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Marginal differences between random plots and plots used by foraging White-backed Woodpeckers demonstrates supreme primeval quality of the Białowieża National Park, Poland

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I compared structural characteristics between foraging plots of an endangered European species, the White-backed Woodpecker *Dendrocopos leucotos* (WbW), and random plots in primeval deciduous stands of Białowieża National Park. I expected that WbW would use plots with higher amount of dead wood in more advanced decay stage, with higher amount of birches *Betula* spp. and aspen *Populus tremula*, and with more large trees. Within 50, 0.25-ha plots (25 used by WbW and 25 random) tree-species composition, tree condition, tree diameter at breast height DBH and characteristics of dead trees were measured. WbW and random plots were similar in overall structure; only the volume of fallen timber was significantly larger in WbW than in random plots (65.3 and 47.4 m^3/ha, respectively). There was also a tendency for the occurrence of more snags of 11–20 cm DBH within WbW plots. Thus, the amount of fallen timber might determine WbW choice of the foraging habitat. However, due to the relatively high similarity of WbW vs. random plots, the sections of Białowieża National Park that are covered with old-growth deciduous stands represent high-quality habitat for WbW foraging.

1. Introduction

The White-backed Woodpecker *Dendrocopos leucotos* (WbW) is a highly specialized forest bird whose European populations have greatly declined during recent decades. This decline is thought to result from forest management and removal of dead and dying trees from forests (Cramp 1985, Aulén & Carlson 1990, Virkkala *et al.* 1993). In the early 1900s the WbW has probably bred all across Europe (Tomiałojć 2000), but its current West European range is limited to certain isolated mountain populations e.g., in Norway and in the Alps and Pyrenees. This woodpecker is listed in the Bird Directive of NATURA 2000, indicating the species' importance in Europe, and prioritizing conservation of its habitats. In Poland, however, the situation for WbW is slightly better, with the population being recently estimated to be about 500 pairs (Tomiałojć & Stawarczyk 2003), including the largest single population in Białowieża Forest (Wesołowski 1995b). However, even in Białowieża the species is not sufficiently protected and is fast declining (Wesołowski 1995a, Czeszczewik & Walankiewicz 2006).

WbW forages mainly on wood-boring larvae living in decaying trees (Matsuoka 1979, Nuorteva *et al.* 1981, Aulén 1988). The species mainly forages in aspen *Populus tremula* and birch *Betula* spp., preferring large dead over small living trees (Hogstad 1978, Cramp 1985, Aulén 1988, Aulén & Lundberg 1991, Melletti & Penteriani 2003, Stenberg & Hogstad 2004). This woodpecker often forages on completely debarked dead trees (Cramp 1985), or on trees that are generally in an advanced stage of decay (Melletti & Pentoriani 2003). WbW occurrence is positively associated with the current area of deciduous and mixed forest of high conservation value (Roberge *et al.* 2008b). Therefore, detailed knowledge on accurate parameters of habitat utilized by this woodpecker under primeval conditions are crucial for conservationists and forest managers alike, especially within protected areas (Cárcamo 2006).

The Białowieża Forest is one of the last remnants of primeval, temperate lowland forest which once used to cover vast areas of Europe. Currently, however, only a small fraction (ca. 17%) of Białowieża is strictly protected so that e.g. dead and dying trees are retained. At this fraction, viz. the Białowieża National Park (hereafter BNP), the breeding population of WbW is relatively stable (Wesołowski 1995b, Wesołowski *et al.* 2003). This park includes many well-preserved stands with a high amount of dead wood (Bobiec 2002). Presumably this habitat is optimal for WbW. The aim of the present study was to analyze the microhabitat structure used by the White-backed Woodpecker in the deciduous forests of BNP by comparing foraging sites and randomly-chosen patches not known to be used by WbW. My predictions were that: (1) foraging WbW's should use patches more frequently the greater amounts of snags and fallen timber; (2) patches used by WbW for foraging should include more dead wood of intermediate or advanced stage of decay; (3) WbW's should forage more frequently in patches with higher amounts of birch and aspen; and (4) among alive trees, larger ones should be preferred by foraging WbW's.

2. Material and methods

The study was conducted in Białowieża Forest, NE Poland. The study area was the best-preserved 47.47-km^2 section of the Białowieża National Park (BNP; 52°29'–52°57'N and 23°31'–24°21'E). BNP is characterized by primeval multi-storey, mixed-species and uneven-aged tree stands. Stands of lime-hornbeam-oak *Tilio-Carpinetum* represent the dominant forest type, covering >45% of the total area, but other deciduous (e.g., swampy ash-alder, with ash *Fraxinus excelsior* and alder *Alnus glutinosa* as dominant trees) and coniferous (spruce-pine, with Scots pine *Pinus sylvestris* and Norway spruce *Picea abies*) stands are common. The main tree species in the lime-hornbeam-oak stands are lime *Tilia cordata*, hornbeam *Carpinus betulus*, spruce, oak *Quercus robur*, maple *Acer platanoides*, ash and elms *Ulmus* spp. Snags and fallen timber, dead wood, are characteristic of this forest type (Faliński 1986, Tomiałojć 1991, Bobiec 2002).

White-backed Woodpeckers were observed while foraging within the study area during 2004–2006. Foraging locations were recorded using a hand-held GPS unit (Garmin 76) or marking directly on a map (1:40,000). Altogether 511 observations of at least 20 different foraging WbW individuals were collected in over 200 observation occasions. At locations where foraging WbWs had been observed at least twice within 50 m on different days, stand-structure attributes (see below) were calculated using 50 m × 50 m sampling plots centered by the observed foraging location. Two sampling plots were established based on single foraging records that were exceptionally long-lasting (18 and 34 minutes). In eight cases both a female and a male were observed foraging in the same patch, whereas in other cases only one individual was recorded at a time. Birds had not been marked, but the distribution of observations helped approximate their territories. The plots chosen for these stand-characteristic measurements were distributed within 16 WbW territories representative of over 20 individuals (Fig. 1).

In addition to measuring stand characteristics of WbW foraging locations, characteristics of 25 control deciduous-forest plots were measured to examine if WbW foraging is independent of these characteristics (see below). Control plots were randomly selected within deciduous stands because WbW rarely occurs in coniferous forest. These random plots were usually within known WbW territories but their distribution did not coincide with WbW foraging plots (Fig. 1).

Habitat characteristics measured included tree

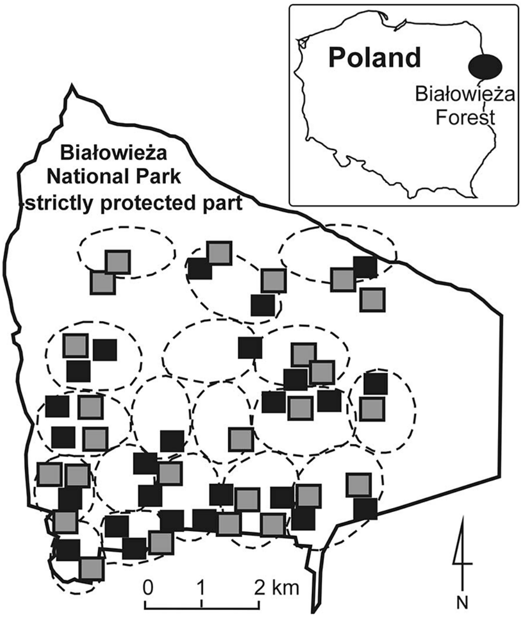

Fig. 1. The study area. Black squares = White-backed Woodpecker (WbW) foraging plots; grey squares = randomly-selected deciduous plots. Dotted lines show the approximate territories of WbWs based on all WbW observations.

species, tree diameter at breast height (DBH) and tree condition (alive, snags and fallen timber) for each dead and live tree occurring within a 50 m × 50 m plot. Only standing trees with DBH at least 4 cm (the thinnest trees used for foraging by WbW; author's unpubl. data) were measured. Snag heights were measured using a Suunto height-meter. At the top of each snag trunk, another diameter was measured. Decay stage of snags was analyzed in two ways: as deterioration of bark cover and as deterioration of crown. Deterioration of the bark cover on a trunk was estimated in the field based on the percentage of remaining bark, based on a modified classification of Imbeau and Desrochers (2002): (1) 95–100%, (2) 75–94%, (3) 50–74%, (4) 25–49%, (5) 0–24%. Deterioration of the crown was classified using the following scale: (1) 81–100%, (2) 61–80%, (3) 41–60%, (4) 21–40%, (5) 0–20% of branches remaining.

For each dead or living standing tree, basal area was calculated using the area of a circle formula. The basal area of each tree within one plot was pooled. For downed wood (all fallen timber with at least 10 cm DBH), the length of each tree and two diameter measures (one at each end) were measured and decay stage based on Maser *et al.* (1979) was estimated: (1) hard wood with intact bark cover; (2) hard wood but some bark lost; (3) medium-soft wood, almost without bark; (4) soft wood, without bark and with a friable texture; and (5) very soft wood that crumbles easily with bare hands.

I also calculated the volume of each dead tree, including snags and fallen timber, using the formula for the volume of a cut-away cone:

$$V = \frac{1}{3}\pi h(R^2 + Rr + r^2) \quad (1)$$

where h is the height (or length) and R and r are lower and upper radii of a tree (see above).

I used Mann-Whitney U test to compare foraging and random habitat plots, and logistic regression to evaluate the importance of individual habitat characteristics in explaining WbW foraging. This non-parametric regression method allows use both discrete and continuous variables. I determined the best logistic regression model, with the highest overall percentage of correctly classified observations, using a stepwise procedure. All calculations were performed with Statistica 7.1. Probabilities of 0.05 or lower determined the statistical significance below.

3. Results

Plots used by foraging WbW contained significantly larger volumes of fallen timber than did the random plots (65.3 vs. 47.4 m^3/ha; Table 1). The most common DBH class of fallen timber was the thickest, i.e., >30 cm. Only in this class was the difference between WbW and random plots significant so that larger numbers of fallen trees >30 cm DBH occurred in WbW plots (36.6 vs. 28.5 n/ha, respectively; Table 1). Snag volume and density within different DBH classes did not significantly differ between WbW and random plots; however, there was a marginally significant tendency for a higher occurrence of 11–20-cm DBH snags in WbW than in random plots (P = 0.056; Table 1).

The distribution of dead wood falling into different decay classes was similar between WbW and random plots. However, there was a tendency

Table 1. Volume and density of downed wood and snags in White-backed Woodpecker foraging plots (WbW) and in random plots. The "% difference" column shows the percent difference between WbW and random plots for each factor and DBH class, and *P* (probability) refers to Mann-Whitney *U* test results (see text).

Factor	DBH class	Mean ± SD		Range		% diffe-rence	*P*
		WbW	Random	WbW	Random		
Downed wood, m^3/ha		65.3 ± 27.80	47.4 ± 29.08	27–121	7–115	27	0.026
Downed wood, *n*/ha	10–20 cm	33.0 ± 21.14	26.1 ± 19.22	12–100	4–68	21	0.083
Downed wood, *n*/ha	21–30 cm	25.0 ± 17.75	18.9 ± 13.34	4–68	0–48	24	0.265
Downed wood, *n*/ha	>30 cm	36.6 ± 14.86	28.5 ± 13.87	8–64	8–60	22	0.038
Downed wood, *n*/ha	All, pooled	94.6 ± 41.12	73.4 ± 29.09	48–196	24–136	22	0.074
Snags, m^3/ha		25.8 ± 20.36	27.0 ± 30.44	2–68	0–119	–5	0.793
Snags, *n*/ha	4–10 cm	25.1 ± 25.02	17.4 ± 13.71	0–88	0–52	31	0.535
Snags, *n*/ha	11–20 cm	13.9 ± 8.73	9.3 ± 8.06	0–32	0–28	33	0.056
Snags, *n*/ha	21–30 cm	5.1 ± 8.04	5.1 ± 8.13	0–32	0–40	0	0.642
Snags, *n*/ha	>30 cm	11.8 ± 10.29	13.1 ± 12.99	0–40	0–60	–11	0.892
Snags, *n*/ha	All, pooled	56.0 ± 32.78	45.0 ± 25.85	8–132	4–112	20	0.233

for a higher amount of snags in the second bark-cover class in the WbW plots (Table 2).

The most common tree species in both WbW and random plots were hornbeam, lime and spruce (Table 3). The total basal area calculated for each tree species separately, for both live trees and snags, was similar in WbW and random plots (Mann-Whitney test, $P > 0.05$ for all tree species; Table 3).

I included five parameters into the logistic regression: volume of fallen timber, snag volume, basal area of living trees >20 cm in DBH, basal area of birches and aspens, and density of all live trees. This model indicated no significant differences between WbW and random plots ($\chi^2 = 5.23$, df = 4, $P = 0.39$). However, the optimal model–with fallen timber volume only correctly classified 56% of WbW and 64% of random plots ($\chi^2 = 4.81$, df = 1, $P = 0.03$).

4. Discussion

The tree characteristics of habitat patches used by foraging White-backed Woodpeckers were relatively similar as compared with randomly-selected deciduous plots in BNP. In fact, in most cases the random plots were located within known WbW territories that can be over hundred hectares (e.g., Wesołowski 1995a). However, foraging WbW were observed in certain parts of their territory more often than in others, and in some areas no ob-

Table 2. Mean (± SD) volume of downed wood and snags (m^3/ha) in White-backed Woodpecker foraging plots (WbW) and in random plots for five decay classes. Snags were separately compared according to bark cover and crown deterioration.

Decay class	Downed trees		Snags (bark)		Snags (crown)	
	WbW	Random	WbW	Random	WbW	Random
1	10.1 ± 12.78	1.2 ± 1.84	6.8 ± 9.40	11.1 ± 15.95	4.6 ± 9.08	5.3 ± 12.19
2	16.4 ± 11.91	12.5 ± 10.88	10.8 ± 12.56	5.5 ± 10.52	1.0 ± 2.60	3.9 ± 11.51
3	22.7 ± 14.77	18.4 ±12.45	2.3 ± 4.28	2.2 ± 6.79	2.4 ± 4.34	2.7 ± 9.09
4	15.2 ± 15.22	14.1 ± 13.23	1.8 ± 4.01	1.3 ± 2.83	2.7 ± 8.84	0.8 ± 1.65
5	0.7 ± 2.04	1.0 ±3.06	3.9 ± 9.34	6.6 ± 12.50	14.8 ± 14.50	12.6 ± 17.01
G test	6.29		3.52		3.13	
P	>0.05		>0.05		> 0.05	

Table 3. Basal area of tree species in White-backed Woodpecker foraging plots (WbW) and in random plots. *n* refers to the number of plots (out of all 50) where a given tree species was recorded.

	Live trees (m^2/ha)			Snags (m^2/ha)		
	WbW	Random	*n*	WbW	Random	*n*
Hornbeam	10.0	10.9	50	0.3	0.3	39
Lime	8.6	7.9	49	0.5	0.1	32
Spruce	4.7	5.1	48	0.9	1.4	41
Oak	3.9	6.2	33	0.6	1.1	12
Ash	1.9	0.8	25	0.1	0.1	9
Maple	1.7	2.3	42	0.2	0.2	8
Birch	1.2	0.3	12	0.1	0.1	6
Aspen	1.1	0.5	11	0.5	0.4	8
Elm	0.9	0.2	29	0.2	0.0	8
Other species	0.7	1.8	38	0.1	0.2	40
All spp.	34.7	36.0	50	3.5	3.9	50

servations were made during the study years. Therefore, a non-random foraging-habitat preference seemed a reasonable assumption.

The initial hypothesis that WbW more frequently forage in plots with higher amount of dead wood was supported. This finding was expected as the WbW is dependent on dead trees, including fallen timber (Ruge & Weber 1974, Matsuoka 1979, Cramp 1985, Aulén 1988). The quantity of dead wood is very high in the primeval Białowieża NP (Bobiec 2002), although this resource appears patchily distributed. In this respect primeval and managed forests are in vast contrast. In the present BNP study area, downed wood was 2–3 times more abundant than in those well-preserved managed-forest fragments of the Białowieża Forest that still support WbW. However, the amount of large snags (>20 cm DBH) in WbW territories was very similar in BNP as compared with WbW territories of managed stands (Czeszczewik & Walankiewicz 2006). Therefore, in spite of some differences in the quantity of downed wood, the whole BNP study area covered with old-growth deciduous stands appears to be optimal foraging habitat for WbW. In NE Poland and Lithuania, the presence of WbW was determined by an average of 1.4 m^2/ha basal area of deciduous snags (Roberge *et al.* 2008a). In the present study, the mean basal area of deciduous snags was considerably higher: 2.6 in WbW and 2.5 m^2/ha in random plots. However, the amount of snags was less important than that of fallen wood. Obviously, if a forest produces abundant snags, these will eventually turn to more downed wood, as logs are not removed. Therefore, deciduous or mixed forests rich in different forms of dead wood represents optimal habitat for many species associated with dead wood, including WbW (Walankiewicz *et al.* 2002).

Fallen trees are important for WbW during breeding season because they often host large Coleopteran larvae that are essential food for WbW's nestlings (Matsuoka 1979, Hogstad & Stenberg 1997). In early spring, before leaves start emerging, these larvae may be particularly crucial for WbW, as it starts breeding earlier than other woodpeckers do (Cramp 1985, Aulén 1988, Wesołowski 1995a). Matsuoka (1979) suggested that WbW, as a relatively large species, may not be able to efficiently utilize caterpillars during the nestling period. Moreover, as leaves are usually fully developed in the first 10 days of May in BNP, leaf-eating caterpillars may not be large enough before the WbW nestlings fledge. Thus, the best sources of food for nestlings at that period may be wood-boring beetle larvae found in thick snags and fallen timber. This idea may also explain why the WbW appeared to choose forest patches with more large downed wood even under the presumably good foraging conditions of BNP.

The prediction that WbW plots would have more dead wood of intermediate or relatively advanced decay stages was partially supported in BNP, as there was a tendency for a higher snag abundance in the second bark-cover class in WbW than in random plots (Table 2). On average, the dead trees with observed WbW foraging activity represented decay classes 2–3 (author's unpubl. data).

I also expected that WbW would more often forage in plots with more numerous aspens and/or birches (Cramp 1985, Aulén 1988). However, these tree species were scarce in the study area (1–2% of all trees). Although aspen and birch may have been over-utilized in BNP, their importance as foraging trees may be minor in this area because of their low density (Walankiewicz & Czeszczewik 2005). The WbW in BNP thus usually forages on other tree species, primarily on the hornbeam that is common there (Walankiewicz & Czeszczewik 2006).

The proportion of large living trees may be essential for WbW (Fernandez & Azkona 1996, Garmendia *et al.* 2006). However, this idea got no support in BNP, as the whole study area is covered by old-growth stands where large trees are rather evenly distributed. In terms of tree size, WbW territories did not significantly differ from uninhabited managed-forest patches of the Białowieża Forest (Czeszczewik & Walankiewicz 2006). However, the presence of old, large trees increases the chance for a higher rate of dead wood.

The characteristics of forests used by foraging WbW's, such as the density of snags or tree composition, influence the woodpecker productivity (Butler & Tappe 2008) and physical condition (Carlson 1998). Aulén (1988) showed that 45% of WbW nestling food consisted of wood-living larvae. These larvae are richer in nutrients than are ground-dwelling insects (Aulén 1988). I did not study the productivity or physical condition of WbW, but WbW population size within BNP has been stable for many years (Wesołowski 1995b, Wesołowski *et al.* 2003), suggesting that this area represents optimal breeding habitat for this woodpecker species.

The total potential food resources for WbW in BNP remain unknown. However, due to the high diversity of tree species and types of dead trees in the Białowieża Forest, supporting a rich invertebrate community (over 11,000 species, including over 1,000 saproxylic insects; Gutowski & Jaroszewicz 2001), food may ecologically limit WbW only during winter, when many invertebrates are unavailable for the woodpecker.

The present results are interesting *per se*, but they can also be applied in nature reserve management. Increasing the number and variety of dead trees, especially deciduous ones may improve the quality of WbW habitats. Planting aspen (and/or other fast-growing tree species) may be a quick way to introduce dead wood into managed stands especially in the northern range of the WbW distribution. Smith (2007) showed a trend for increasing downed dead wood and snags in Britain, although it is a slow process. However, these resources are scarce in most of European managed forests. The WbW preferred patches with a high volume of fallen timber, which suggests that the best way of active protection of WbW would be retaining more snags and downed thick wood in the forest floor in low-density WbW areas, such as the managed part of the Białowieża Forest, or other managed forests in eastern Poland. Such management strategy should be applied in the whole Białowieża Forest to maintain a stable population of the White-backed Woodpecker.

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Vähäiset erot satunnaisten ja valkoselkätikan ruokailulaikkujen välillä osoittavat Białowieżan kansallispuiston erinomaista laatua

Vertasin tutkimuksessani uhanalaisen valkoselkätikan (*Dendrocopos leucotos*) ruokailuunsa käyttämiä metsälaikkuja satunnaisesti valittuihin vanhoihin lehtimetsälaikkuihin Białowieżan kansallispuistossa. Oletin valkoselkätikkojen käyttävän laikkuja sitä useammin, mitä enemmän niillä on pitkälle lahonnutta puuta, koivuja ja haapoja, sekä suurikokoisia puita. Arvioin puulajisuhteen, puiden kunnon, rinnankorkeusläpimitan ja lahopuuston laadun 50 laikulla, kukin kooltaan 0,25 ha;

näistä 25:llä havaittiin valkoselkätikan ruokailuja (”ruokailulaikut”) ja 25:llä ei (”satunnaislaikut”).

Ruokailu- ja satunnaislaikut olivat rakenteeltaan samankaltaisia; ainoastaan maapuiden kokonaistilavuus oli merkitsevästi korkeampi ruokailukuin satunnaislaikuilla (65,3 vs 47,4 m^3/ha). Ruokailulaikuilla näytti myös usein olevan enemmän pökkelöitä, joiden läpimitta oli 11–20 cm. Tulokseni viittaavat siihen, että valkoselkätikat saattavat valita ruokailuympäristönsä maapuiden perusteella. Koska ruokailu- ja satunnaislaikut kuitenkin olivat puustoparametreiltään varsin samanlaisia, Białowieżan kansallispuiston vanhimmat lehtimetsät ovat kaikkiaan erinomaista ruokailuympäristöä valkoselkätikalle.

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