavia, birds fed

exclusively on mound-building *Formica rufa* ants in old forest stands (Rolstad *et al.* 2000). Hence, it is conceivable that Levaiillant's Woodpecker is more sensitive to the availability of specific food resources on the ground than food resources associated with woody vegetation structure.

The lack of difference between habitat structure around nests and foraging sites might also reflect this woodpecker's foraging area relative to nest-searching plot size (2 ha). Green Woodpeckers can move up to 100 m from the nest to foraging sites (Cramp *et al.* 1998). Thus, nests of the foraging birds we detected might have been located just outside our plots.

The nesting habitat requirements of the Great Spotted Woodpecker have been widely documented. Overall, our results confirm its ability to use a wide range of substrates and to adjust, to some degree, to local substrate availability (Michalek & Miettinen 2003). Great Spotted Woodpeckers showed a preference for Cork Oak and selected dead and declining trees for nesting, the latter pattern being consistent with Smith (1997) in southern England, and Pasinelli (2007) in Switzerland. In Spain, Barrientos (2010) reported that Great Spotted Woodpeckers select larger trees than those generally available for nesting and avoid younger stands. In contrast, in western and central Poland, the species generally excavated large live trees, mainly in trunks (Kosinski & Winiecki 2004, Kosiński & Kempa 2007). We also found that Great Spotted Woodpeckers clearly preferred large trees (>50 cm dbh) as nesting substrates, consistent with Kosinski *et al.* (2006). Around nest sites, densities of large trees and dead wood were higher than around foraging sites.

The two woodpecker species showed contrasts in both nesting habitat (80-m radius) and nest substrate selection. Levillant's Woodpeckers mainly used Zen Oak, which is the dominant tree species in our study area, whereas Great Spotted Woodpeckers showed a preference for Cork Oak and trees dbh >50 cm. Great Spotted Woodpecker nests were surrounded by higher densities of trees and dead wood than foraging locations. In Levillant's Woodpecker, no significant difference was detected between nesting and foraging sites.

Despite the fact that we found little evidence for higher habitat requirements around nest sites than at foraging sites, a focus on nesting requirements of the most demanding species with respect to large-diameter trees and dead wood, such as woodpeckers, appears to be a more cautious approach when setting conservation guidelines. Developing conservation objectives for woodpeckers would in turn benefit secondary cavity users such as Atlas Flycatcher *Ficedula speculigera*, Short-toed Treecreeper *Certhia brachydactyla*, and African Blue Tit *Cyanistes teneriffae*, which are also present in El Feija National Park (Touihri *et al.* 2014).

El Feija National Park is under pressure from the local population and portions of the Park have experienced human-caused fires in recent years. Natural regeneration of Cork and Zen Oak forests is nearly absent owing to intense grazing by sheep and goats in some areas, as well as browsing by overabundant native deer. Lack of regeneration will be a major problem over the long-term for species requiring a steady supply of dead wood. Unfortunately, there is no buffer zone around the Park to cushion the effects of human activities, nor are there measures to control native deer. A large proportion of forests adjacent to El Feija National Park have also been converted into agricultural land. Given these conservation challenges, strong political will is critical to protect and maintain suitable habitat for these focal species and others requiring large-diameter trees and dead wood.

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