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Distribution and abundance of hole-nesting birds in Mediterranean forests: impact of past management patterns on habitat preference

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This study explores the relative abundance of hole-nesting birds in four Mediterranean forest types, each of which has undergone different patterns of forest management. Nine species were sampled in 24 study plots, to compare cork oak forest, turkey oak forest, holm oak forest and pine plantation. The abundance of hole-nesters was greater in cork oak forest and turkey oak forest. Three species were most frequently detected: Great Tit (*Parus major*), Blue Tit (*Cyanistes caeruleus*) and Nuthatch (*Sitta europaea*). Bird abundance was significantly lower in holm oak forest, particularly in the cases of Great Spotted Woodpecker (*Dendrocopos major*), Green Woodpecker (*Picus viridis*), Nuthatch and Short-toed Treecreeper (*Certhia brachydactyla*). The Great Spotted Woodpecker showed a positive correlation with the abundance of three secondary cavity nesters: Nuthatch, Short-toed Treecreeper and Starling; in contrast, Green Woodpecker showed a negative correlation with Starling. Habitat structure varied significantly among forest types, especially the mean and maximum tree height, these being lower in holm oak forest. The Great Spotted Woodpecker proved to be a good indicator of less disturbed woodlands. In fact, maximum tree height turned out to be a significant and positive explanatory variable for woodpecker abundance. We consider that intensive coppicing and timber management in holm oak forest during the 20th century widely affected trees' age-profile, with consequences for their suitability for woodpeckers and other hole-nesting birds. To monitor the response of hole-nesting birds to forest management in terms of abundance, we propose the use of the great spotted woodpecker as an indicator species.

1. Introduction

The hole-nesting birds (i.e., all those birds that nest in tree holes) are among the most specialized bird species of forest ecosystems (Devictor *et al.* 2010). Some of these species, in particular woodpeckers, require old-growth forests with a high structural diversity and large amounts of dead wood (Angelstam 1990, Spies 2004). The removal of old and dead trees is considered to be one of the most negative activities associated with intensive forestry management of remaining woodlands in temperate zones, because of its harmful impact on both vertebrates and insects (Redolfi De Zan *et al.* 2014).

The guild of hole-nesting birds can be divided in two groups: primary cavity nesters (e.g., woodpeckers, willow tit) (Mullarney *et al.* 1999, Hinsley *et al.* 2007), which excavate holes in trees; secondary cavity nesters (e.g., other tits, nuthatches, treecreepers), which nest in tree holes generally excavated by other species or in cavities generated by natural ageing of the tree (Martin & Li 1992, Blanc & Walters 2008).

In a tree, different ecological niches are available from bottom to the top (roots, trunks, branches and canopy), and from the outside to the inside (from the bark towards the centre of the stem) (Speight 1989). Woodpeckers, with their excavation activity, create different potential niches for other organisms, and are thus considered keystone species in forest ecosystems (Daily *et al.* 1993). Indeed, woodpeckers mainly feed on the larvae of saproxylic insects, which develop within dying and dead trees, typically old trees that are more abundant in mature forest (Fayt 1999, Smith 2007).

Hole-nesting birds are highly sensitive to alterations in habitat structure due to forest management (Matthysen *et al.* 1995, Kosenko & Kaygorodova 2001). In fact, the presence and abundance of these species could provide important information about the status of forests and their resources (Drever & Martin 2010).

Most of the studies on hole-nesting birds and their habitat relationships are mainly species-oriented, particular those regarding woodpeckers (Kosiński & Winiecki 2004, Pasinelli 2007). Few studies focus on the relationships between habitat and the whole hole-nesting guild, and the interspecific relationships between the two groups (primary and secondary cavity nesters) (Bai & Mühlenberg 2008). Also scarce are studies investigating hole-nesting birds and habitat relationships in the Mediterranean region (Fraticelli & Guerrieri 1988, Gil-Tena *et al*. 2007, Zangari *et al.* 2013, Redolfi De Zan *et al*. 2014).

In this paper, we explore how forest habitat structure can affect the birds' relative abundance and, consequently, the relationships among the species within the hole-nesting bird guild. In particular, we are interested in the following objectives: (i) to investigate how the hole-nesting birds' abundance can vary in four forest types characterized by different past management; ii) to assess whether there is a significant correlation between the relative abundance of primary and secondary cavity nesters; (iii) to detect indicator species of the forest types and examine relationships between species and habitat variables, in order to suggest measures that forest managers could take to promote conservation of hole-nesting birds.

2. Materials and methods

2.1. Study area

The study was carried out in the Circeo National Park (CNP), a protected area of 8,500 ha, located along the Tyrrhenian coast of Lazio region, central Italy. The climate matches that of the meso-Mediterranean xeric region (Kottek *et al.* 2006). This Park was appointed by UNESCO as a Biosphere Reserve. During the 1930s and 1940s, the forests in this area were transformed into coppiced woods in order to produce the raw material for railway. Timber exploitation of CNP woods continued up to the early 1970s according to the local high forest management plan, affecting in particular the holm oak stands of Mount Circeo.

We investigated four forest types with different management histories (Fig.1):

1) Cork oak forest (ca. 600 ha), dominated by *Quercus suber* aged around 100–150 years, with scattered trees of *Q. frainetto* and *Q. robur*, and a shrub layer dominated by *Erica arborea* and *Ruscus aculeatus.* In the CNP, this

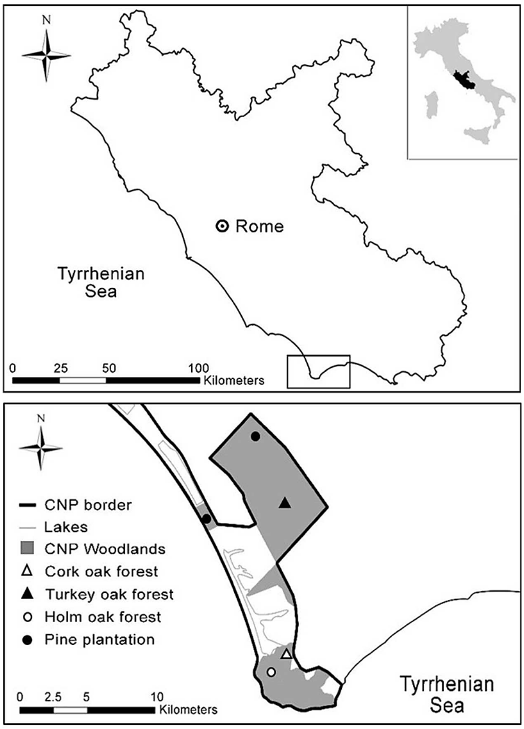

Fig. 1. Study area. The map shows the borders of the Circeo National Park (CNP), Lazio region, central Italy, the mainland wooded surface and the symbols indicating the centroid of the study plots.

forest type occurs only on a plain at the foothills of Mount Circeo.

2) Turkey oak deciduous forest (ca. 2,800 ha), dominated by 70–80 years old *Quercus cerris* stems derived from coppicing activity, interspersed with older trees of up to 100–150 years old. The sub-canopy vegetation layers include *Ruscus aculeatus*, *Rubus ulmifolius*, *Crataegus monogyna, Prunus spinosa, Cistus salvifolius, Cyclamen repandum, Narcissus poeticus, Polypodium australe* and *Hedera helix*. In the CNP, this forest type occurs only in the lowland forest, in the innermost part of the protected area.

3) Holm oak evergreen forest (ca. 700 ha) dominated by 30–70 years old *Quercus ilex*, with isolated trees of *Q. frainetto, Q. pubescens, Q. suber, Fraxinus ornus, Ostrya carpinifolia*, and an understorey of *Arbutus unedo, Ruscus aculeatus* and *Cyclamen repandum.* In the CNP, this forest type occurs only on Mount Circeo's northern slope.

4) Sublittoral pine plantation (ca. 700 ha), started around 1930–1960 (age of trees at the time of this study ranging from 50 to 80 years old), dominated by *Pinus pinaster* and *P. pinea*, with a shrub layer of *Phillyrea latifolia, Rhamnus alaternus* and *Pistacia lentiscus*. In the CNP this artificial forest type shows a discontinuous distribution (a block along the Tyrrhenian shore and another in the northern part of the lowland forest).

2.2. Bird sampling

Bird data were collected during March–July 2009 using the Standard Point Count Method (Sutherland 2006), the most appropriate for sampling birds in dense and homogeneous forest (Bibby *et al.* 2000). This method provides data on bird abundance and richness localization within a circular-plot and allows an overall estimate of abundance in the study area.

The total sampled area was 20 hectares, approximately 5 hectares per forest type. In particular, we surveyed 6 study plots in each forest type (24 study plots in total).

Each plot had a radius of 50 m and was a minimum distance of 350 m from the other plots (edge to edge) to prevent pseudo-replication (Bibby *et al*. 2000). We measured the radius of the study plots with a laser rangefinder (Swarovski mod. 70002); the exact location of the study plots was established in the field by means of a Global Positioning System (GPS) receiver (Garmin 60CSX).

The survey started one hour after sunrise and was carried out until 11:00 a.m. Each plot was surveyed for eight minutes. All birds seen or heard within 50 m were recorded. We made replicates every 15 days for a total of eight sessions per plot (192 surveys). From one session to another, the order of plot surveys was randomly performed in rotation. For each study plot, we obtained the maximum number of individuals recorded over the eight sessions, considered as a measure of species' relative abundance to make intra-specific (or whole assemblage) comparisons between different forest types. Different species differ in their detectability, so there is the possibility to under /overestimate their abundance in each plot. To minimize this bias produced by some specific features (e.g., small and quiet species, large foraging territory etc.) or by the wood structure (e.g., tree density), the same observer conducted all the surveys (Sutherland, 2006). We collected data on nine hole-nesting bird species divided in two groups, which occur in the study area:

- Primary cavity nesters: Great Spotted Woodpecker (*Dendrocopos major*), Lesser Spotted Woodpecker (*Dendrocopos minor*) and Green Woodpecker (*Picus viridis*).

- Secondary cavity nesters: Great Tit (*Parus major*), Blue Tit (*Cyanistes caeruleus*), Nuthatch (*Sitta europaea*), Short-toed Treecreeper (*Certhia brachydactyla*), Hoopoe (*Upupa epops*) and Starling (*Sturnus vulgaris*).

2.3. Sampling of habitat variables

In order to obtain information on habitat structure (vertical stratification and forest density), we collected environmental data along a 100 m transect in each of the 24 study plots, with each transect oriented in a randomly chosen direction and centered on the middle of the plot (James & Shugart 1970). Along the transect we measured the following continuous variables: a) mean tree diameter at breast height (DBH) of the 10 largest trees; b) mean and maximum height of the 10 largest trees; c) mean and maximum nearest-neighbor distance between the 10 largest trees; d) mean percentage vegetation cover for shrubs, canopy under 20 meters and canopy over 20 meters. The latter was estimated by visual assessment of the area 10 meters either side of the transect. Distances and heights were measured with a laser rangefinder (Swarovski mod. 70002), while DBH was measured using a tree caliper.

2.4. Data analysis

For each study plot, we reported the maximum number (i.e. the highest number) of individuals of each species recorded over the eight sessions. Next, these values per plot have been added up to obtain the total number of individuals for each forest type. To derive information about the distribution of the species within the community, we calculated intra-habitat proportional abundance (hereafter, "frequency", i.e., number of individuals found in a forest type expressed as a proportion of total number of individuals of all species recorded in that forest type).

Principal Component Analysis (PCA) was computed on the data of relative abundance to identify differences in the distribution of the species among the forest types. A non-parametric Kruskal–Wallis test was performed on the abundance dataset (by adding up and averaging values of the six study plots per forest type) to find significant differences in species distribution among the forest types. This analysis was computed, at first for the hole-nesting guild, then for the two groups (using the sum of the relative abundance for primary and secondary cavity nesters), and finally for single species.

To assess relationships between the abundance of primary cavity nesters and secondary cavity nesters we used the Pearson's product moment correlation.

The MANOVA test was used to assess if the habitat variables varied significantly among the forest types; a Ward's hierarchical clustering method was used to discriminate the study plots in relation to their habitat variables. From the results of cluster analysis, we selected the clustered study plots (i.e., plots with similar habitat structure) to obtain the "site groups" used in the Indicator species analysis.

Indicator species analysis allows determination of species that can be used as indicator of a site group (e.g. habitat types, community types, disturbance states), by calculating the species Indicator Value (IndVal) (Dufrêne & Legendre, 1997). The IndVal index ranges from 0 to 1 (100%), and is defined as the measure of the association between a species and a site group. R function "multipatt" (package "indicspecies") was used to compute species Indicator Value both for individual site group and combination of site groups (De Cáceres et al. 2010). The index is the product of two components called "A" and "B". "A" is the exclusivity or positive predictive value of the species as an indicator of the target site group; this means that

Table 1. Abundance of hole-nesting birds recorded in four forest types. For each species is shown: the average abundance and standard deviation for each forest type (A ± SD) (i.e., average abundance of 6 study plots and standard deviation); frequency or intra-habitat proportional abundance (*f*) (i.e., proportion of total number of individuals for each species recorded in a forest type); total number of individuals recorded for each species (Σ *N*). Each forest type was named according to the dominant tree species.

	Q. suber		*Q. cerris*		*P. pinea*		*Q. ilex*		
Species	A ± SD	*f*	A ± SD	*f*	A ± SD	*f*	A ± SD	*f*	Σ N
P. major	2.50 ± 0.84	0.19	2.17 ± 0.75	0.18	2.00 ± 0.89	0.21	2.17 ± 1.17	0.33	53
C. caeruleus	2.83 ± 1.33	0.22	2.50 ± 0.55	0.20	1.67 ± 1.03	0.18	2.17 ± 0.41	0.33	55
D. major	1.67 ± 0.82	0.13	1.67 ± 0.52	0.14	1.00 ± 0.63	0.11	0.33 ± 0.52	0.05	28
D. minor	0.00 ± 0.00	0.00	0.33 ± 0.82	0.03	0.33 ± 0.82	0.04	0.00 ± 0.00	0.00	4
P. viridis	0.67 ± 0.82	0.05	1.50 ± 0.55	0.12	1.00 ± 0.63	0.11	0.33 ± 0.52	0.05	21
S. europaea	2.67 ± 0.52	0.20	2.00 ± 1.10	0.16	2.17 ± 0.75	0.23	0.67 ± 0.82	0.10	45
C. brachydactyla	1.33 ± 0.52	0.10	1.83 ± 0.75	0.15	1.00 ± 1.10	0.11	0.83 ± 0.75	0.13	30
U. epops	0.33 ± 0.52	0.03	0.00 ± 0.00	0.00	0.17 ± 0.41	0.02	0.00 ± 0.00	0.00	3
S. vulgaris	1.17 ± 1.33	0.09	0.33 ± 0.52	0.03	0.17 ± 0.41	0.02	0.17 ± 0.41	0.03	11

when A is equal to 1, the species occurs only in those sites belonging to the target site group and does not occur in sites belonging to other groups. "B" is the fidelity or sensitivity of the species as an indicator of the target site group; this means that when B is equal to 1, the species occurs in all sites belonging to the target site group, its therefore being a "real indicator" of that site group. The statistical significance of this analysis was tested with a permutation test (n. perm. = 999).

Finally, multiple regression analysis was performed to investigate the relationship between species and forest type, in order to find out significant habitat explanatory variable affecting the species abundance (response variable) in the forest types. The Spearman's correlation coefficient (r_s) with the Bonferroni's correction was used to select the habitat variables for the regression analysis.

For parametric analyses, species abundance were log transformed and habitat variables were normalized using "scale" R function; all the analyses were performed using R 3.0.3 (R-Development Core Team 2010) with α set (two-tailed) at 0.05.

3. Results

We sampled 250 individuals belonging to the nine target species from the four forest types (Table 1). Observing the species' relative abundance correlated with the first two PCA axes (explained cumulative proportion of variance PCA1:PCA2 = 56%) (Table 2 and Fig. 2), all the species, except Green Woodpecker, showed positive correlation to axis PC1. Great Spotted Woodpecker, Nuthatch, Short-toed Treecreeper and Starling showed the longest vectors contributing more to the explained variation of the abundance data. The first three species proved to be correlated with their vectors pointing in the same direction mostly in the case of cork oak and turkey oak forests. The Green Woodpecker showed the longest arrow positively correlated to axis PC2 and its vector points in the opposite direction respect to Great Tit, Starling and Hoopoe; therefore, the latter three species tend to occur with low frequencies in the same study plot where Green Woodpecker is more abundant, particularly in pine plantation plots. As shown in Fig. 2, the holm oak forest sites resulted in low relative abundance values for all the species; in particular the guild abundance of this forest type proved to be significantly lower when compared to both cork oak forest (Kruskal–Wallis test: $H = 7.85$, $p = 0.005$) and turkey oak forest (Kruskal–Wallis test: $H = 7.41$, $p = 0.006$). Similar results were obtained separately for the two groups: primary cavity nesters (Kruskal–Wallis test: *Q. ilex* vs *Q. suber*: $H = 6.56$, $p = 0.007$; *Q. ilex* vs *Q. cerris*: $H = 8.31$, $p = 0.003$) and secondary cavity nesters (Kruskal–Wallis test: *Q. ilex* vs *Q. suber*: $H = 6.65$, $p = 0.009$; *Q. ilex* vs *Q. cerris*: $H = 4.67$, $p = 0.028$; *Q. suber* vs *P. pinea*: $H = 4.01$, $p = 0.043$). Among the species, only Great Spotted Woodpecker, Green

Table 2. PCA performed on the abundance data of the species. Importance of the components shows eigenvalues, relative proportion of variance and cumulative proportion of variance for each axis. Rotation shows the eigenvectors of the species for each axis.

Importance of components	PC1	PC2	PC3	PC4	PC5	PC6	PC7	PC8	PC9
Eigenvalues	0.081	0.053	0.025	0.023	0.020	0.016	0.011	0.007	0.004
Prop. of variance	0.338	0.221	0.106	0.095	0.085	0.066	0.044	0.028	0.017
Cum. proportion	0.338	0.559	0.665	0.759	0.844	0.910	0.955	0.983	1
Rotation	**PC1**	**PC2**	**PC3**	**PC4**	**PC5**	**PC6**	**PC7**	**PC8**	**PC9**
P. major	0.148	–0.093	0.412	–0.076	–0.042	–0.176	0.823	–0.289	0.025
C. caeruleus	0.189	–0.063	0.044	0.023	0.872	–0.249	–0.031	0.141	0.337
D. major	0.492	0.131	0.637	0.107	–0.036	0.096	–0.223	0.372	–0.354
D. minor	0.077	0.323	–0.364	0.153	–0.171	–0.541	0.294	0.559	–0.111
P. viridis	–0.122	0.717	0.267	0.115	–0.074	–0.308	–0.238	–0.397	0.267
S. europaea	0.492	0.424	–0.390	0.184	0.132	0.536	0.231	–0.180	–0.009
C. brachydactyla	0.410	0.063	–0.112	–0.843	–0.177	–0.115	–0.126	0.008	0.212
U. epops	0.111	–0.142	0.126	0.270	–0.346	0.196	0.031	0.300	0.793
S. vulgaris	0.507	–0.384	–0.193	0.358	–0.181	–0.413	–0.243	–0.406	–0.045

Woodpecker, Nuthatch and Short-toed Treecreeper varied significantly between forest types (Table 3).

Some significant relationships were found between the relative abundance of primary and secondary cavity nesters; the Great Spotted Woodpecker proved to be positively correlated with Nuthatch (coeff = 0.45, R^2 = 0.21, df = 22, p = 0.03), Short-toed Treecreeper (coeff = 0.40, R^2 = 0.16, df = 22, p = 0.05) and Starling (coeff = 0.41, R^2 = 0.17, df = 22, p = 0.04). Inversely, the green woodpecker showed a negative correlation with starling (coeff = –0.45, R^2 = 0.20, df = 22, p = 0.03).

The habitat variables varied significantly among the four forest types, except for the mean distance and canopy cover under 20 m (Table 4). Therefore, we can assume that wood density had little effect on the species detectability. In general, the cluster analysis showed that the study plots were grouped according to their own habitat structure (with few exceptions), and were therefore homogeneous for each forest type (Fig. 3). From the cluster analysis, we selected three site groups for indicator analysis: Group 1 (left cluster: eight study plots, from P5 to C4), Group 2 (central cluster: seven study plots, from I2 to I4) and Group 3 (right cluster: nine study plots from P3 to S5) (Fig. 3).

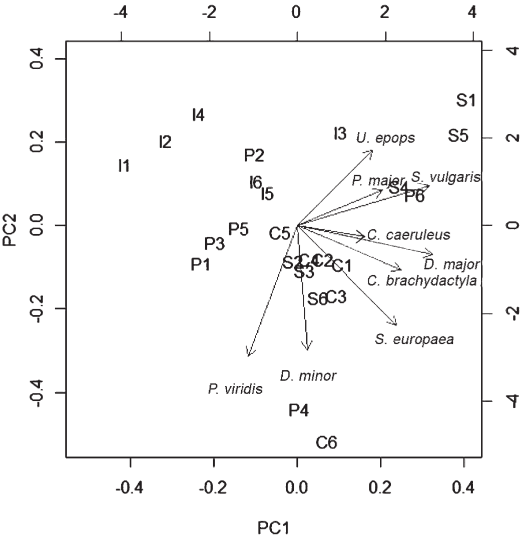

Fig. 2. Ordination biplot obtained by PCA performed on the species abundance data recorded from six study plots per forest type: S = *Q. suber*, C = *Q. cerris*, P = *P. pinea* and I = *Q. ilex*.

No indicator species resulted for single site groups although the results indicate that one species is the indicator for the combination G1 + G3, which represents three forest types: cork oak forest, turkey oak forest and pine plantation. The indicator species for this combined site group was the great spotted woodpecker (IndVal = 0.915, A =

Table 3. Kruskal–Wallis test performed on the abundance data of the species recorded in six study plots of each forest type. Of the nine hole-nesting birds sampled, we reported only the species with significant results (*). Each forest type was named according to the dominant tree species.

	D. major		*P. viridis*		*S. europaea*		*C. brachydactyla*	
Forest types	*H*	*p*	*H*	*p*	*H*	*p*	*H*	*p*
Q. suber vs *Q. cerris*	0.03	0.858	2.83	0.073	2.08	0.127	1.26	0.212
Q. suber vs *Q. ilex*	5.76	0.010 *	0.41	0.533	7.41	0.005 *	1.26	0.206
Q. suber vs *P. pinea*	1.64	0.149	0.64	0.382	1.26	0.212	0.92	0.282
Q. cerris vs *Q. ilex*	6.54	0.007 *	5.77	0.011 *	4.01	0.037 *	3.39	0.051 *
Q. cerris vs *P. pinea*	2.56	0.074	1.44	0.171	0.31	0.546	2.31	0.111
P. pinea vs *Q. ilex*	2.56	0.074	2.56	0.074	5.39	0.016 *	0.01	0.931

Table 4. Average values and standard deviation of habitat variables and results of MANOVA test (R^2 and *p* value) performed among the four forest types, (DBH = tree diameter at breast high), (*) significant results. Each forest type was named according to the dominant tree species.

Habitat variables	*Q. suber*	*Q. cerris*	*P. pinea*	*Q. ilex*	R^2	*p*
Mean DBH (cm)	41.7 ± 4.4	27.4 ± 2.8	39.8 ± 8.5	24.1 ± 3.2	0.54	0.003 *
Mean Tree Height (m)	15.1 ± 1.5	19.0 ± 0.9	16.0 ± 2.2	11.9 ± 0.7	0.65	0.001 *
Maximum Tree Height (m)	19.7 ± 1.3	24.3 ± 0.7	18.2 ± 2.3	15.0 ± 0.7	0.76	0.001 *
Mean Distance (m)	8.6 ± 1.1	8.2 ± 1.1	6.6 ± 1.3	8.3 ± 1.4	0.22	0.14
Maximum Distance (m)	23.8 ± 7.1	20.7 ± 4.7	13.2 ± 4.2	15.3 ± 2.3	0.32	0.03 *
% Shrub	72 ± 18	40 ± 10	33 ± 7	38 ± 8	0.53	0.002 *
% Canopy under 20 m	85 ± 5	88 ± 3	83 ± 4	90 ± 0	0.31	0.08
% Canopy over 20 m	13 ± 5	30 ± 0	18 ± 14	0 ± 0	0.36	0.02 *

0.915, B = 1.000, $p = 0.001$). Finally, the Spearman's correlation coefficient calculated between eight habitat variables showed significant collinearity among canopy cover over 20 m, mean tree height and maximum tree height (n. perm. = 56, *p*-value Bonferroni's corrected = 0.001). Among these three habitat variables, we excluded for the regression analysis the canopy over 20 m, since it was correlated with both tree height measurements. Next, between the two remaining variables, we retained the maximum tree height, which replaces the canopy over 20 m, while we excluded the mean tree height represented by canopy cover under 20 m in the data set. The results of regression analysis highlighted a significant relationship with six selected habitat variables only for the great spotted woodpecker (adj. $R^2 = 0.42$, $F = 3.83$, $\mathrm{df}_1 = 6$, $\mathrm{df}_2 = 17$, $p = 0.01$) and the green woodpecker (almost significant, adj. $R^2 = 0.28$, $F = 2.51$, $\mathrm{df}_1 = 6$, $\mathrm{df}_2 = 17$, $p = 0.06$). The maximum tree height was the explanatory variable positively correlated with both species (Great Spotted Woodpecker: coeff = 0.14, $t = 4.19$, $p = 0.0006$; Green Woodpecker: coeff = 0.10, $t = 2.66$, $p = 0.02$).

4. Discussion

The observed abundance of hole-nesting birds was highest in cork oak forest and in turkey oak forest. The two most frequently detected species were Great Tit and Blue Tit, followed by Nuthatch and Short-toed Treecreeper, as observed in other studies focused on Mediterranean forests (e.g., Zangari *et al*. 2013, Redolfi De Zan *et al.* 2014). Considering the low detectability of Short-toed Treecreper, it is possible that its abundance values have been underestimated compared to other species. The highest value of guild abundance did not vary significantly between cork oak forest and turkey oak forest even if these two forest types showed different habitat structure. This result for cork oak forest may be explained by its mature forest structure (Nikolov 2009). On the other hand,

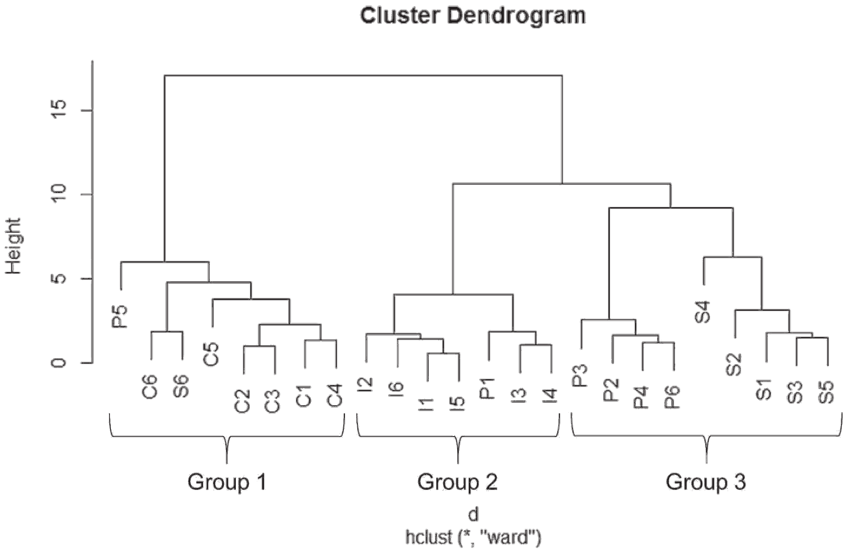

Fig. 3. Hierarchical clustering of 24 study plots produced by Ward's method performed on the habitat variables data recorded in each study plot per forest type: S = *Q. suber*, C = *Q. cerris*, P = *P. pinea* and I = *Q. ilex*. The three main clusters were used as site groups for the Indicator species analysis (see 2.4): Group 1, Group 2 and Group 3.

in turkey oak forest, which has a younger age structure than cork oak forest (see 2.1), the high abundance could be due to the occurrence of old oaks, which could increase the availability of food resources and potential nest sites in this forest type (Keller *et al.* 2003).

Observing how the species are distributed among the four forest types, it is noticeable how the whole guild and the two groups (primary and secondary cavity nesters) tend to be less abundant in holm oak forest than in other forest types. This is particularly true for the Green Woodpecker, the Great Spotted Woodpecker, the Nuthatch and the Short-toed Treecreeper. This may be explained by these species having a higher degree of ecological specialization than do tits or starling (Smith 1997, Caprio *et al.* 2009). In fact, the four above mentioned species are more abundant in forests where human activity (past or present) had a lower impact on woodland structure and habitat quality. Despite the Lesser Spotted Woodpecker being highly specialized and its distribution mainly related to core woodland area (Delahaye 2010), it showed no significant values, probably due to the small number of records, thereby making its role negligible in our analyses.

The positive correlation between abundance of the Great Spotted Woodpecker and the abundance of Nuthatch, Short-toed Treecreeper and Starling, could be explained by the woodpecker's strong activity drilling different holes every year for its own nest, vacating the old nests for the other species (Aitken *et al.* 2002, Bai & Mühlenberg 2008). These positive correlations concur with the previously suggested role of woodpeckers as indicator species of bird richness (Mikusiński et al. 2001, Drever et al. 2008). We expected a positive correlation between Nuthatch and Great Spotted Woodpecker abundance because of the former's habit of using old woodpecker nests (Wesolowski & Rowiński 2004). The abundance of Green Woodpecker may be negatively correlated to the abundance of Starling and other secondary cavity nesters (as shown in the ordination plot) since small-sized species such as these rarely use large holes (e.g., of green woodpecker) for nesting (Camprodon *et al.* 2008). It is probable that tits and Starling prefer smaller holes to avoid exposure to predatory activity or to competitive eviction (Wesolowski 2002, Paclík *et al.* 2009).

On the other hand, the negative correlation might be also the consequence of differences in suitable habitats among these species. As previously mentioned, tits and starling are less specialist than woodpeckers, Nuthatch and Short-toed Treecreeper (Julliard *et al.* 2006), because they live not only in woodlands but also in rural and urban areas, such as those surrounding our study areas, where they find good nesting opportunities (Cowie & Hinsley 1987, Hedblom & Söderström 2012). Moreover, the Green Woodpecker has been considered a coarse-grained mosaic species living in forest mosaics with the presence of large open areas, while tits and Starling may be considered as forest-edge species, living in patchy landscapes with a fine-grained "harlequin" structure (Blondel *et al.* 1992, Hinsley *et al.* 1995). We cannot confirm a similar assertion for Hoopoe and Lesser Spotted Woodpecker due to the small sample sizes.

Among the species, the Great Spotted Woodpecker can be considered a good indicator of the combined site group of cork oak forest, turkey oak forest and pine plantation. It occurred in all the sampled sites of these grouped forest types and proved to be almost exclusive. These three forest types can be grouped in a single forest macro-type where the past forest management trace is vanishing; therefore the Great Spotted Woodpecker can indicate a good status of these forest habitats (Wübbenhorts & Südbeck 2003, Virkkala 2006).

The holm oak forest showed the lowest value of the maximum tree height and consequently of canopy cover over 20 meters, probably, as a result of the past local forest management based on coppicing. In this study, woodpeckers seemed to prefer higher trees; this is probably not only because nesting in high positions protects their brood from predators (Nilsson 1984, Paclík *et al.* 2009), but also because high trees could provide a greater variety of micro-habitats. Young tree structure and low height in holm oak forest, due to historical transformation to coppice, probably explain its poverty in terms of trophic resources and nest availability for woodpeckers and hole-nesting birds (Fuller 1992, Brazaitis & Angelstam 2004, Quine *et al.* 2007, Robles *et al.* 2011). Studies conducted in other European countries have shown that avian communities increase in abundance and richness along a gradient of forest succession, from younger to older stages (Kati *et al.* 2009, Domokos & Cristea 2014). In our case, we suppose that intensive coppicing activity and the subsequent conversion of holm oak stands to high forest until 1970, has affected this forest type, inducing a stress which could explain the pattern of species abundance.

To conclude, the hole-nesting bird guild seems to prefer mature and heterogeneous forests where different age classes of trees are available. The Great Spotted Woodpecker confirmed its role as an indicator species of undisturbed forest habitats, characterized by high vertical structure and vegetation complexity. Furthermore, this species showed a strong positive effect on the presence of secondary cavity nesters, therefore also playing the role of an indicator for the entire hole-nesting bird guild.

In the Mediterranean region, due to the continuous and strong anthropogenic impact on woodlands, a forest management strategy focused on both conservation of hole-nesting birds and on sustainable exploitation of wood should ensure the occurrence of old trees scattered within the forest, preserving the woodlands' natural heterogeneity. The effectiveness of these management measures could be monitored using Great Spotted Woodpecker as an indicator species.

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Kolopesijöiden levinneisyys ja runsaus Välimeren alueen metsissä: metsänhoidon vaikutus elinympäristön valintaan

Tutkimuksessa selvitetään koloissa pesivien lintujen määriä neljässä Välimeren alueen metsätyypissä, joilla on erilainen metsänhoidon historia. Yhdeksän lintulajin runsauksia verrattiin korkkitammi-, turkintammi- ja rautatammimetsissä sekä istutetuissa mäntymetsissä, yhteensä 24:llä tutkimusalueella.

Kolopesijöitä havaittiin eniten korkkitammi- ja turkintammimetsissä. Kolme useimmin tavattua lajia olivat talitiainen, sinitiainen ja pähkinänakkeli. Rautatammimetsissä havaittiin huomattavasti vähemmän lintuja, varsinkin käpytikkaa, vihertikkaa, pähkinänakkelia ja etelänpuukiipijää. Käpytikkojen määrä korreloi positiivisesti pähkinänakkelin, etelänpuukiipijän ja kottaraisen määrien kanssa. Sen sijaan vihertikan ja kottaraisen määrien välillä oli negatiivinen yhteys. Eri metsätyyppien välillä oli huomattavia eroja pesimäympäristön

ominaisuuksissa, erityisesti puun keski- ja maksimikorkeudessa: matalimmat puut löytyivät rautatammimetsistä.

Käpytikka osoittautui indikoivan luonnontilaista metsää ja suuri puun maksimikorkeus selittikin käpytikan runsaan esiintymisen. Todennäköisesti 1900-luvun intensiivinen vesakointi ja puuntuotanto rautatammimetsissä on vaikuttanut laajasti puiden ikäjakaumaan: nyt ne tarjoavat vähemmän sopivia elinympäristöjä tikoille ja muille kolopesijöille. Ehdotamme käpytikkaa indikaattorilajiksi, jonka avulla voidaan seurata metsänhoitotoimenpiteiden vaikutusta kolopesijöiden runsauteen.

References

Aitken, K.E.H., Wiebe, K. & Martin, K. 2002: Nest-site reuse patterns for a cavity-nesting bird community in interior British Columbia. — Auk 119: 391–402.

Angelstam, P. 1990: Factors determining the composition and persistence of local woodpecker assemblages in taiga forests in Sweden – a case for landscape ecological studies. — In Conservation and Management of Woodpecker Populations (ed. Carlson, A. & Aulen, G.): 147–191. Swedish University of Agricultural Sciences, Department of Wildlife Ecology, Uppsala.

Bai, M.L. & Mühlenberg, M. 2008: Sequential use of holes by birds breeding in a natural boreal forest in Mongolia. — Bird study 55: 161–168.

Bibby, C.J., Burgess, N.D. & Hill, D.A. 2000: Bird Census Techniques 2nd edn. — Academic Press, London, UK.

Blanc, A. & Walters, J.R. 2008: Cavity excavation and enlargement as mechanisms for indirect interactions in an avian community. — Ecology 89: 506–514.

Blondel, J., Perret, P., Maistre, M. & Dias, P.C., 1992. Do harlequin Mediterranean environments function as source-sink for Blue-Tits (*Parus caeruleus* L.)? — Landscape Ecology 6: 213–219.

Brazaitis, G. & Angelstam, P. 2004: Influences of edges between old deciduous forest and clearcuts on the abundance of passerine hole-nesting birds in Lithuania. — Ecological Bulletins 51: 209–217.

Camprodon, J., Salvanya, J. & Soler-Zurita, J. 2008: The abundance and suitability of tree cavities and their impact on hole-nesting bird population in beech forest of NE Iberian Peninsula. — Acta Ornithologica 43: 17–31.

Caprio, E., Ellena, I. & Rolando, A. 2009: Assessing habitat/landscape predictors of bird diversity in managed deciduous forests: a seasonal and guild-based approach. — Biodiversity and Conservation 18: 1287–1303.

Cowie, R.J. & Hinsley, S.A. 1987: Breeding success of blue tits and great tits in suburban gardens. — Ardea 75: 81–90.

Daily, G.C., Ehrlich, P.R. & Haddad, N.M. 1993: Double keystone bird in a keystone species complex. — Proceedings of the National Academy of Sciences of the United States of America 90: 592–594.

De Cáceres, M., Legendre, P. & Moretti, M. 2010: Improving indicator species analysis by combining groups of sites. — Oikos 119:1674–1684

Delahaye, L., Monticelli, D., Lehaire, F., Rondeux, J. & Claessens, H. 2010: Fine-scale habitat selection by two specialist woodpeckers occurring in beech forest and oak-dominated forest in southern Belgium. — Ardeola 57: 339–362.

Devictor, V., Clavel, J., Julliard, R., Lavergne, S., Mouillot, D., Thuiller, W., Venail, P., Villéger, S. & Mouquet, N. 2010: Defining and measuring ecological specialization. — Journal of Applied Ecology 47: 15–25.

Domokos, E. & Cristea, V. 2014: Effects of managed forests structure on woodpeckers (*Picidae*) in the Niraj valley (Romania): Woodpecker populations in managed forests. — North-Western Journal of Zoology 10: 110–117.

Drever, M.C., Aitken, K.E.H., Norris A.R. & Martin, K. 2004: Woodpeckers as reliable indicators of bird richness, forest health and harvest. — Biological Conservation 141: 624–634.

Drever, M.C. & Martin, K. 2010: Response of woodpecker to changes in forest health and harvest: implications for conservation of avian biodiversity. — Forest Ecology and Management 259: 958–966.

Dufrêne, M. & Legendre, P. 1997: Species assemblages and indicator species: the need for a flexible asymmetrical approach. — Ecological Monographs 67: 345–366.

Fayt, P. 1999: Available insect prey in bark patches selected by the Threetoed Woodpecker *Picoides tridactylus* prior to reproduction. — Ornis Fennica 76: 135–140.

Fraticelli, F. & Guerrieri, M. 1988: Aspects of the foraging niche of great tits *Parus major*, and blue tit *Parus caeruleus* and long-tailed tits *Aegithalos caudatus* in a Mediterranean wood. — Avocetta 12: 71–82.

Fuller, R.J. 1992: Effects of coppice management on woodland breeding birds. — In The ecology and management of coppice woodlands (ed. Buckley, G.P.): 169–192. Chapman & Hall, London.

Gil-Tena, A., Saura, S. & Brotons, L. 2007: Effects of forest composition and structure on bird species richness in a Mediterranean context: Implications for forest ecosystem management. — Forest Ecology and Management 242: 470–476.

Hedblom, M. & Söderström, B. 2012: Effects of urban matrix on reproductive performance of great tit (*Parus major*) in urban woodlands. — Urban Ecosystems 15: 167–180.

Hinsley, S.A., Bellamy, P.E. & Newton, I. 1995: Birds species turnover and stochastic extinction in woodland fragments. — Ecography 18: 41–50.

Hinsley, S.A., Carpenter, J.E., Broughton, R.K., Bellamy, P.E., Rothery, P., Amar, A., Hewson, C.M. & Gosler, A.G. 2007: Habitat selection by Marsh Tits *Poecile palustris* in the UK. — Ibis 149 (Suppl. 2): 224–233.

James, F.C. & Shugart, H.H. 1970: A quantitative method of habitat description. — Audubon Field Notes 24: 727–736.

Julliard, R., Clavel, J., Devictor, V. & Jiguet, F. 2006: Spatial segregation of specialists and generalists in bird communities. — Ecology Letters 11: 1237–1244.

Kati, V., Dimopoulos, P., Papaioannou, H. & Poirazidis, K. 2009: Ecological management of a Mediterranean mountainous reserve (Pindos National Park, Greece) using the bird community as an indicator. — Journal for Nature Conservation 17: 47–59.

Keller, J.K., Richmond, M.E. & Smith, C.R. 2003: An explanation of patterns of breeding birds species richness and density following clearcutting in northeastern USA forests. — Forest Ecology and Management 174: 541–564.

Kosenko, S.M. & Kaygorodova, E.Y. 2001: Effect of habitat fragmentation on distribution, density and breeding performance of the middle spotted woodpecker *Dendrocopos medius* (Aves, Picidae) in Nerussa-Desna Polesye. — Zoologichesky Zhurnal 80: 71–78.

Kosiński, Z. & Winiecki, A. 2004: Nest-site selection and niche partitioning among the Great Spotted Woodpecker *Dendrocopos major* and Middle Spotted Woodpecker *Dendrocopos medius* in riverine forest of Central Europe. — Ornis Fennica 81: 145–156.

Kottek, M., Grieser, J., Beck, C., Rudolf, B. & Rubel, F. 2006: World map of the Koppen-Geiger climate classification updated. — Meteorologische Zeitschrift 5: 259–263.

Martin, T.E. & Li, P. 1992: Life history of open- vs. cavity-nesting birds. — Ecology 73: 579–592.

Matthysen, E., Lens, L., Van Dongen, S., Verheyen, G.R., Wauters, L.A., Adriaensen, F. & Dhondt, A.A. 1995: Diverse effects of forest fragmentation on a number of animal species. — Belgian Journal of Zoology 125: 175–183.

Mikusiński, G., Gromadzki, M. & Chylarecki, P. 2001: Woodpeckers as indicators of forest bird diversity. — Conservation Biology 15: 208–217.

Mullarney, K., Svensson, L., Zatterström, D. & Grant, P.J. 1999. Collins bird guide: the most complete field guide to the birds of Britain and Europe. — HarperCollins, London, UK.

Nikolov, S.C. 2009: Effect of stand age on bird communities in late-successional Macedonian pine forests in Bulgaria. — Forest Ecology and Management 257: 580–587.

Nilsson, S.G. 1984: The evolution of nest-site selection among hole-nesting birds: the importance of nets predation and competition. — Ornis Scandinavica 15: 167–175.

Paclík, M., Misík, J. & Weidinger, K. 2009: Nest predation and nest defence in European and North American woodpeckers: a review. — Annales Zoologici Fennici 46: 361–379.

Pasinelli, G. 2007: Nest site selection in middle and great spotted woodpeckers *Dendrocopos medius* & *D. major*: implications for forest management and conservation. — Biodiversity and Conservation 16: 1283–1298.

Quine, C.P., Fuller, R.J., Smith, K.W. & Grice, P.V. 2007: Stand management: a threat or opportunity for birds in British woodland? — Ibis 149: 161–174.

R-Development Core Team 2010: R: a language and environment for statistical computing. — R Foundation for Statistical Computing.

Redolfi De Zan, L., Battisti, C. & Carpaneto, G.M. 2014: Bird and beetle assemblages in relict beech forests of central Italy: a multi-taxa approach to assess the importance of dead wood in biodiversity conservation. — Community Ecology 15: 235–245.

Robles, H., Ciudad, C. & Matthysen, E. 2011: Tree-cavity occurrence, cavity occupation and reproductive performance of secondary cavity-nesting birds in oak forests: The role of traditional management practices. — Forest Ecology and Management 261: 1428–1435.

Smith, K.W. 1997: Nest site selection of the Great Spotted Woodpecker *Dendrocopos major* in two oak woods in Southern England and its implications for woodland management. — Biological Conservation 80: 283–288.

Smith, K.W. 2007: The utilization of dead wood resources by woodpeckers in Britain. — Ibis 149: 183–192.

Speight, M.C.D. 1989: Saproxylic invertebrates and their conservation. — Strasbourg: Council of Europe, Publications and Document Division.

Spies, T.A. 2004: Ecological concepts and diversity of old-growth forests. — Journal of Forestry 102: 14–20.

Sutherland, W. 2006: Ecological Census Techniques, 2nd ed. — Cambridge University Press, Cambridge, UK.

Virkkala, R. 2006: Why study Woodpeckers? The significance of woodpeckers in forest ecosystem. — Annales Zoologici Fennici 43: 82–85.

Wesolowski, T. 2002: Anti-predator adaptations in nesting marsh tits *Parus palustris*: the role of nest-site security. — Ibis 144: 593–601.

Wesolowski, T. & Rowiński, P. 2004: The breeding behavior of the nuthatch *Sitta europaea* in relation to natural hole attributes in a primeval forest. — Bird Study 51: 143–155.

Wübbenhorts, J. & Südbeck, P. 2003: Woodpecker as indicator of sustainable forestry? First results of a study from lower Saxony. — Nationalpark Berchtesgaden Forschungsbericht 48: 179–192.

Zangari, L., Ferraguti, M., Luiselli, L., Battisti, C. & Bologna, M.A. 2013: Comparing patterns in abundance and diversity of hole-nesting birds in Mediterranean habitat. — Revue d'Ecologie-Terre Vie 67: 1–8.