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Authors: Bocca, Massimo, Carisio, Loredana, and Rolando, Antonio

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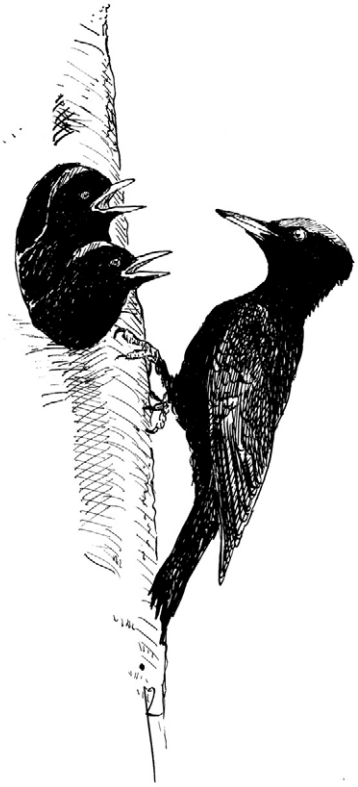
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Habitat use, home ranges and census techniques in the Black Woodpecker *Dryocopus martius* in the Alps

Massimo Bocca[1], Loredana Carisio[2] & Antonio Rolando[2,*]



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We focused upon habitat use and home range size variation in an alpine population of the Black Woodpecker *Dryocopus martius*. Habitat selection analyses showed that the dominant local forest type, i.e. Mountain Pine *Pinus mugo uncinata*, was significantly avoided. Scots Pine *Pinus sylvestris* stands were positively selected, likely because of the abundance of ants; Beech *Fagus sylvatica* was chosen for nesting and roosting. A high level of flexibility in ranging behaviour and habitat selection, with remarkable among- and within-individual variability, was recorded. We assessed the reliability of census techniques by comparing results obtained by radio-telemetry and territory mapping, which showed that territory mapping failed to identify all pairs detected through radio-tracking. Several behavioural and ecological traits may bias count results irrespective of the methods used. Mapping methods are particularly ineffective because the Black Woodpecker is weakly territorial: in our study area home range overlap was rather high and no territorial defence was detected. Based on these results, the potential of the Black Woodpecker as ecological indicator is questioned.

Key words: Black Woodpecker, censuses, ecological indicators, habitat selection, mapping methods, Mountain Pine, radio-tracking

[1]Parco Naturale Mont Avic, località Fabbrica 164, 11020 Champdepraz (Aosta), Italy; [2]Dipartimento di Biologia Animale e dell'Uomo, Università di Torino, via Accademia Albertina 13, 10123 Torino, Italy; *corresponding author (antonio.rolando@unito.it)

INTRODUCTION

Safeguarding forest biodiversity is an important branch of conservation biology, especially in Europe, where quality of the residual post-glacial forests has been severely reduced by anthropogenic activities (Thirgood 1989, McNeely 1994). Measuring forest biological diversity and determining appropriate policies of sustainable forest management are first steps in conservation efforts. Woodpeckers may be considered in this framework because they have already been proposed as indicators for forest biodiversity (Angelstam & Mikusiński 1994, Mikusiński & Angelstam 1998). To be an effective indicator species, patterns of distribution and abundance must reflect those of other taxa. This is the case, for instance, with the Lesser Spotted Woodpecker *Picoides minor* (Jansson 1998). In general, woodpeckers are adapted to habitat structures of old forests, and these very same structures (large and old trees, dead wood etc.) are likely important for a lot of other species. In Europe, this may be true for the Black Woodpecker *Dryocopus martius*, because it is the only woodpecker which creates breeding holes which other large hole nesters may use as well

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Figure 1. A typical Mountain Pine stand with Alpen Rose underbrush in the foreground. Trunks with low-growing branches on the right.

(Johnsson *et al.* 1993, Nilsson 1997). Although this species has never been considered as an indicator species *per se*, it is regarded, together with other woodpecker species, as a part of an indicator system for avian diversity (Mikusiński *et al.* 2001).

The Black Woodpecker usually favours tall and large trunks of many coniferous and broad-leaved trees forming extensive unbroken forests (Glutz & Bauer 1980, Cramp 1985). Habitat use is possibly related to its peculiar food requirements, especially carpenter ants (Formicidae) (Cuisin 1988, Ceugniet 1989, Pechacek & Krištin 1993, Rolstad & Rolstad 2000). The Black Woodpecker is considered a territorial species (Cuisin 1988), but it is also known that territorial boundaries are not clearly delineated (Glutz von Blotzheim & Bauer 1980) and that defence is concentrated at key sites like nest cavities (Cramp 1985).

In the light of the above, it could be affirmed that the Black Woodpecker is an ecologically relevant forest species which may be useful as part of an indicator system. However, to use a species as an indicator, local information on habitat use, home ranges, predators, energetics and food supply is needed because biological parameters may differ between areas. The ecology of the Black Woodpecker in the Alps, in particular, is poorly known.

The main aims of this radio-telemetry study were: i) to reveal habitat selection patterns, ii) to investigate home range variation over space and time, and iii) to assess the reliability of census methods used to count individuals. Accordingly, we studied habitat selection and home range spacing of a population of Black Woodpeckers inhabiting an Italian Alpine protected area characterized by extensive Mountain Pine woods, and assessed the reliability of census techniques by comparing results obtained by radio-telemetry and territory mapping. Finally, our findings are used to discuss the indicator potential of this species.

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METHODS

Study area

The research was carried out from February 2000 to August 2003 in the Mont Avic Natural Park (Chalamy valley, in Aosta Valley) in the northwestern Italian Alps. The area (about 20 km^2) was largely covered by coniferous forests ranging from 1100 to 2000 m a.s.l. The Mountain Pine *Pinus mugo uncinata* (Aeschimann *et al.* 2004) and, to a lesser extent, Scots Pine *P. sylvestris* were the dominant trees, occurring in mostly pure coniferous forests (47.3 and 26.1% of the forest area, respectively). The Mountain Pine, in particular, is not widespread in Italy and the forest of Mont Avic Natural Park (classified among the 'seed national forests') is the largest in the country (over 1100 ha). It creates dense forests with thick Alpen Rose *Rhododendron ferrugineum* and Blueberry *Vaccinium myrtillus* underbrush. Trees are characterized by straight, upright trunk and pyramid-shaped foliage from top to bottom, with low-growing branches (Fig. 1). Dwarfed and prostrate Mountain Pines were confined to higher altitudes (above 2000 m) and to a few deep gorges subject to avalanches. Another common conifer was Larch *Larix decidua* (pure Larch formations 1.3%; Larch-Mountain Pine formations 9.9%). Alpen Rose was particularly dense in Mountain Pine and Larch-Mountain Pine forests. Common broad-leaved trees were Beech (4.7%) and others like Chestnut *Castanea sativa*, Downy Oak *Quercus pubescens*, Birch *Betula pendula* and Aspen *Populus tremula* (together 10.8%). All forest types were spontaneous. Deciduous trees were dominant at low altitudes (below 1100 m; locally up to 1500 m), whereas coniferous trees mostly occurred at middle and high altitudes (1100–2000 m).

Snow depths, as a whole, were moderate because the Aosta Valley is a xeric area. Moreover, the ground of Mountain Pine stands below 1700–1800 m was very often snow-free because of the high density foliage, and snow did not persist for a long time in Scots Pine sectors because they were usually south-oriented. Vegetation types and their distribution in the study area are shown in Fig. 2.

Radio-tracking

Woodpeckers were trapped in winter with long-handled dip nets set at night in front of the roosting hole. Most roosting cavities were already known because of previous studies (see below). Birds were banded and fitted with radio transmitters (4 g, i.e. less than 2% of the bird's body mass), which were glued and tied to the base of one of the two central tail feathers (Kenward 1978, 2001). Individuals were tracked with a portable receiver and a hand-held antenna, and locations were taken at intervals not shorter than 30 min while approaching the birds or by triangulation. Data were collected on 2–4 days each week until the loss of the tag for the late summer moult (on average 7.2 ± 0.39 months). A 100 x 100 m grid map was used.

During tracking specific efforts were made to detect territorial disputes. The so-called 'static interactions' between individuals were studied by calculating overlaps of home ranges of birds radio-tracked during the same period. To meet the assumption of independence between individuals, only the male's range of breeding pair was considered.

Counts

Summer detectability of the Black Woodpecker is rather poor, potentially leading to underestimates of numbers present (Majewski & Rolstad 1993). In our study area Black Woodpeckers were easily and regularly observed only from mid-February to April. Hence, pairs were counted by territory mapping from 1 March to 30 April 2002. We used this census method because it is a generally accepted way to identify areas or habitats of importance to species (Bibby *et al.* 2000). Moreover, territory distributions could be efficaciously matched with home range distributions obtained from radio tracking. Birds were recorded during 90 min-per-day visits. We discarded the play-back option (Tjernberg *et al.* 1993, Fernandez & Azkona 1996) because when crowded individuals (as in our case) are attracted by taped calls, there is the risk of obtaining erroneous information about their actual distribution.

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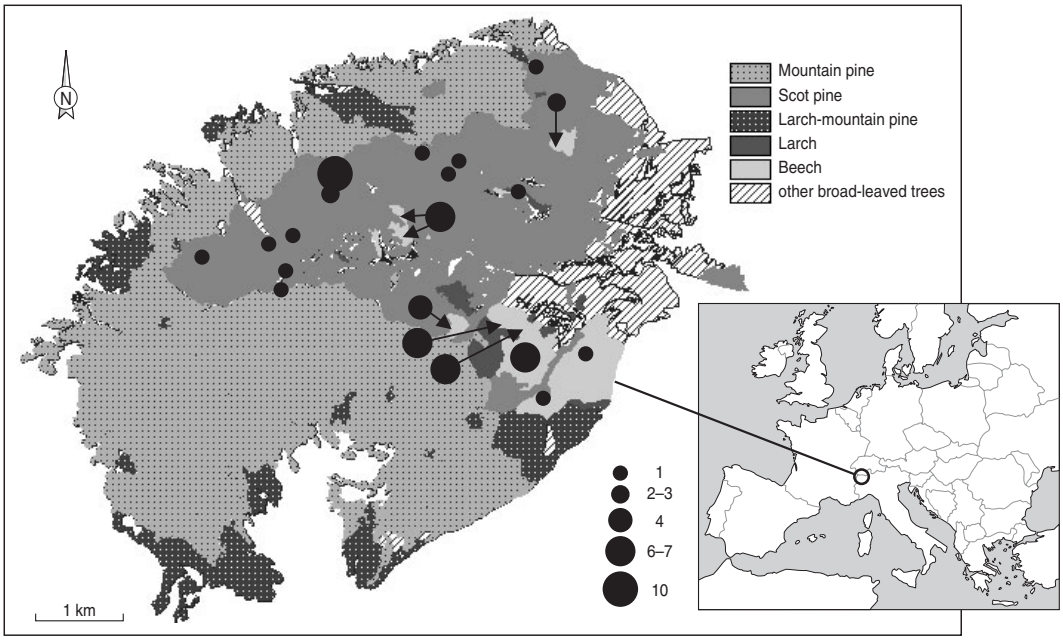


Figure 2. The six major forest types identified by means of tree species prevalence: Mountain Pine, mixed Larch-Mountain Pine (both with underbrush), Scots Pine, Larch, Beech, and other broad-leaved trees (Downy Oak, Chestnut, Birch, Aspen). Black dots indicate the number of trees with cavities/site. All trees used in Beech stands were Beeches, whereas three of those used in Scots Pine stands were not Scots Pines. Deciduous trees mostly occurred at low altitudes (below 1100 m, on the right of the map), whereas coniferous trees were dominant at higher altitudes (1100–2000 m, on the left). Note the widespread distribution of the Mountain Pine.

The study area had been systematically surveyed for Black Woodpecker holes in all forest types in previous years. During the present study a few additional holes were found. The status of each cavity (i.e. nest, roost, not used) was ascertained routinely.

Statistical analyses

Home range

We used Ranges VI software in the analysis of radio-tracking data (Kenward *et al.* 2002). We computed range size and overlap by the Kernel method (KER 95% of fixes for home ranges, 50% for core areas), given that the presence of disjunct home ranges and/or of multiple core-areas may be efficaciously pointed out by kernel estimator. The presence of stable home ranges was checked by incremental area plots, by sequential addition of fixes. In this case we used a minimum convex polygon for all locations (MCP 100%) since with KER the animal's range size estimate can diminish as locations are added sequentially (Kenward 2001). To avoid inadequate sampling, only stable ranges with more than 50 fixes collected during at least 4 different days in 2 consecutive months were analyzed to calculate home range size.

Static interactions and territoriality were examined using range overlap analyses, the Ranges VI program producing a matrix of the percentage overlap of range A on B and B on A for any dyad of ranges. A mean overlap value was calculated by using all overlap percentages, with a sample size of $2k$ where k is the number of dyads.

Coefficients of variation (CVs) were computed to estimate among- and within-individual variability in home range size. CVs were calculated for

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each re-captured individual, as a measure of within-individual variation, and for the overall radio-marked sample (in this case only the first recorded home range, following first capture, was considered), as a measure of among-individual variation. The ratio of the CV for the overall sample to the mean CV of individuals gives a measure of home range size individuality, being higher than 1 when among-individual variation is greater than within-individual variation.

Habitat selection

Up-to-date digital maps of the study area were placed at our disposal by the Mont Avic Natural Park. Land cover GIS data digitised from 1:10 000 aerial photographs were used to detect forest types (Morra di Cella & Cremonese 2004). Six major types were identified based upon tree species prevalence: Mountain Pine, mixed Larch-Mountain Pine (both with underbrush, mostly Alpen Rose), Scots Pine, Larch, Beech, and other broad-leaved trees. Structural features of the vegetation were obtained from field measurements within circular sampling random plots (radius of 10 m). Structural variables were: tree density, i.e. the number of trees/ha with trunk diameter (measured at breast height) exceeding 12.5 cm, dominant tree height, i.e. the mean height of the 100 tallest trees in the plot and canopy cover, i.e. the canopy projection on the ground. Raster maps (10 x 10 m pixels) were treated by Arc View 8 to be imported by the Ranges VI software for habitat selection analyses.

Habitat availability was measured within the whole study area identified by estimating a KER100% boundary round all the locations used in all the ranges. Preliminary tests indicated that this level of scale gave more information than that regarding individual home range. A 50 m radius buffer round every individual location was considered, and habitat class proportions were calculated within the area.

To examine whether individuals differed from random use of habitats, we employed χ^2-tests of differences between observed and expected number of locations. Bonferroni confidence intervals were fitted to test whether individuals used habitats by availability (Neu *et al.* 1974, Byers *et al.* 1984). The sign test was used to test the hypothesis that positive and negative selections for each habitat category were sampled from a population in which the two kinds of selections were present in equal proportions (Sokal & Rohlf 1995). In this context, 'preferred' is said of a habitat type that is used significantly more than expected from its availability. We also used the terms 'positive selection', 'negative selection' (habitat type that is used more or less than expected), and 'no selection' (habitat used proportionally to its availability). A main problem with Bonferroni confidence intervals is that locations are treated as independent locations and that the 'unit-sum constraint' is ignored (Aebischer *et al.* 1993, Kenward 2001). Hence, to address these problems, we also used compositional analysis, by which the use of each habitat is expressed relative to each of the other habitats. We first verified overall significant departure from random use of habitat with Wilk's Lambda. Then habitat types were ranked according to relative use with regard to each bird (individual ranking) and the overall sample (general ranking). In the case of general ranking, Student's *t* was used to test whether the preference differed significantly from zero for each habitat pair (Aebischer *et al.* 1993).

To compare Bonferroni and compositional analyses, we checked whether the habitats which were classified as positively selected by the former method were classed as high-ranking by the latter.

RESULTS

A total of 18 woodpeckers were captured (11 males and 7 females); 10 individuals were re-captured and radio-tracked for more than one year (6 were recaptured once, 4 twice). We treated locations of the same bird in different years as independent samples. Admittedly, individual site fidelity was a source of pseudo-replication. To overcome this problem, in keeping with Nikula *et al.* (2004), we checked whether locations of each

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re-captured individual overlapped in consecutive years: if overlap percentage was higher than 50%, only the home range with the highest number of fixes was used.

Home range

Individual analyses

On average, core areas covered about a third of whole home ranges (92.4 ± 10.9 ha vs. 316.3 ± 32.8 ha, $n = 27$). Among-individuals variation in home range size was rather high, standard deviation being greater than 50% of the mean, both for home ranges and core areas (CVs = 0.527 and 0.595, respectively). The ratio of the CV for the overall sample to the mean CV of individuals was 1.48 for home ranges and 1.39 for core areas.

Home ranges during the breeding period (15 March – 30 June) were smaller than during the non-breeding period (median values 232.8 and 298.0 ha, respectively, $n = 20$, $P = 0.03$, Wilcoxon matched pair test). In most instances (17 out of 20) breeding and non-breeding home ranges greatly overlapped, in two instances breeding ranges were totally encompassed in non-breeding, and in another they were separated (mean seasonal auto-overlap 70.4 ± 5.3%, $n = 20$). Breeding core areas were not significantly smaller than non-breeding core areas ($P = 0.33$, Wilcoxon matched pair test). In most instances (14 out of 20) breeding and non-breeding core areas overlapped to a high degree, in three instances breeding core areas were totally encompassed in non-breeding core areas and in three they were different (mean seasonal auto-overlap 53.2 ± 7.4%, $n = 20$).

Seasonal home range (but not core area) size significantly varied from year to year (Kruskal-Wallis test, breeding ranges: $H_{3,23} = 10.33$, $P = 0.02$; non-breeding ranges: $H_{3,26} = 10.69$, $P = 0.01$), being larger in 2003 and smaller in 2001. The structure of ranges was also variable: disjunct home ranges (in 3 birds the feeding area was about 3.7 km from the roosting site) and multiple core areas were found in several instances (9 and 5, respectively, out of 27; Fig. 3).

Analysis of all-year ranges of the recaptured individuals showed high site-fidelity. Mean auto-overlap between successive years was 71.0 ± 3.5% for home ranges and 61.4 ± 4.5% for core areas.

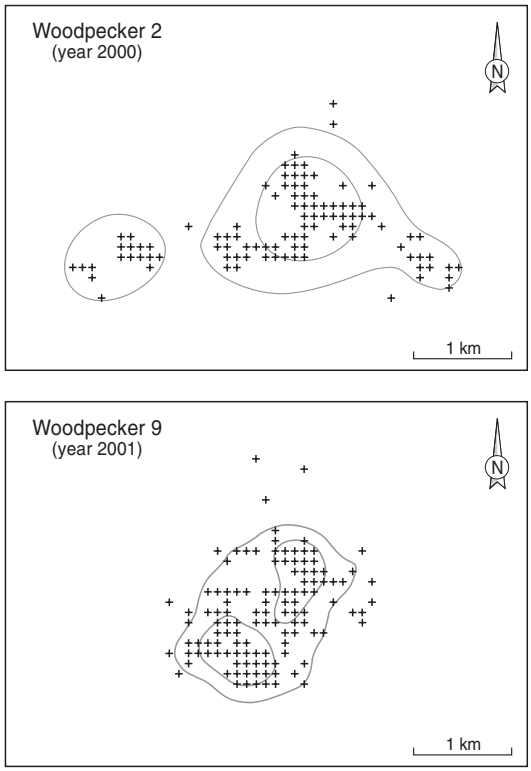


Figure 3. Variability in the structure of home ranges: a case of disjunct home range (woodpecker 2, above) and one of home range with two core areas (woodpecker 9, bottom). Outer lines: 95% kernel contours ; inner: 50% kernel contours. Fixes are indicated.

Social interactions

Overlap of home ranges was much broader than overlap of core areas (on average 27.1% vs. 8.3%, breeding period; 35.7 vs. 11.2, non-breeding period, Table 1). Non-breeding overlap was usually not significantly broader than breeding overlap. Overlap values significantly varied among years, whatever the period considered (Kruskal-Wallis tests). No evident territorial interaction was detected.

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Habitat selection

Forest types

Bonferroni confidence intervals analysis pointed out a significant avoidance of Mountain Pine and mixed-Larch-Mountain Pine stands and a significant preference for Scots Pine stands. In Beech the number of positive selections was not significantly higher than the number of negative ones. Birds bred and roosted in Beech, but fed in Scots Pine habitat (Table 2). Although this was the general pattern, individual choices were not necessarily consistent over time: 23.1% of birds (out of 26) completely modified their preference from breeding to non-breeding and 15% (out of 20, i.e. 10 birds for each period) from year to year.

Table 1. Static interactions, showing the degree of overlap between individuals radio-tracked during the same period. Mean overlap values (percentages) are given. To meet the assumption of independence between individuals, of each breeding pair only the male's range was taken into account. See methods for computation details.

	n		Overlap			
			KER50%		KER95%	
Year	Dyads	Birds	Breeding	Non-breeding	Breeding	Non-breeding
2000	12	4	0.9 ± 0.6	1.6 ± 1.2	17.5 ± 4.4	13.6 ± 5.1
2001	20	5	1.6 ± 1.1	5.1 ± 2.8	14.5 ± 4.9	16.9 ± 4.0
2002	12	4	12.7 ± 6.3	13.0 ± 4.2	43.0 ± 5.5	45.6 ± 5.1
2003	42	7	12.3 ± 2.8	16.4 ± 3.1	31.3 ± 3.9	48.2 ± 2.7
Overall	86	20	8.3 ± 1.7	11.2 ± 12.8	27.1 ± 2.6	35.7 ± 2.5

Table 2. Selection of forest types pointed out through Bonferroni confidence interval and Compositional analyses. The number of home ranges considered is 29 for the breeding period and 26 for the non-breeding period.

	Bonferroni								Compositional															
	Breeding				Non-breeding				Breeding								Non-breeding							
Forest types	+	–	ns	*P*	+	–	ns	*P*	0	1	2	3	4	5	R	*t*	0	1	2	3	4	5	R	*t*
Scots Pine	14	4	11	*	19	2	5	*	0	1	7	5	6	10	4	2	0	0	3	5	4	14	5	4
Larch	4	11	14		1	13	12	*	1	2	8	6	7	5	2	2	0	4	6	9	4	3	2	2
Larch-Mountain Pine	0	28	1	*	0	26	0	*	15	13	1	0	0	0	0	-	13	10	3	0	0	0	0	-
Mountain Pine	0	28	1	*	2	23	1	*	13	10	1	2	3	0	1	1	11	7	3	2	2	1	1	1
Beech	14	7	8		9	7	10		0	3	2	4	8	12	5	3	1	3	3	3	9	7	4	3
other deciduous trees	2	9	18		3	10	13		0	0	10	12	5	2	3	2	1	2	8	7	7	1	3	2

Bonferroni analysis: number of positive (+), negative (–) or no (ns) selections; *P* = results of the sign test showing whether the positive and negative selections for each habitat category differ significantly from a sample in which the two kinds of selection are present in equal proportions (* = $P < 0.05$).

Compositional analysis: number of individual classifications of the forest types according to six ranks (5 indicates the top-ranking type, 0 the bottom-ranking one). R = the general rank of each habitat type. Student's *t* was used to test whether the preference differs significantly from zero ($P < 0.05$) for each habitat pair. This implies that every habitat has been compared with any other habitat ranked behind it. In the breeding period, for instance, the Scots Pine (rank 4) has been compared with the other deciduous trees (rank 3), the Larch (rank 2), the Mountain Pine (rank 1) and the Larch-Mountain Pine (rank 0). In the *t* column the number of habitat pairs for which preferences differ significantly from zero is given. *T*-test significant differences always regarded pairs of habitats at the extremes of the ranking order; for instance, in the breeding period the two significant *t*-tests of the Scots Pine (rank 4) regarded comparisons with the Larch-Mountain Pine (rank 0) and the Mountain Pine (rank 1).

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Table 3. Selection of forest structure traits (tree height, tree density and canopy cover) pointed out by Bonferroni confidence interval and Compositional analyses. Symbols and number of home ranges considered as in Table 2.

	Bonferroni								Compositional																
	Breeding				Non-breeding				Breeding									Non-breeding								
Variables	+	–	ns	*P*	+	–	ns	*P*	0	1	2	3	4	5	6	R	*t*	0	1	2	3	4	5	6	R	*t*
Tree height (m)																										
<10	0	27	2	*	0	26	0	*	26	3	0	0				0	-	22	3	1	0				0	-
10–15	2	12	15	*	1	17	8	*	2	14	13	0				1	1	2	16	7	1				1	1
15–20	14	2	13	*	22	1	3	*	0	8	10	11				3	2	0	1	10	15				3	3
>20	1	6	22		0	8	18	*	1	4	6	18				2	1	2	6	8	10				2	1
Tree density (n/ha)																										
<600	0	22	7	*	2	21	3	*	4	6	7	8	3	0	1	3	0	12	6	3	1	0	1	3	0	-
600–800	1	22	6	*	0	22	4	*	8	4	7	7	1	1	1	2	0	5	7	5	1	6	1	1	2	0
800–1000	6	2	21		7	4	15		0	0	0	0	7	19	3	6	5	0	0	1	5	7	9	4	6	4
1000–1200	8	17	4		7	8	11		3	3	1	7	6	3	6	4	1	0	1	3	6	5	5	6	5	3
1200–1400	13	8	8		9	8	9		2	2	3	2	4	1	15	5	4	6	1	1	3	2	6	7	4	2
1400–1600	0	19	10	*	0	14	12	*	3	10	5	4	3	2	2	0	-	2	5	8	6	4	1	0	1	0
>1600	0	17	12	*	2	10	14	*	9	4	6	1	5	3	1	1	0	1	6	5	4	2	3	5	3	1
Canopy cover (%)																										
<20	0	28	1	*	0	25	1	*	1	0	9	13	6	0	0	2	1	1	1	7	15	2	0	0	2	2
20–40	0	27	2	*	0	25	1	*	0	8	13	7	1	0	0	1	0	0	8	16	2	0	0	0	1	0
40–50	0	28	1	*	0	26	0	*	8	14	7	0	0	0	0	0	-	9	16	1	0	0	0	0	0	-
50–60	2	22	5	*	1	21	4	*	13	6	0	3	2	3	2	3	2	15	1	1	3	1	3	2	3	2
60–70	1	21	7	*	1	14	11	*	7	0	0	4	15	2	1	4	4	1	0	0	3	15	4	3	4	4
70–80	11	6	12		12	3	11	*	0	1	0	0	0	17	11	5	5	0	0	0	1	1	14	10	5	5
80–90	13	2	14	*	8	5	13		0	0	0	2	5	7	15	6	5	0	0	1	2	7	5	11	6	5

In compositional analysis, Mountain Pine and mixed Larch-Mountain Pine stands scored the highest number of low individual ranks (i.e. 0 and 1), whereas Beech and Scots Pine scored the highest number of high individual ranks (4 and 5); *t*-tests showed that there was a clear significant split between the four top ranking habitats (which were sometimes interchangeable in the ranking order) and the two bottom ranking habitats (Table 2). Bonferroni-preferred habitats mostly corresponded to the top-ranking habitats (29 out of 34 in both periods; Table 2).

Forest structure

Bonferroni confidence intervals indicated that forest stands characterized by short trees were significantly avoided, whereas those with taller trees were positively selected. Birds significantly avoided both low density and very high density stands. Low and medium canopy closure stands were also significantly avoided. This general picture emerged in the same way both in the breeding and in the non-breeding period, with only few exceptions (Table 3).

In spite of this habitat selection constancy over time at the population level, individual variability was considerable. On average, 41% of individuals totally changed their structural choices (e.g. from tall to short trees, from low to high density stands) from one period to the next, and 26.7% from year to year.

In compositional analysis, *t*-tests showed that in all analyses there was a clear split between the two (or three) top-ranking habitat types and the

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low-ranking types (Table 3). Correspondence between Bonferroni-preferred habitats and individual top-ranking types of compositional analysis was very good for canopy cover (25 out of 27 in the breeding period and 20 out of 22 in the non-breeding) and trees density (24 out of 28; 23 out of 27), slightly less for dominant tree height (10 out of 17; 15 out of 23).

Counts

Breeding pairs

Radio-telemetry and direct observations at the nests showed the presence of at least 9 nesting pairs and 3 single birds (Fig. 4A). Censuses succeeded to identify and locate only 4 pairs (i.e. A, C, D and F) and failed to find and discriminate pairs nesting at close distance. Three close nesting pairs (G, H, and J) remained undetected because a single, spurious, unresolved cluster of points was mapped, so that a single territory was consequently assumed (Fig. 4B). Conversely, two nesting pairs with a large core area spatially shared the same area with non-breeding individuals (B and E), whereas the presence of four pairs was erroneously assumed on the ground of two distinct clusters of points within the home range of each of two nesting pairs (Fig. 4B). All in all, censuses were not accurate and resulted in both under- and overestimates.

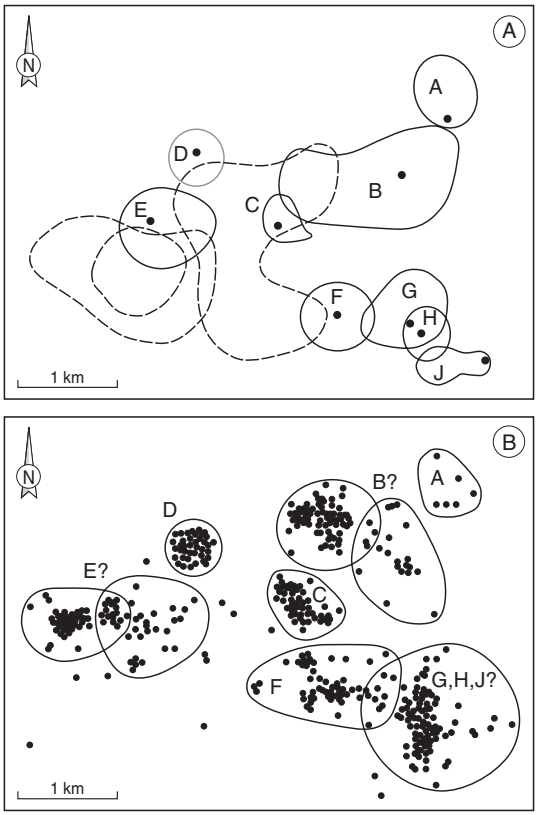


Figure 4. Comparisons of census techniques in 2002. (A) Distribution of pairs known from radio-tracking (kernel 50% contours of the breeding period are shown) and nest surveys. Contours indicate radio-tracked nesting individuals (solid line), radio-tracked single individuals (dashed line) and untagged nesting pairs (grey line), dots indicate nests. (B) Distribution inferred from territory mapping. Contours indicate presumed nesting territories; question marks denote territories that were not confirmed by radio-telemetry and nest surveys; dots indicate locations of birds recorded during territory mapping.

Cavities

Trees with cavities were not uniformly scattered over the study area; despite the broad expanse of Mountain Pine forests and the research effort we made, no cavity was found in sectors covered by this conifer (Fig. 2). Mostly Beeches and Scots Pines were used for nest building (respectively 62.1 and 32.7% of all nests found, $n = 58$). When tree availability was calculated from the proportion of the area covered, preference for the Beech was apparent ($\chi^2 = 86.03$, $P < 0.001$).

Bonferroni confidence intervals indicated that woodpeckers preferred Beech stands. As for forest structure, stands with high canopy closure (80–90%) and medium-high tree densities (1200–1400 trees/ha) were significantly and positively selected. These same categories were classified as top-ranking by compositional analysis. Surveys conducted from 1991 to 2004 pointed out that several nest and roost cavities were continuously used over time (the longest record: 8 successive years), often by the same birds (4 successive years).

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DISCUSSION

Three main results of the present research deserve to be discussed as regards the indicator potential of the Black Woodpecker for forest biodiversity and habitat management.

First, the classification of this woodpecker as specialist or generalist is ambivalent and should be used sparingly. According to Mikusiński *et al.* (2001), the Black Woodpecker can be considered a habitat generalist. At the same time, given its peculiar diet (Cuisin 1988, Ceugniet 1989, Pechacek & Krištin 1993, Rolstad & Rolstad 2000), it can be considered a specialist feeder. In our study area, for instance, woodpeckers are known to forage on ants of the genera *Camponotus* and *Formica* (unpubl. data). Ants are abundant and available in Scots Pine stands (pers. observ.), which were positively selected. In contrast, Mountain Pine sectors were significantly avoided, maybe because the presence of the thick underbrush hampered collection of food and trees (with dense foliage from top to bottom) were not suitable for excavating holes. It is worth mentioning that Mountain Pines in the Pyrenees, characterised by large straight trunks free of branches, are used as nesting trees (Ceugniet 1989). Beech was positively selected mostly for nesting and roosting. Forest stands with taller trees were positively selected, whereas those with low canopy closure were avoided. The conclusion is that our Black Woodpecker population seems rather flexible in the use of habitats, at the same time showing clear preferences for particular habitats, likely depending on feeding, nesting and roosting requirements. This is in keeping with other results which pointed out that the species is not absent from fragmented or managed forests, provided that tree composition and food supply are suitable (Tjernberg *et al.* 1993, Mikusiński 1997, Rolstad *et al.* 1998).

Second, individual habitat use and spatial behaviour are flexible as well. We pointed out high among- and within-individual variability in habitat selection and in home range size. The year-round home range size was comparable to home range size observed in Scandinavian forests, where sizes decreased with increasing proportion of young plantations in the landscape (Rolstad *et al.* 1998). Even the structure of home ranges was not constant because, in addition to the typical home range with a single core area, disjunct ranges with multiple core areas were also recorded. All in all, in spite of the consistent site-fidelity and individuality in the size of home range (as indicated from CV analyses), the overall degree of variability in spatial behaviour was rather high.

Third, widely accepted census techniques may give rise to unreliable results. We showed that censuses failed in identifying all the pairs inhabiting the area. This can be partly explained by the occurrence of several individuals at one site due to a concentration of trees suitable for nesting, which is not uncommon in this species (Lang & Rost 1990, Johnsson *et al.* 1993, Lange 1995, 1996). However, even in areas with a scattered distribution of woodpeckers, ecological and ethological traits of this species may contribute to invalidate census estimates. Both sexes share the same vocal repertoire and instrumental signals are often used for contact between partners. This may easily produce overestimates of breeding pairs; the occurrence of two interacting individuals is not necessarily a clue of the presence of two territories and, contrary to the rule, simultaneous registrations are not the key to reliable mapping. Analogously, the presence of two or more territories may be incorrectly scored when individuals with disjunct home ranges and/or multiple core areas are involved. However, the most striking hindrance to the use of mapping methods results from the limited territorial performances of this species. Cuisin (1988) reports that territories are fiercely defended and this seems to be consistent with the occurrence of regularly spaced territories in Sweden (Tjernberg *et al.*1993). However, it has also been stated that territories may overlap with those of neighbours without leading to disputes, and that boundaries are not clearly delineated (Cramp 1985). We did not find any cue of territoriality despite the potential or agonistic behaviour induced by the clumped distribution of some birds. Contrary to true territorial woodpeckers (Bachmann & Pasinelli 2002),

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home ranges of neighbouring birds overlapped to a high degree and core areas overlapped as well, albeit to a lesser extent. Home range overlap was not significantly higher in the non-breeding than in the breeding period, again suggesting that territoriality was weak. Accordingly, in the Black Woodpecker the basic assumption underlying territory mapping is violated. It must be underlined that even the results obtained from non-mapping techniques may be biased by some of the previously discussed ethological and ecological traits of this species (movements between portions or cores areas within the same home range, vocalisations produced by both sexes).

Our results suggest therefore caution in considering the Black Woodpecker as a potential ecological indicator, at least in the Alps. Indicator species are those species whose ecological requirements guarantee the existence of particular environmental conditions (Campbell & Lack 1985). A flexible species as the Black Woodpecker may adapt to a variety of conditions, and the existence of particular environmental conditions is therefore not guaranteed. Unreliability of standard census methods means that bird density cannot be properly assessed. Moreover, while most of the other woodpecker species suffer from intensive forest management (Angelstam & Mikusiński 1994), the Black Woodpecker is less sensitive to man-induced structural changes in forests (Tjernberg *et al.* 1993, Mikusiński 1997, Rolstad *et al.* 1998). Hence, we cast doubts upon the convenience of the Black Woodpecker *per se* to monitor ecosystem health, in keeping with doubts risen for several other vertebrates proposed as indicators (Simberloff 1997, Hilty & Merenlender 2000, Carignan & Villard 2002).

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SAMENVATTING

Beheer van bossen wordt in toenemende mate opgehangen aan indicatorsoorten, de veronderstelde vlaggenschepen van een compleet ecosysteem. In Europa worden daartoe verschillende spechtensoorten gerekend, waaronder Kleine Bonte Specht *Dendrocopos minor* en Zwarte Specht *Dryocopus martius*. Die laatste is de hofleverancier van grote boomholtes, vaak de enige broedgelegenheid voor tal van andere soorten in een verder ongeschikt bos. Het zijn bovendien echte voedselspecialisten (vooral bosmieren en hun broed) met een habitatkeus die daarmee samenhangt. Zwarte Spechten worden daarom vaak beschouwd als indicator voor de diversiteit van de avifauna. Niettemin kleven er aan Zwarte Spechten allerlei problemen, die een klakkeloze toepassing als indicatorsoort in de weg staan. Zo heeft de soort een groot activiteitsgebied en wordt zijn gedrag wisselend geïnterpreteerd. Voor de Alpen geldt bovendien dat zijn biologie slecht bekend is. Met het onderhavige radiotelemetrische onderzoek in de Aosta-vallei in de Noordwest-Italiaanse Alpen wordt getracht inzicht te krijgen in habitatkeus en terreingebruik. Daarnaast wordt de betrouwbaarheid van standaardbroedvogelkarteringen getoetst aan de hand van de uitkomsten van het telemetrische onderzoek.

Het studiegebied omvat zo'n 2000 ha, grotendeels bedekt met naaldbos op hoogtes van 1100–2000 m boven zeeniveau. De dominante boomsoorten zijn Bergden *Pinus mugo uncinata* en in mindere mate Grove Den *P. sylvestris*. Vooral Bergdennen komen voor in dichte

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opstanden met een weelderige ondergroei van Alpenroos *Rhododendron ferrugineum* en Blauwe Bosbos *Vaccinium myrtillus*. Loofbomen beperken zich goeddeels tot hoogtes lager dan 1100 m.

In totaal werden elf mannetjes en zeven vrouwtjes gevangen en van een zendertje voorzien. De kernactiviteiten van deze vogels vonden plaats in een gebied van gemiddeld 92 ha, maar het totale activiteitsgebied was ruim drie keer zo groot (316 ha). Er werden echter grote individuele verschillen gevonden. In de broedtijd (half maart – eind juni) waren de activiteitsgebieden kleiner dan daarbuiten (gemiddeld respectievelijk 233 en 298 ha), met een hoge mate van overlap tussen beide. De structuur van de activiteitsgebieden was variabel, waarbij sommige spechten hun foerageergebied tot op 3,7 km afstand van de slaapplaats hadden. Andere waren actief in verschillende ruimtelijk van elkaar gescheiden gebieden. Zwarte Spechten die opnieuw konden worden gevangen, vertoonden alle een hoge mate van plaatstrouw. Tussen de spechten was een behoorlijke overlap in activiteitsgebieden, zij het wat minder tussen de individuele kerngebieden en met een significante variatie van jaar op jaar.

Terreindelen begroeid met Bergden en gemengd bos van Bergden en Lariks werden grotendeels gemeden. Daarentegen waren Grove Den en Beuk favoriet, de eerste als foerageergebied, de tweede als nest- en slaapplaats. De spechten lieten dichte en zeer open opstanden links liggen, en concentreerden hun activiteiten in opgaand bos met een gesloten kronendek. Ook hier waren de individuele en temporele verschillen groot.

Een vergelijking tussen de uitkomsten van telemetrie, systematisch nesten zoeken en territoriumkartering laat zien dat de laatste methode ongeschikt is om een goed beeld te krijgen van verspreiding en talrijkheid van Zwarte Spechten. Van de negen bekende nesthoudende paren (en drie solitaire vogels) werden er volgens de territoriumkartering maar vier gevonden; paren die dicht in elkaars nabijheid broedden, werden niet als zodanig onderkend maar als één territorium opgevoerd. Omgekeerd, op basis van twee activiteitsclusters binnen hetzelfde activiteitsgebied werden abusievelijk twee territoria aangehouden (in plaats van één), terwijl solitaire vogels niet werden onderscheiden van paren omdat ze in dezelfde gebieden actief waren. Territoriumkarteringen leverden dus over- èn onderschattingen op, ingegeven door het beperkte voorkomen van nestbomen en door de ruimtelijk gescheiden nest- en foerageerplekken.

Dit onderzoek maakt duidelijk dat het gebruik van de Zwarte Specht als indicatorsoort met enige reserve moet worden toegepast. De soort is behoorlijk flexibel in zijn habitatgebruik, maar vertoont evenzeer duidelijke voorkeuren voor bepaalde nestbomen en foerageergebieden. Tegelijkertijd is de individuele variatie in habitatkeus en gedrag fors, ondanks een consistente plaatstrouw. Tot slot is de territoriumkartering volgens standaardpraktijken ongeschikt om een goed beeld van een populatie Zwarte Spechten te krijgen, nog versterkt door het feit dat beide seksen hetzelfde geluidenrepertoire hebben en nauwelijks territoriaal zijn. (RGB)

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