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Intra-annual variation in habitat choice by an endemic woodpecker: Implications for forest management and conservation

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ABSTRACT

The Canary Islands great spotted woodpecker Dendrocopos major canariensis is an endemic bird restricted to the Pinus canariensis forests of Tenerife and Gran Canaria. Classification tree models were applied to explore the relationship of the occurrence of this picid and habitat variables between two contrasting periods (breeding vs. non-breeding seasons) and for the entire annual cycle. During the reproductive period the availability of mature trees (DBH > 60 cm), and snags (dead trees), for nesting and roosting, characterize the breeding territory. Outside the breeding season the choice of locations was driven by a tree cover larger than 28.5% and the presence of trees taller than 8.5 m on average, a pattern explained by the availability of pine seeds in the cones of well-developed canopies, and less so by predation risk. Overall, during the annual cycle, well-developed canopy sites influenced the presence of this picidae (tree cover > 38%) and on more open sites (<38%) the presence of mature trees (DBH> 60 cm) became the second most important predictor of occurrence. We suggest that food abundance and availability could be the ultimate factor explaining the intra-annual variation observed, with the availability of snags being an important factor during nesting. In the range of this endemic, we recommend selective cuts in pine plantations, to allow the trees to set seed and improve their crops, minimizing the elimination of snags, and killing some large pine trees if the priority is to expand the distributional range of the woodpecker. © 2009 Elsevier Masson SAS. All rights reserved.

1. Introduction

The great spotted woodpecker *Dendrocopos major* is widely distributed across Eurasia and occupies continental islands (e.g. Great Britain), continental fragments (Corsica, Sardinia and Sicily), but also oceanic islands such as Japan and the Canary Islands (del Hoyo et al., 2002). On the Canary Islands, the south-western limit of its range, the great spotted is the only woodpecker present and has differentiated, based on mitochondrial DNA, into an endemic race (*D.m. canariensis*) (Garcia-del-Rey et al., 2007). Originally, two different races, *D.m. thanneri* on Gran Canaria and *D.m. canariensis* on Tenerife, have been described based on plumage colour differences (Cramp, 1985).

Woodpeckers became residents in the Canaries between 150,000 and 50,000 years ago (Garcia-del-Rey et al., 2007) and today they inhabit only the forests of Canary Islands pine *Pinus canariensis* on Gran Canaria and Tenerife. This tree is adapted to live near sea level up to 2400 m (Jimenez et al., 2005), but today is restricted to 500–2400 m in the south and 1000-2000 in the north.

This pine tree is well adapted to volcanism (Climent et al., 2004), its needles exhibit morphological drought adaptations (Grill et al., 2004) and its cones and seeds vary in size with altitude (Gil et al., 2002). A Canary pine tree can grow 40–50 m in height and live for more than 700 years (Ceballos and Ortuño, 1951).

Despite the taxonomic uniqueness of this ecological system, very little is known about the ecology of this picidae in the Canaries. Habitat selection has been a major topic in ecology (Cody, 1981) and is widely considered as a primary research tool to develop effective forest management policies. The pine forests on the Canary Islands are currently protected by law and can not be exploited for timber (Martín-Esquivel et al., 1995). However, some forest management actions are taking place, particularly on the island of Tenerife, mainly with the aim of achieving the naturalization of the high density pine plantations.

The main objective of this study was to identify which environmental factors influence the choice of sites by the Canary Islands great spotted woodpecker during the entire annual cycle, as well as the choice of territory occupancy (breeding period) and the selection of winter foraging sites (non-breeding period) by this species. We use our findings to recommend forest management actions that will benefit the conservation of this species.





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Fig. 1. Distribution of different types of pine forest areas on the island of Tenerife (Canary Islands, Spain). The black circle indicates the location of the study site during the non-breeding period.

2. Material and methods

This study was undertaken on the island of Tenerife (28°20'N-16°20'W), Canary Islands, during two contrasting periods in the annual cycle of this woodpecker. The pine forest on this island ranges from 700 to 2400 m above sea level, with special variations according to the exposition. The adult pine trees can reach normally 15–25 m height, and exceptionally 40-50 m height, with a diameter at breast height (hereafter DBH) larger than 2.5 m (Blanco et al., 1989), but nowadays this is very rare. Today, three main pine forest zones can be identified, in the island (del Arco et al., 2006) (see Fig. 1), from which for this comparative study, the "typical pine forest" stratum was chosen. This stratum, comprises an unmanaged total pine forest area of c. 20 000 hectares (i.e. 62% of today's total pine forest area) and an understorey dominated by two endemic leguminous shrubs: Chamaecytisus proliferus and Adenocarpus viscosus. Hence, recently burnt areas and currently managed plantations, with different intensity of selective cuts, have been excluded from the analyses.

2.1. Breeding period

As part of a long term breeding bird survey by Sociedad Ornitológica Canaria (SOC) (i.e. Programa de Seguimiento de Aves Canarias), 45 great spotted woodpecker territories were identified during the breeding seasons of 2005–2007, along 370 point counts, distributed systematically on randomly selected plots, around the entire pine forest area of Tenerife (see Fig. 1 in Garcia-del-Rey and Cresswell, 2005). All territories within the stratum under study were surveyed during the reproductive period of 2008 (April–May) to look for active nests. The microhabitat around 30 active nests (within the typical pine forest stratum under study) was characterized, within a 25 m radius plot, by measuring nine variables (Table 1): the percentage of tree cover was measured with a spherical convex densitometer (Lemmon, 1956, 1957), the percentage of shrub cover, the number of trees of different thickness and the number of dead trees (snags) were measured visually. The average heights of trees, the mean shrub height and the terrain slope were estimated with a dendrometer (Haglöf Vertex IV). A rangefinder $(\pm 1 \text{ m error})$ was used to delimit the 25 m radius area around the observer. All nine variables were also measured, within a 25 m radius plot, at random points (n = 30) from each nest site. The UTM coordinate of the centre of every nest/random point was measured with a Global Positioning System reader. These explanatory variables (Table 1) were selected based on the most important ecological requirements of the woodpecker genus (Dendrocopos) (Snow and Perrins, 1998).

2.2. Non-breeding period

A plot $(2.5 \times 2.5 \text{ km})$ was randomly selected (UTM coordinates of the SW corner: 336000-3118000), 2225 m asl, on the stratum under study. The plot was divided (with the aid of Arcview maps) by a 500 × 500 m grid and cells were visited systematically (one visit/ cell only), to record birds actively foraging during the winter of 2008 (1 December–1 February). Birds were identified with binoculars (Zeiss 10 × 40). Special care was taken to avoid pseudo-replication through mapping of movements of previously observed individuals on 1:5000 maps. The sampling effort was also standardised to 1 h per cell and a single observer (EGDR) collected all the data. No surveys were done during rain or strong wind and bird detection field work was only conducted between 7.30 (dawn) to 10.30 h. The microhabitat around each bird foraging was characterized, within a 25 m radius plot, by measuring the same 9 variables (see Table 1).

The microhabitat structure representative of this study site (hereafter, available) was also characterized by measuring the same 9 variables (Table 1), within a 25 m radius plot, located at the intersections (nodes) (n = 30) of the gridlines (500 × 500 m cell), (see Sutherland et al., 2004 for the robustness of this method).

2.3. Statistical analysis

Two analytical approaches were used to study the habitat preferences of the woodpecker: 1) Habitat selection: the explanatory habitat variables for occupied and random/available sites were compared using Mann–Whitney *U*-test. 2) Modelling of habitat preferences: potential intercorrelations between variables were examined using Spearman's rank correlation tests. Occupied and random/available places were scored as a binary dependent variable and the habitat measures as independent explanatory variables (Manly et al., 1993).

Table 1

Explanatory variables used to characterize, within a 25 m radius circular plot, the vegetation architecture of the microhabitat of the Canary Islands great spotted woodpecker *D. major canariensis* during the breeding (nest-site selection) and the non-breeding (foraging site selection) period. Mean values $(\pm SD)$ of the habitat variables measured in nest-sites and random points also included.

Predictor	Description	Nest-sites ($n = 60$)	Random points ($n = 60$)	
TC	Cover of pine trees (%)	42.72 ± 22.95	10.61 ± 9.16	
T1	Number of trees with a diameter at breast height (DBH) > 60 cm	1.50 ± 1.37	0.93 ± 1.36	
T2	Number of tress with a DBH between 35 and 60 cm	1.57 ± 2.43	2.29 ± 2.26	
T3	Number of tress with a diameter (DBH) < 35 cm	14.19 ± 12.84	15.56 ± 15.39	
MTH	Mean tree height of the six closest trees (m)	12.93 ± 3.68	9.86 ± 2.76	
SC	Cover of shrubs (%)	20.05 ± 22.09	23.84 ± 20.41	
MSH	Mean shrub height (m)	1.02 ± 0.61	0.84 ± 0.50	
SL	Slope (degrees)	19.82 ± 13.98	12.32 ± 6.08	
DT	Number of dead trees (snags)	0.82 ± 0.74	0.79 ± 1.40	

Species occurrence (presence = 1, represents the occurrence of the woodpecker in winter and the presence of a nest in spring; absence = 0, represents random locations both in winter and in spring) in all the plots sampled (60 random/available vs. 60 occupied) was modelled introducing all the nine original explanatory variables, and analysed using classification trees (data were not transformed). This relatively new, but powerful, technique in ecology (DéAth and Fabricus, 2000) was used to analyse woodpecker presence-absence in relation to environmental variables (generally, during breeding and during non-breeding seasons) and hence explore the relationship between a single response variable and multiple explanatory variables (Chambers and Hastie, 1992; DéAth and Fabricus, 2000). The response variable undergoes successive univariate splits, according to threshold values of the explanatory variables that maximize the differences between the two resulting groups of samples. Tree models deal better with non-linearity and interaction between explanatory variables than regression, generalised linear models (GLM) and generalised additive models (GAM), they can be used to find interactions missed by other methods in complex ecological studies, they indicate the relative importance of different explanatory variables, are not affected by transformation on the explanatory variables (Zuur et al., 2007) and minimize the problems of stepwise (forward or backward) procedures, which are becoming less popular among ecologists today (see Whittingham et al., 2006 for a well explanation of another powerful method: Information Theoretic Approach). The predictive power of the obtained classification tree was evaluated by means of crossvalidation procedure using 10 random sampling iterations. This objectively allows selecting the optimal tree size and avoids complex suboptimal trees (for a full explanation of this process see Zuur et al., 2007). The minimum number of observations that must exist in a node, in order for a split to be attempted was set to 5 and the full tree was obtained with the default complexity parameter set to 0.001.

Basic statistical methods followed Zar (1998) and were implemented using the SPSS v.12 statistical software package (SPSS, 2006). Brodgar 2.5.6.(www.brodgar.com) was used for all univariate tree model analyses.

3. Results

3.1. Habitat selection

Overall, significant results were found between occupied and random/available sites for tree cover percentage (TC) (Mann–Whitney *U*-test: U = 320.0, p = 0.0001) and the number of trees

with diameter (DBH) larger than 60 cm (T1) (Mann–Whitney *U*-test: U = 1198.0, p = 0.001). For both variables the average in used sites was larger than the mean of unused locations, suggesting the woodpecker prefer sites with greater percentage of tree cover and larger number of mature (DBH > 60 cm) trees.

A similar result was found when the differences between sites were explored among the different (breeding vs. non-breeding) periods. During the breeding season significant results were found between used and unused sites for the percentage of tree cover (Mann–Whitney *U*-test: U = 68.0, P = 0.0001), the number of trees with a diameter (DBH) greater than 60 cm (Mann–Whitney *U*-test: U = 265.5, p = 0.005) and the mean tree height (Mann–Whitney *U*-test: U = 271.0, p = 0.008). This suggests that woodpecker prefer sites with greater tree cover, larger number of mature and taller trees during breeding (means in used sites were also larger than in unused sites).

During the non-breeding period significant results were found between used and available sites for the percentage of tree cover (Mann–Whitney *U*-test: U = 93.5, p = 0.0001), the number of trees with a diameter (DBH) greater than 60 cm (Mann–Whitney *U*-test: U = 315.5, p = 0.04), the number of trees with a diameter (DBH) between 35 and 60 cm (Mann–Whitney *U*-test: U = 285.0, p = 0.01) and the mean tree height (Mann–Whitney *U*-test: U = 226.0, p = 0.001). This suggests that woodpeckers prefer sites with greater percentage of tree cover, larger number of mature trees and medium diameter at breast height (35–60 cm), and taller trees on average.

3.2. Modelling of habitat preferences

Collinearity (i.e. significant correlation coefficient larger than 0.70) was not found between variables and all nine explanatory variables were used for all the univariate classification tree model analyses (see Table 2).

Overall, the optimal classification tree indicates that tree cover larger than 28.5% influence the occupancy of sites by the woodpecker (Fig. 2). When the percentage of tree cover is smaller than 28.5%, the presence of one or more mature trees (DBH > 60 cm) influence the probability of finding a woodpecker (i.e. TC < 28.5; T1 > 0.5). The classification tree correct prediction of occurrence of this species was 52%, but increased to 69% where the species was present (i.e. adding up all branches were the species was found, those ending in 1).

The optimal classification tree for the breeding period can be seen on Fig. 3. There is a high probability of finding woodpeckers nesting in territories with mature tree (DBH > 60 cm) (T1 > 0.5)

Spearman's rank correlations between the nine variables used in multivariate analyses. Significant values in bold. Below is significance value. N = 120

	TC	T1	T2	T3	MTH	SC	MSH	SL	DT		
ТС	1,000	0,301	0,031	0,159	0,213	0,033	-0,050	0,112	0,145		
		0,001	0,739	0,082	0,020	0,721	0,588	0,223	0,115		
T1	0,301	1,000	-0.178	-0,152	0,359	-0,118	-0,164	0,043	-0,118		
	0,001		0,052	0,098	0,000	0,198	0,074	0,641	0,199		
T2	0,031	0,178	1000	0,137	0,435	0,036	0,073	0,174	0,211		
	0,739	0,052		0,136	0,000	0,694	0,430	0,058	0,020		
Т3	0,159	-0,152	-0,137	1,000	0,074	0,250	0,248	0,039	0,200		
	0,082	0,098	0,136		0,423	0,006	0,006	0,670	0,029		
MTH	0,213	0,359	0,435	0,074	1,000	-0,058	-0,115	-0,095	-0,131		
	0,020	0,000	0,000	0,423		0,532	0,210	0,300	0,153		
SC	0,033	-0,118	-0,036	0,250	-0,058	1,000	0,548	0,009	0,412		
	0,721	0,198	0,694	0,006	0,532		0,000	0,919	0,000		
MSH	-0050	-0164	-0073	0,248	-0115	0,548	1,000	0,156	0,374		
	0,588	0,074	0,430	0,006	0,210	0,000		0,089	0,000		
SL	0,112	0,043	-0,174	0,039	-0,095	0,009	0,156	1,000	0,011		
	0,223	0,641	0,058	0,670	0,300	0,919	0,089		0,907		
DT	0,145	-0,118	-0,211	0,200	-0,131	0,412	0,374	0,011	1,000		
	0,115	0,199	0,020	0,029	0,153	0,000	0,000	0,907			

Table 2

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Fig. 2. Optimal classification tree (according to Fig. 5), describing the overall pattern of nesting/foraging habitat preferences of the Canary Islands Great Spotted Woodpecker *Dendrocopos major canariensis.* Branch lengths are proportional to deviance explained by each split criteria. If a statement is true, follow the left branch. Numbers at the end of a branch are the predicted group (1 = presence, 0 = absence) and classifications per group (errors/number of observations). Correct prediction of presence-absence is 52% (69% when the species is present). T1 = number of trees with DBH > 60 cm; T2 = number of trees with DBH 35–60 cm.

and snags (dead tree) (DT > 0.5). This classification tree correctly classified the occurrence of the woodpecker in 80% of the occasions.

During the non-breeding period, the optimal classification tree suggests that the occupancy of woodpeckers foraging/feeding is influenced by a percentage of tree cover larger than 28.5% and a mean tree height larger than 8.5 m (see Fig. 4). This classification tree correctly classified the occurrence of the woodpecker in 87% of the occasions. See Fig. 5, the pruning diagram resulting from 10



Fig. 3. Optimal classification tree, describing the nesting territory of the Canary Islands Great Spotted Woodpecker *Dendrocopos major canariensis*. Branch lengths are proportional to deviance explained by each split criteria. If a statement is true, follow the left branch. Numbers at the end of a branch are the predicted group (1 = presence, 0 = absence) and classifications per group (errors/number of observations). Correct prediction of presence-absence is 80%. T1 = number of trees with DBH > 60 cm; T2 = number of trees with DBH 35-60 cm.



Fig. 4. Optimal classification tree, describing the non-breeding foraging site selection of the Canary Islands Great Spotted Woodpecker *Dendrocopos major canariensis*. Branch lengths are proportional to deviance explained by each split criteria. If a statement is true, follow the left branch. Numbers at the end of a branch are the predicted group (1 = presence, 0 = absence) and classifications per group (errors/number of observations). Correct prediction of species occurrence is 87%. T1 = number of trees with DBH > 60 cm; T2 = number of trees with DBH 35-60 cm.

cross-validations, as an example of how the complexity parameter has been estimated for every tree model.

4. Discussion

Our results on the basic habitat selection analysis suggests that woodpeckers on Tenerife select mature pine tree areas during the breeding and the non-breeding periods, but also tolerates sites with thinner pine trees (less mature zones) in the winter time. A clear shift in habitat choice is suggested between the two periods under study.



Fig. 5. Pruning diagram resulting from 10 cross-validations. The dots are the averages of the cross-validations and the vertical lines the standard deviation. The one standard deviation rule dictates to select the left-most tree for which the mean relative error is below the dotted line, which is in this case a tree of size 7 (cp = complexity parameter) (see Fig. 2).

4.1. Breeding period

Many aspects of the biology of the great spotted woodpecker, across its range, has been studied in detail (see references in Winkler et al., 1995), and particularly, during the breeding season (Kosinski and Kempa, 2007; Pasinelli, 2007). Our results for this period do not depart from these findings as the Canary Islands woodpecker selects and prefers territories with mature pine trees and with the availability of snags (dead trees). In pine forests elsewhere, the great spotted woodpecker selects snags in old-growth to excavate nest and roost sites (Summers, 2007) and tend to breed in the largest pine snags (Summers, 2004). Despite that the great spotted woodpecker breeding in oakwood in England has been observed to nest in living trees (Smith, 2007), this has never been recorded on Tenerife (pers. obs.). Therefore, nesting seems to become less suitable in areas where there are no mature trees and not a single snag available, as has been found in a Mediterranean pine forest in Spain (Barrientos and Bolonio, 2003) and elsewhere for other woodpecker species (Aubry and Raley, 2002). We did not measure food abundance or availability during the breeding period, but suggest that wood-living insect larvae for nestlings and the availability of nest sites might explain the pattern of territory choice by the Canary Islands woodpecker in Tenerife.

4.2. Non-breeding period

During the non-breeding period woodpeckers prefer sheltered locations for foraging and feeding with a tree cover greater than 28.5% and with pine trees taller than 8.5 m on average. The greater-DBH and taller Canary Pine trees (i.e. trees with very well-developed canopies) tend to produce the biggest crops (Ceballos and Ortuño, 1951). It has been observed in a continental (e.g. Poland) pine area and during winter, that woodpeckers feed mainly on pine cones and males more often than females (Osiejuk, 1994). Indeed, the majority of our foraging and feeding observations (84%) during this period were of birds actually attaching the open pine cones high up in the canopy of the trees, to exploit the left over seeds that did not disperse during the previous summer (unpublished data). Very small number of potential woodpecker predators can be found in Canarian pine forests (i.e. a single introduced mammal, Felis catus, and the native sparrowhawk, Accipiter nisus). Hence, food availability and abundance (mediated by the pine seed crop), and less predation risk, could explain the pattern observed in Tenerife outside the nesting period.

To conclude, in this endemic forest system, the presence of mature trees (DBH > 60 cm) and the availability of snags (dead trees) characterize the breeding territory of this endemic woodpecker. Wood-living insect larvae for nestlings, the pine seed crop, and the availability of snags are all possible ultimate factors explaining the intra-annual variation observed, whereas predation risk seems to be low.

4.3. Conservation implications

The knowledge of the microhabitat requirements of a species is fundamental for establishing meaningful conservation strategies. According to our finding, we recommend:

 In high density pine stands (i.e. plantations actually occupying 11,233 hectares in Tenerife), selective cuts are recommended to recreate those conditions that allow the trees to improve their canopies and set seed, so it can be exploited by the woodpeckers, especially during the non-breeding period. Managing these stands towards a structure that allow the tress to reach maturity (more than 60 cm DBH), in the shortest period of time, could be considered as a priority for the conservation of this pine forest specialist. 2) In the range of this species (Tenerife and Gran Canaria) particularly attention should be paid to snags and cutting down these dead trees should be minimized as much as possible during silviculture management and forest fire restoration actions. If improving the distributional range of the woodpecker is a priority, forest and wildlife managers should consider killing some large pine trees (DBH > 60 cm if possible, if not trees with a DBH between 35 and 60 cm) in plantations where other endemic wildlife interests are not compromised (e.g. this should not be undertaken on Inagua Nature Reserve, where the Gran Canaria Blue Chaffinch is in the brink of extinction). Future research should investigate how gap-phase dynamics influence the settlement of new woodpecker territories.

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