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Forest management considerations for conservation of Black Woodpecker *Dryocopus martius* and White-backed Woodpecker *Dendrocopos leucotos* populations in Quinto Real (Spanish Western Pyrenees)

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Abstract. The woodlands of Quinto Real (Quinto Real, Erreguerena and Legua Acotada) are a 3,000 hectare beech (*Fagus sylvatica*) forest managed by the shelterwood system applied to even-aged (regular) stands. This study analyses how forest management determines the local distribution of the white-backed woodpecker (*Dendrocopos leucotos*) and black woodpecker (*Dryocopus martius*) and its relationship with the type, structure and size of the stands used for nesting by both species, as well as their dead wood requirements. The most suitable nesting habitat of both species is the mature forest (stands of regular large final crop trees), but the size of the mature fragments and a minimum quantity of dead wood is also important.

Introduction

Woodpeckers (*Picidae*), particularly the white-backed (*Dendrocopos leucotos*) and black woodpeckers (*Dryocopus martius*), are associated with the existence of mature forests (Voous 1947). The black woodpecker and the white-backed woodpecker are two of the most threatened species in the Pyrenean Region of Spain. They need large areas of mature deciduous forest, particularly woodlands with beech (*Fagus sylvatica*), or beech-fir (*Abies alba*) or beech-pine (*Pinus* spp.) mixed forests (Cuisin 1967; Purroy et al. 1990; Fernández et al. 1994). The surfaces of these forests are decreasing and those that still remain are variously degraded in most of continental Europe (Cramp 1985; Avery and Leslie 1990), especially in Mediterranean countries (Purroy et al. 1990; Tellería 1992).

Two legal instruments that were recently approved by the Regional Government of Navarre, Spain – The forest plan (Gobierno de Navarra 1998), and The Biological Diversity Conservation Strategy (Gobierno de Navarra 1999) – are based on the sustainable management of natural resources. In Quinto Real

woodland, this environmental standard involves forestry management and offers the chance to provide, if not an optimum, at least a suitable habitat for these species.

Woodpecker species are an interesting group as 'umbrella species for biodiversity conservation (Simberloff 1999; Fleishman et al. 2000; Fleishman et al. 2001; Roberge and Angelstam 2004) because they need large areas of well conserved forest with little alteration of their structure and with a sufficient amount of old trees and recently dead large trees (Hogstad 1970; Angelstam 1990; Angelstam and Mikusinsky 1994; Mikusinsky and Angelstam 1997; Murphy and Lehnhausen 1998; Imbeau and Desrochers 2002; Butler et al. 2004). Therefore, the modern forestry practices of removing old and dead trees can compromise their conservation (Nilsson 1992, Tucker and Heath 1994).

The Pyrenees white-backed woodpecker (*Dendrocopos leucotos* ssp. *lilfordi*) population is particularly interesting from a bio-geographical perspective. The Pyrenees represent the south – western fringe of its world distribution (Fernández et al. 1994), and it has been catalogued as endangered in Spain (Blanco and González 1992). This subspecies has a patchy and discontinuous distribution in mountains of southern Europe, such as the Pyrenees, the Apennines and the Carpathian ranges (Voous 1947). The Pyrenees population is the only one in the Iberian Peninsula and its conservation is therefore very important. This population has been estimated to be composed of 60–70 pairs, of which approximately 20% can be found in the woodlands of Quinto Real (Fernández et al. 1994).

The white-backed woodpecker feeds mainly on wood-boring beetle larvae, mostly *Cerambycidae*. Therefore, the availability of dead wood in this area is an important factor for its survival (Aulén 1988, Aulén and Lundberg 1991). Of all Picidae, this species is the most specialised in feeding habits. Thus, it is probably the most vulnerable to changes in forestry management (Conner 1979).

Another limiting factor for the distribution of this species is the presence of optimum nesting sites. During the breeding season, foraging is confined to relatively small areas around the nest site. This forces this species to choose nesting sites with abundant insects, such as groups of dead trees and borders between different forest areas (Fernández et al. 1994).

The black woodpecker (Dryocopus martius) is widely distributed throughout northern and temperate forests of Europe and Asia. It inhabits mature forests, where there are usually beech trees. However, in northern Europe and Siberia it is also found in coniferous forests. In the Iberian Peninsula, this species occupies the beech forests of the Pyrenees and the Cantabrian Mountains (Martinez-Vidal 1999). It has also been spotted in the relict beech forests situated in the central portion of the Iberian Peninsula, but it seems not to be an established population, but rather composed of young dispersing individuals (Brooks 1985). It has a broad feeding spectrum: most of its food consists of ants, although it also eats many kinds of wood-boring beetle larvae. It frequently feeds on the ground, digging out ant nests or forages in the stumps of felled trees and other types of dead wood (pers. obs.).

The black woodpecker is an indicator species of mature forests. It is especially reliant upon dense, tall stands, and tends to disappear when the forest is degraded (Brooks 1985, Fernández and Azkona 1996). Nevertheless, a limited use of forest resources can be beneficial for this species if small clearings are created and a considerable amount of standing dead wood are left over in the process. Indeed, this can increase the availability of its prey (Brooks 1985).

The conservation of the black woodpecker and the white-backed woodpecker depends, to a large extent, on how the beech forests they inhabit are managed. Inappropriate management may lead to the disappearance of one or both of these species. Consequently, it is very important to implement suitable management programmes in these woodlands.

The most widely-used cutting method in the beech forests of Navarre is the shelterwood system. Current management has resulted in the development of patches of different ages. Protected patches have also been designated where no exploitation can be carried out for logistical reasons. On the other hand, there is a legal obligation to designate non-exploitable areas on at least 5% of the area (Gobierno de Navarra 1990,1992) which involves the creation of several core 'biodiversity reserves' areas, that complement other extensive measures for protecting the habitat.

During spring 1993, Fernández and Azkona (1996) conducted a census of both species in the Quinto Real group of woodlands. The study revealed that the population density of the two species was relatively high in all the study area. They linked the presence of territories for both species with forest stands with high basal areas (>20 m^2/ha). They also noticed a clear overlap between the locations of territories of both species. Dead wood amount in these woodpeckers habitats have not been quantified for this area, and the existence of dead wood threshold value has never been tested.

The objective of this study was to establish how forest management affects woodpeckers' density. In particular, the addressed question is how the type and size of the forest patches, and the amount of dead wood, affects the nesting sites selection for both species. Do these species utilize all the forest stands for their territories or do they prefer one? Which is the threshold stand size of the preferred type? What is more important in this area, the stand type and its size or the dead wood amount? Do all kinds of dead wood serve the same or there are some preferred diameters? Is it really necessary that the dead wood is standing, or could it be lied down? These are the questions addressed in this article.

Methods

Study area

The study was carried out in the Quinto Real group of woodlands, located in northern Navarre in the Baztán and Erro valleys on the Spanish side of the Pyrenees. The Quinto Real area consists of three woodlands: Quinto Real

(1666 ha), Erreguerena (941 ha) and Legua Acotada (907 ha), listed under numbers 2, 3 and 4 in the Navarre's Public Utility Woodlands Catalogue (Gobierno de Navarra 1998). These woodlands are some of the best-preserved beech forests in the Pyrenees. As a result, the Regional Government of Navarre recently proposed them as a Place of Community Interest within the framework of the European Union's Natura 2000 Network. Forest management in this area is governed by a Management Project and its subsequent reviews (Schwendtner and Larrañaga 2001).

The Quinto Real group of woodlands has been managed for timber production since 1904. Extensive areas of regeneration, resulting from shelterwood system harvesting, are present. This kind of exploitation was particularly intensive in the period 1950–1970. There are also mature areas where thinning has been carried out with varying degrees of intensity, while others have not been harvested in the last 70 years. Other areas are characterised by their heterogeneity and unevenness as a result of high-grading of the valuable timber.

Forest characterization

The Quinto Real Natural Resources Management Plan carried out a detailed inventory for the different forest stands and their classification according to structural criteria (Schwendtner and Larrañaga 2001). Table 1 provides information on the different stand types on which the three woodlands of Quinto Real were divided. A total of 397 different homogenous forest patches (stands) were distinguished in the three woodlands. The following variables were measured to characterize the forest structure: dominant height (DH), measured as the mean height of those trees with an average diameter, excluding the stems under 20 cm of diameter, except for the young stands (RY), in which only stems under 10 cm of diameter are excluded; basal area (BA) of all stems over 10 cm of diameter; average diameter (AD) of the stems over 10 cm, measured at breast height; and average age (AA) of the stand, based on several individuals (approximately 1%) of each stand, by counting the growth rings on wood samples. All these measures were made on all stands over all the stand area for management purposes.

Site quality is a variable that is calculated from the relationship between the mean growth rate and tree age. Site quality can be categorized on a scale ranging from I to V: very good and good quality sites are I and II, while III and IV would represent intermediate qualities, and V poor quality sites (Schwendtner and Larrañaga 2001). In better quality sites, trees grow more rapidly that on poorer quality sites, where the harvesting cycle is not as rapid. Schwendtner and Larrañaga (2001) proposed to exploit site qualities I and II, but advised against timber harvest on the lower quality sites.

Basal area of standing dead trees (DBA) and the amount of felled trunks were also determined for each stand.

Table 1. Stand classification by management objectives on the Quinto Real Natural Resources Management Plan (Schwendtner and Larrañaga 2001).

Stand type	Abreviation	Principal characteristics
1. Stand of regular large final crop trees	RLF	Mature forest. Average tree diameter >45 cm. Suitable for final cutting.
2. Stand of regular medium sized crop trees	RM	Medium sized and aged stand. Average tree diameter from 20 to 45 cm. For intermediate cuttings with economic value.
3. Stand of regular young trees	RY	Young stand. Average diameter from 10 to 20 cm. For thinning without economic value.
4. Heterogeneous and irregular stand	HI	Mixed stand, It is heterogeneous when it has different species and irregular when it has different age classes and structures. Various diameters.
5. Low forest stand	LF	Low forest stand. Generally on sites of poor quality.
6. Open large final crop trees	OF	Open zones in regeneration process. Some residual large trees. Basal Area <15 m^2/ha.

Woodpeckers census

The distribution and density of the black woodpecker and the white-backed woodpecker were established by determining their breeding territories during spring 2001. The low density of both species makes sampling difficult. However, since they are highly territorial animals, the location of breeding territories was used to census these species (Svenssons 1979; Tellería 1986; Bibby et al. 1992). The method was the same as the one used in the previous censuses by Fernández and Azcona (1996), so that the densities and distribution of territories could be compared. Recordings of the birdcalls and tapping patterns of both species were used as decoys for locating the breeding territories. For the density estimates, the 'open land' or patches with no trees were excluded of the total study area (3200 ha) and not sampled, though all the other stands of the study area were sampled. To attract territorial birds or to provoke their response during the search, the tapped calls were played every one or two hundred meters, alternating with periods of 30 s of silence, thus permitting to detect the bird response and to locate the individual. Once an individual was located, it was followed to locate the nest and the partner, registering the stands they defended and used for foraging. The wood boring signs were only taken into account when they were extremely recent and very abundant and they were only used to determine areas where investigation should be intensified. Alone they were not considered as sufficient proof of the existence of a nesting area. Sightings of non-territorial individuals were excluded.

Habitat selection

The effect of different forest variables on the breeding area selection of the two bird species (presence or absence of bird territories) was investigated. Therefore, the conclusions that may be drawn from this study concern the territories used for breeding and not the habitats used during other seasons. For the study on dead wood, the three woodlands of Quinto Real were subdivided into 'quarters' that represent smaller management units. Quinto Real was divided into three quarters, and Erreguerena and Legua Acotada into two quarters each (Schwendtner and Larrañaga 2001).

Statistical analysis

The χ^2 test was used to compare the presence/absence frequencies of woodpeckers in the different stand types and site qualities. Only the stands included in the territories were considered as presence, wandering individuals were not taken into account. As the number of low forest (LF) stands was small, these data were eliminated from the statistical analysis.

To estimate the threshold stand size of the type preferred by woodpeckers, different size classes have been separated to compare the percentages of stands of different size classes included in territories. Also an analysis of variance (ANOVA) has been made to compare the sizes of these stands used and not used by each species.

To compare quantitative variables for the forest stands used by each woodpecker species in their breeding territories, analysis of variance (ANOVA) was combined with the comparison of means of each group (LSD, student's *t*). Also the differences between woodlands and stand types have been tested.

To reduce the complexity of the data set and to detect the interactions between species occurrence and environmental variables, a principal component analysis (PCA) based on the correlation matrix was carried out. In this analysis only beech forest stands with data available for the four variables were used ($n = 243$).

To determine the importance of the amount of dead wood in the territories, different ANOVA analyses have been done at different scales. A first analysis was made comparing the amount of dead wood in the stands included and not included in each woodpecker territories. As no results were found with this analysis, a more detailed analysis was made, repeating it for each quarter and for each stand type. Also, the amount of dead wood in large RLF stands is analysed.

The comparisons between woodlands were made on means of each quantitative variable for each stand, weighted by the area of the stand. For all the ANOVA analyses, a test for normality has been carried out to fulfil the assumptions. All of the statistical analyses were conducted using the Statistica 4.5© for windows from Statsoft, Inc.

Results

Forest stand classification

From the analysis of forest stands, it appears that approximately 40% of the area consist of high-quality sites (I and II), 30% of intermediate quality sites (III and IV), and 30% of low quality sites. In the low quality sites are included the non-exploitable sites due to environmental constraints (known as protection patches). Extraction priority was given to areas that are more productive or easily accessible (Schwendtner and Larrañaga, 2001), so there is a certain imbalance in the age histogram according to site qualities (results not shown). Stand type distribution in the studied area is explained in Table 2.

Census

As can be seen in Table 3, there were 11 reproductive pairs of white-backed woodpecker (7 pairs in Quinto Real, 1 pair in Erreguerena, 1 pair between Quinto Real and Erreguerena and 2 pairs in Legua Acotada) and 14 pairs of black woodpecker (7 pairs in Quinto Real, 4 pairs in Erreguerena, 1 pair between Quinto Real and Erreguerena and 2 pairs in Legua Acotada).

Comparing these data with the densities found by Fernandez and Azkona (1996) on spring 1993 (Table 3), can be seen that the population remains stable with a downward trend in the case of the white-backed woodpecker and an upward trend in the case of the black woodpecker in the whole study area, but a clear decline is detected for the white-backed woodpecker in Erreguerena and for the black woodpecker in Legua Acotada. This decline is compensated in both cases with increases in Quinto Real and for the black woodpecker in Erreguerena.

Table 2. Area (hectares), number of stands and average stand size (hectares) of the tree woodlands of Quinto Real: Quinto = Quinto Real; Erreg. = Erreguerena; Legua = Legua Acotada.

Stand type	Area (ha)				Number of stands				Average stand size (ha)			
	Quinto	Erreg.	Legua	Total	Quinto	Erreg.	Legua	Total	Quinto	Erreg.	Legua	Total
1. RLF	355.1	300.7	260.4	916.2	33	32	17	82	10.8	9.4	15.3	11.2
2. RM	382.6	140.3	265.3	788.2	54	16	8	88	7.1	8.8	14.7	9.0
3. RY	236.7	233.1	148.6	618.3	32	22	17	71	7.4	10.6	8.7	8.7
4. HI	346.1	152.0	135.4	633.5	58	38	19	115	6.0	4.0	7.1	5.5
5. LF	200.5	0.0	6.3	206.8	31	0	1	32	6.5		6.3	6.5
6. OF	18.3	3.6	16.1	37.9	4	1	4	9	4.6	3.6	4.0	4.2
Total	1539.3	829.7	832.0	3200.9	212	109	76	397	7.3	7.6	10.9	8.1

The abbreviations of the stand types come from Table 1: RLF, stands of regular large final crop trees; RM, stands of regular medium sized crop trees; RY, stands of regular young trees; HI, heterogeneous and irregular stands; LF, low forest stands.

Table 3. Number of territories and density (pairs/Km^2) of each woodpecker species (WW = White backed woodpecker, BW = Black woodpecker) in all the forested area (Total) of the three Woodlands, and in each of them (Quinto = Quinto Real, Legua = Legua Acotada). The 2001 are the census carrried by the authors of this article and the 1993 are the census carried by Fernández and Azcona in 1993 (see Fernández and Azcona 1996).

	2001		1993	
	WW	BW	WW	BW
Number of territories				
Total	11	14	12	13
Quinto	7.5	7.5	6	6
Erreguerena	1.5	4.5	4	4
Legua	2	2	2	3
Density (pairs/Km^2)				
Total	0.34	0.44	0.38	0.41
Quinto	0.49	0.49	0.48	0.48
Erreguerena	0.18	0.54	0.38	0.38
Legua	0.33	0.33	0.33	0.49

The territories of both species reveal certain mobility compared to the 1993 census carried out by Fernández and Azkona (1996). Many of the territories are still located in exactly the same forest stands. Others clearly occupy the sites situated between former territories, presumably using the areas that were less used on the 1993 territory distribution. In territories where felling has been carried out, the pairs affected have moved out, probably to other unoccupied patches.

Preferences according to stand classification and site qualities

Frequencies of sightings of the two species in the different forest types show significant differences (χ^2, p lt 0.005 for the black woodpecker and $p < 0.00001$ for the white-backed woodpecker). Both species show a clear preference for regular large final crop stands (RLF). For both species there is also a distinct negative selection against heterogeneous (mixed with conifers) and uneven (mixed ages) stands (HI); this is less marked in the case of the black woodpecker. Sightings in regular medium sized crop stands (RM) and regular young stands (RY) do not reveal any significant differences.

Although most of the territories cover various forest stand types, nearly all cases – except in one black woodpecker and one white-backed woodpecker territories – include an RLF stand. When nests were found, they were usually located in this stand type, while the others – mainly RM and RY – are also defended and used for feeding. In the two territories identified in a place without RLF, there were RM stands of a considerable age (on the boundary of stands regarded as RLF). In one of these cases, the territory may have been moved from a recently exploited mature stand (RLF). Nevertheless, in

Table 4. Means comparison (LSD) of dominant height (DH), average age, average diameter (AD) and basal area (BA) from the Quinto Real Natural Resources Management Plan (Schwendtner and Larrañaga 2001).

Stand use	DH (m)	Age (years)	AD (cm)	BA (m^2/ha)
Without territory	20.1 D	97.8 C	26.4 C	22.7 B
WT without BT	21.8 C	109.9 B	31.5 B	23.1 B
BT without WT	22.8 B	104.9 B	27.4 C	22.1 B
BT and WT	25.6 A	148.7 A	33.8 A	26.5 A
Woodlands				
Quinto Real	20.4 B	108.3 A	28.0 AB	21.5 C
Erreguerena	22.1 A	106.5 A	28.2 A	25.8 A
Legua Acotada	21.9 A	96.5 B	27.1 B	23.2 B
Stand types				
RLF	26.0 A	155.3 A	36.7 A	26.9 B
RM	21.9 B	91.2 D	28.8 B	28.5 A
RY	15.8 D	45.3 E	15.0 D	13.0 E
HI	20.0 C	119.6 B	28.4 B	21.9 C
LF	15.9 D	113.3 C	25.6 C	16.9 D

Stands with black woodpecker territories (BT), with white-backed woodpecker territories (WT), both or none, the different woodlands, and stand types (see Table 1: RLF, stands of regular large final crop trees; RM, stands of regular medium sized crop trees; RY, stands of regular young trees; HI, heterogeneous and irregular stands; LF, low forest stands) are compared. Within each comparison, different letters represent significative mean differences ($p < 0.05$).

all cases in which a territory is included in only one big stand (3 white-backed woodpecker territories and 4 black woodpecker territories), this is a RLF stand.

No significant differences were found between the site quality of the stands used by each species with those not used. Therefore, woodpeckers do not appear to choose stands for their site quality, but rather for the physiognomic characteristics of the forest which is best reflected in the stand classification (see Table 1 and 4). This supports the option for only harvesting stands with high site quality, and conserving the poorer quality sites with well-preserved mature forest (RLF).

Stand size

One of the typical questions that arises from the management of these forests concerns the minimum stand size that must be left as mature forest for these species to establish their territory. To answer this question, a study was conducted on the size differences between RLF stands where territories were present and those where they were not. Figure 1 illustrates that the stands where territories for both species were present were considerably larger than those where there were not.

The RLF stands in which the black woodpecker appears have an average size of 24 ha, while those of the white-backed woodpecker average 19 ha. The

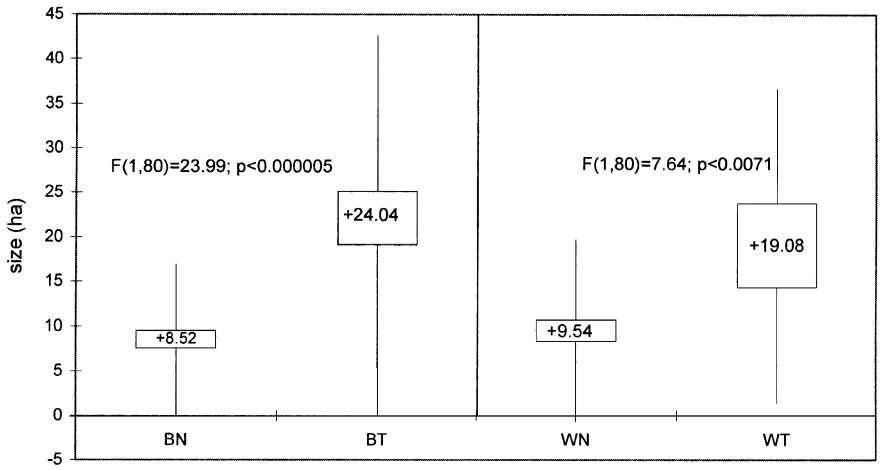

Figure 1. Analysis of variance on the regular large final crop trees (RLF) forest stands size according to their occupation for each woodpecker species: BN, stands where the black woodpecker territories are studied; WN, stands where the white-backed woodpecker does not appear; WT, stands where the white-backed woodpecker territories are situated. The rectangles represent the standard error and the lines the standard.

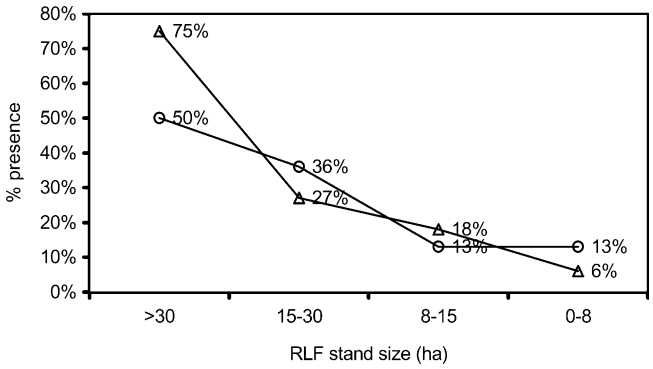

Figure 2. Percentage of RLF stands of different sizes included in territories of black woodpecker (triangles) and white backed woodpecker (circles).

actual surfaces required are probably somewhat greater, since some territories occupy more than one mature stand. In fact, most RLF stands with an area exceeding 30 ha (8 stands) are included in a territory, except three stands in which recent cutting was carried out. In Figure 2 can be seen the percentages of the different sizes of RLF stands that are included in the territories of each species. The total percentage for each species is higher that 100 because one territory usually extend over several stands. The occupation percentage in large stands is much higher than that for small stands.

Forest physiognomy

Although the stand types reveal considerable differences with regard to habitat selection by *Picidae*, it is still basically a subjective classification that depends on the criterion of the forest engineer responsible for the management plan. For this reason, and in order to assess the classification more objectively, an analysis of the quantitative variables was performed using variance analysis (ANOVA), LSD means comparison and principal component analysis (PCA).

There was a considerable difference between stands where the two species shared territories and the other stands (see Table 4). These stands had the tallest, oldest and largest trees, and also the largest basal area. Stands with a territory of only one of both species have intermediate values, and those with no territories have the lowest values. The white-backed woodpecker clearly prefers forests with a larger average tree diameter. However, when both woodpeckers do not occur in the same area, it selects stands of a lower height than those chosen by the black woodpecker.

The first PCA axis represents 72.6% of the total variance, while the second axis represents 12.8% (Figure 3a). On the same axes, Figure 3b shows the larger RLF stand of each territory for the black and white-backed woodpecker. It can be noted that the first axis is a good predictor for the presence or absence of each species. Their territories were linked to high values of the first axis, which corresponds to high values of the four morphometric variables used. The second axis separates the four variables, but there is not a clear relationship with territories and it is much less reliable.

Dead wood

When stands of the three woodlands of Quinto Real were used, no significant differences were found for total dead wood (number of trunks per ha) between stands used by each species or those that were not used, probably because many stands with considerable amounts of dead wood were not used by neither of the two species. Nevertheless, there were notable differences in the amount of thin dead wood (from 10 to 20 cm), i.e., the type of dead wood most abundant and most representative (Table 5).

Comparing only stands from quarters that had comparatively little dead wood, significant differences were found among stands where the white-backed woodpecker appeared, particularly for the 20–30 cm range ($p < 0.05$). This species did not choose stands with more dead wood in quarters where it was abundant, but in those quarters with little dead wood, it did a positive selection for stands with more dead wood.

For the dead wood in RLF, considerable differences might be identified between stands where the white-backed woodpecker was found and stands where it was absent for the two largest diameter classes of dead wood

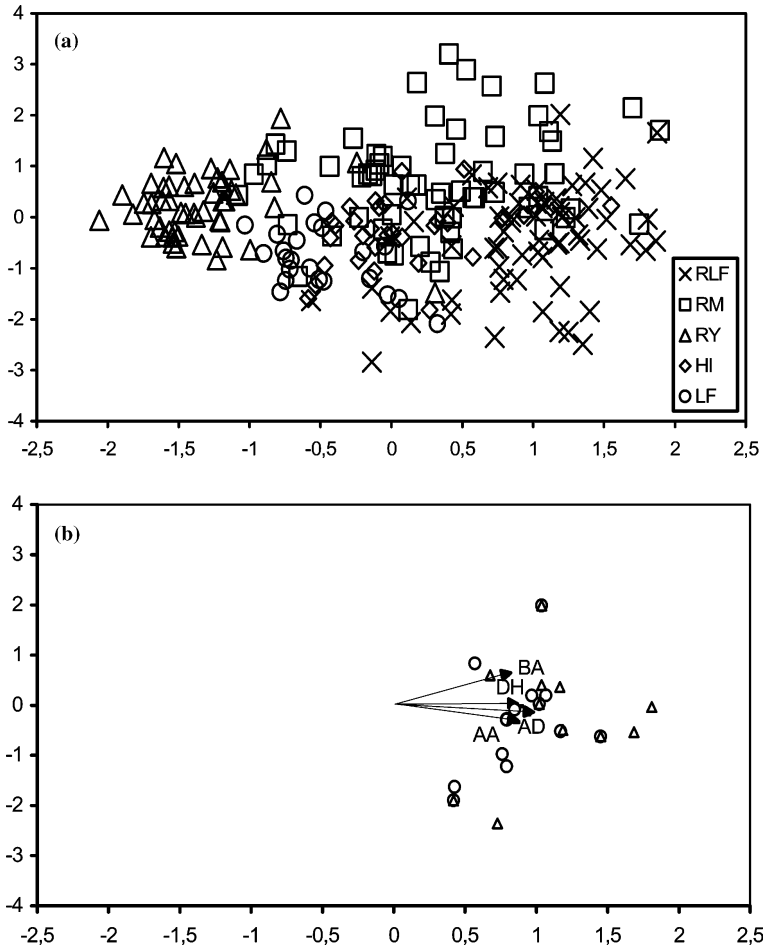

Figure 3. Principal components analysis of the stands described by the four variables that describe the forest structure. The first two axis do account for the 85% of the variance. (a) scatter diagram of all the stands; symbols indicate the stand classification according to Table 1. RLF, stands of regular large final crop trees; RM, stands of regular medium sized crop trees; RY, stands of regular young trees; HI, heterogeneous and irregular stands; LF, low forest stands. (b) scatter diagram of the larger RLF stand of each woodpecker territory on the same axis that (a). Circles represent the black woodpecker territories and triangles the white backed woodpecker territories. Also the descriptors of the four variables that describe the forest structure are represented. BA, basal area; DH, dominant height; AD, average diameter; AA, average age.

(20–30 cm and >30 cm; $p < 0.001$). This implies that the species clearly chooses those RLF that contain a larger amount of dead wood. This relationship remains significant comparing the differences between large-size RLF stands (>15 ha) whether the white-backed woodpecker is present or not. For the black woodpecker no differences were found for all the comparisons.

Table 5. Standing dead wood on the seven quarters of Quinto Real Woodlands: three in Quinto Real (Q1,Q2, Q3), two in Erreguerena (E1, E2) and two in Legua Acotada (L1, L2).

Quarters	Standing dead trees			
	Trunk diameter			
	10–20 cm	20–30 cm	> 30 cm	DBA
Q1	22.2 A	5.4 AB	2.0 A	0.915 A
Q2	17.4 A	5.7 AB	1.1 A	0.728 AB
Q3	12.0 B	4.6 AB	1.6 A	0.645 AB
E1	7.0 B	4.5 AB	0.4 A	0.394 B
E2	6.4 B	6.9 A	1.7 A	0.666 AB
L1	22.7 A	3.5 AB	0.7 A	0.662 AB
L2	4.0 B	1.2 B	0.6 A	0.208 B

Trunk number per ha is given for each of the three diameter classes and dead trees basal area (DBA) is given in m^2/ha. Within each column, different letters indicate significant differences ($p < 0.05$).

Discussion

Although the overall densities of the two woodpecker species remain rather stable for each of the woodlands of Quinto Real, according to the 1993 census (Fernández and Azkona 1996) and the one obtained in 2001, it appears that the white-backed woodpecker is declining in Erreguerena, and the black woodpecker is declining in Legua Acotada and increasing in Erreguerena. These differences are probably due to forestry management. Nevertheless, the Quinto Real populations have increased, which seems to indicate that management has been more appropriate than in Erreguerena and Legua Acotada. It does not seem that this difference can be explained by other ecological variables, because topography, climate, and other non-anthropic factors are quite similar.

Over the years both species remained faithful to their breeding territories (as also observed by McClelland and McClelland 1999). By comparing both censuses (1993–2001), it appears that there have been some shifts of territories, possibly due to forestry activities. A possible explanation could be that changes on the forest structure due to felling in a woodpecker territory, (a RLF stand is converted on a RY stand) may cause a territorial movement towards another place with more mature forest, thus 'pushing' adjacent territories.

One of the most obvious conclusions is that the most suitable habitat for both species is the mature forest stands (RLF). These are also referred to in the Natural Resources Management Plan (Schwendtner and Larrañaga 2001) as stands where final cutting is most likely to be carried out because these sites have the largest amount of timber trees for felling. If the exploitation of these woodlands by town councils is intensified, these stands will soon become extremely scarce.

A negative selection is observed, in both species, against heterogeneous and irregular stands. The same occurs within the stands in which other species

rather than beech are dominant (*Larix*, *Pinus*, *Quercus*). Although the black woodpecker occasionally feeds in these forests, the white-backed woodpecker has been found exclusively in monospecific beech forests.

The dominant height (26 m), age (149 years), mean diameter (34 cm) and basal area (27 m^2/ha) of stands where both the black and white-backed woodpecker territories coincide may help to determine the characteristics that the stands left for conservation should have (5% of the total). A sufficient amount of this type of stand should be left in the rest of the woodlands to ensure that the population of these species do not decrease.

It has been confirmed that the size of the RLF stand is another decisive factor for both species in establishing breeding territories, with minimum sizes close to 20–30 ha. As these are territorial birds, it does not appear to be a good idea to leave all the RLF stands grouped in one area. It seems much more appropriate to keep sufficiently large (>30 ha) RLF patches separated from one other (the number of patches depends on the desired size of the population). Moreover, given that there is no correlation between the site quality and the distribution of territories, it is advisable to concentrate exploitation in the best sites with short felling cycles. The worst sites should be left unexploited in order to fulfill the above objectives.

The amount of dead wood does not appear to be the main factor for choosing breeding territories for these birds at the scale of the whole study area, probably because it is very abundant in most of the area and therefore it is not a limiting factor. In fact, when the analysis is concentrated in the areas where dead wood is scarcer, this variables becomes an important factor for the distribution of the white-backed woodpecker territories, but the black woodpecker territories distribution do not seem to be affected by this variable. This can be explained by the diet of the black woodpecker, which feeds mainly on ants, and is not so dependent on dead wood.

The white-backed woodpecker territories distribution shows a relationship with the amount of thicker standing dead wood in the quarters where total dead wood is less abundant. Also the amount of dead wood seems important when comparing the territories occupancy frequencies between all RLF stands and also only with large RLF stands. But not all dead wood classes are of the same importance: thick standing dead wood seems to be more important than other classes of dead wood. This reinforce the importance of well conserved, large enough RLF stands, also with sufficient amount of standing thick dead trees, that could be increased by ringing some trees if necessary. It is more important in the places where the surroundings have less dead wood. There are other authors that have also found important the amount of dead wood for the woodpeckers, in particular with the specialist species (Angelstam et al. 2003; Butler et al. 2004).

Although the number of felling activities is insufficient to analyse their effect from a statistical point of view, their effects on the territories of both species seem to be very clear. When a RLF stand included in a 1993 territory disappeared, the territory has ‘moved’ to include another RLF stand in it. In this

study, the movement of territories have not been analysed, and we do not know if the new territories (or even the old ones) are done by the same individuals or different ones. As example, the black woodpecker territory that has disappeared in Legua Acotada, correspond to a place where the RLF stand included in it has been fallen down, and no mature stand can be found nearby.

At the moment in Legua Acotada it seems unlikely that the population of both species can be increased to levels similar to those in Quinto Real unless management is changed, for example by using smaller stand sizes and leaving the small number of mature RLF stands (there were 3 in 1993, but one has already been harvested). There is a territory of each species in each of these stands, but the nearby forests are regular young stands (RY) or final cuttings that are extremely homogenous and have been exhaustively 'cleaned out'. As a result, they are of no use to the *picidae*. If the RLF stands that remain are cut down, the territories in them will surely disappear.

Nevertheless, the situation in Erreguerena is slightly more encouraging. There are sufficiently large RLF stands in this area. Although it appears that several white-backed woodpecker territories have disappeared due to recent cuttings, they may have established in other RLF stands that were unoccupied. Black woodpecker seems to be attracted by these felling activities, possibly due to an increase of felled dead wood and therefore an increase of the amount of ants. Appropriate management would mean cutting the unoccupied stands in order not to disturb existing pairs. As the territories may vary in location, it is necessary to conduct yearly censuses in order to determine the situation before planning felling activities.

The patchwork situation in Quinto Real – stands that are relatively small, with a relatively high abundance of large enough RLF stands sufficiently separated ones from the others – has allowed the creation of a large number of breeding territories. Nevertheless, it is advisable to exploit only the stands that remain between territories and leave those that currently contain breeding territories.

Another general recommendation from the results is to leave enough dead wood in all stands and to leave dead trees standing because this is where the white-backed woodpecker mainly feeds. Girdling can be carried out instead of harvesting in some cases, since this technique leaves standing dead wood. Some management plans which aimed at protecting yew trees (*Taxus baccata*) by girdling the beech trees that overshadow them, may be also beneficial to specialist species (see Carlson 2000). White-backed woodpeckers are also beneficial for the health of the beech forest as it eats a lot of the forest plagues, and keeps them under control (Butler and Schlaepfer 2003).

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