

Effects of habitat structure, floral composition and diversity on a forest bird community in north-western Italy

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Abstract During the breeding period, I analysed bird community-habitat relationships in a managed broad-leaved forest of north-western Italy (a newly established nature reserve). Species richness, diversity, biomass and abundance of some ecological groups of birds were analysed with respect to habitat variables, summarising habitat structure, canopy and understorey floral composition. Two major patterns of relationships among bird and habitat were traced: the first involved changes in tree structure during their growth (canopy height and diameter of the dominant tree), the second was related to characteristics associated with floral richness. Bird diversity, species richness, the amount of hole nesters, of trunk and ground feeders were positively associated with stands age. The abundance of some groups of birds was positively related to plant species richness: understorey species richness influenced shrub feeders, shrub nesters and edge species; canopy species richness affected trunk feeders. Canopy species richness also affected bird diversity, richness, biomass, abundance of hole nesters, trunk feeders and forest interior species.

Key words: diversity, species richness, broad-leaved woodland

Introduction

The effect of spatial configuration, productivity and diversity of vegetation on bird communities has been widely documented (Cody 1985, Wiens 1989). Much of the current information concerning bird assemblages derives from studies on temperate-forest birds (James 1971, Fuller 1995). These forests offer a wide variety of habitats that differ in extent, physical structure, and food and nest availability to birds over both space and time (Cody 1985). Aspects of the environment that influence distributional patterns in forest birds include the presence or availability of foraging resources, which in turn are affected by the diversity and composition of the habitat. Preferred nesting, roosting or perching sites are also affected by forest configuration. Elevation, sensitivity to hunting or other human activities and interaction among bird species may also influence the distribution of birds among habitats.

The availability of resources is by far the better predictor of the structure of forest birds assemblages, but it is hard to quantify (Bellamy et al. 2000). Hence, some general features of habitat that are more easily characterised have been used to analyse bird-habitat relationships. Traditionally, the emphasis in studies of bird habitats has been on features relating to the structural configuration or floral composition of the habitat (Wiens 1989). The structure of a woodland can be broken down into a large number of components that may be used as explanatory variables of birds community structure. The stage of forest growth exerts a strong affect on bird assemblages. Bird species richness tends to increase with stand age (Lack 1939, Lack & Lack 1951, Moss 1978, Helle & Mönkkönen 1990), although many species prefer a particular stage of growth. Most hole-nesters select those stages with mature trees, while many migrant passerines are confined to the earliest stages when the vegetation is open (Fuller 1995). A prominent

influence on bird communities is played by the vertical foliage profile (Solonen 1996, Freifeld 1999). Woodland birds differ considerably in the heights at which they forage and nest; the canopy, the understorey and the field layers all have their own species. It is widely accepted that increased structural complexity generally provides a wider diversity of foraging sites upon which birds can specialise, allowing the addition of more species in existing assemblages (Karr 1990). The availability of tree holes is fundamental for woodland birds, and can result in severe competition among hole-nesters. Another important micro-structural feature for forest birds is dead wood: the huge invertebrate community it supports is a rich food resource for many birds (Nilsson 1979). MacArthur & MacArthur (1961) have suggested that the structural variables mentioned above are important in explaining variations in woodland bird communities, conversely, tree species composition or diversity are often irrelevant. However, several studies have demonstrated that floral composition and plant diversity may be important determinants of habitat use in birds (Holmes & Robinson 1981, Robinson & Holmes 1984). In Europe, species exhibit differences in habitat use, foraging behaviour and even morphology as a function of leaf type (Karr 1990). Since floral diversity strongly influences physical structure (Horn 1971), it is difficult to separate the effects of these two factors.

In the present study I analysed bird-habitat relationships in a managed broad-leaved forest of north-western Italy during the breeding season. In this area, a protected reserve was recently established. Bird species diversity, richness and biomass were analysed in relation to measured features of habitat structure, floral composition and diversity. Since the analysis of habitat relationships is an important part of wildlife management and conservation biology, I also analysed how the variations in the abundance of ecological groups were associated with certain habitat characteristics.

Material and Methods

The study was carried out in the Val Sarmassa Nature Reserve (44°48'N, 8°20'E; north-western Italy). The reserve, ranging from 140 to 270 m a.s.l., comprises mostly broad-leaved woods, but scattered farmland is present. Human impact has always been strong in the study area, as woods have been harvested and managed since the XVII century. The reserve mainly consists of a mosaic of small coppice patches at different growth stages. Some coppice is grown with scattered single-stem trees (standards), which are fallen on a longer rotation time than underwood. The predominant tree species were sweet chestnuts (*Castanea sativa*), oaks (*Quercus petraea*, *Q. cerris*, *Q. pubescens* and *Q. robur*) and locust trees (*Robinia pseudoacacia*). In the study area young locust tree woods (established in many abandoned vineyards), small clearances, poplar plantations (in the valleys) and vineyards (on the top of the hills) also occur.

I surveyed species presence using a single visit point-count method (Biondel et al. 1970, Biondel 1975, Järvinen & Lokki 1978). This technique involved a count of all birds seen or heard inside or outside a 50 m radius circular plot; overflying birds that did not land in trees or on the ground were recorded but not included in the analysis. Each point was sampled for 10 minutes between sunrise and 3hr later, since this morning period yields the best results (Lynch 1995). Field work was carried out from 5 March to 28 June 2000, as census performances for counts from the beginning to the end of the breeding season proved to be significantly better than counts that were concentrated in either one of these periods (Drapeau et al. 1999). Overall, 95 survey plots were distributed through a wide range of environmental conditions within the forest.

In each census station, habitat data were collected. Measurements were made after each session of point counts was completed, in plots centred in the avian census plots (50 m radius). I measured the following abiotic variables: (1) ground slope, (2) elevation (m above see level) and (3) distance from the forest edge (m).

The structure of vegetation was quantified by measuring: (1) mean diameter at breast height (DBH) of the dominant tree species (the closest four canopy trees of the dominant species were located, one within each quartile: north, south, east and west; DBH was measured directly with a tape measure); (2) mean canopy height (measured on the same trees chosen for DBH, a hypsometer was used), (3) mean understorey height (the closest four shrubs were located, one within each quartile: north, south, east and west), (4) mean canopy density (the distance among the four closest trees was paced in metres; the inverse of distance gave the measure of density), (5) understorey density (the distance among the four closest shrubs was paced; gave the measure of density), (6) percentage of trees with climbers (such as ivy *Hedera helix*).

The abundance of canopy species and understorey species was expressed as percentage of cover. Canopy species richness and understorey species richness were also calculated. In the interest of clarity, I used the term canopy to denote trees higher than 8 m, and understorey to point to shrub layer (as synonymous of midstorey in North American literature).

I calculated bird species diversity (Shannon's index), richness and total biomass (i.e. the sum of birds weights) at each individual points. Bird weights were those reported in Cramp (1988, 1992) and Cramp & Perrins (1993, 1994a, 1994b). To avoid including birds that were outside the habitat sampling plots, I used detections within the 50 m radius plot only, in keeping with Page et al. (2000), Sallabanks et al. (2000). Bird abundance was expressed as percentage of occurrence, i.e. no. of times a species occurred in the point-counts divided by the total number of point-counts.

Principal component analysis (PCA, Gunch 1984) was chosen to reveal patterns in the data for structure, using standardised data (zero mean and unit standard deviation). The paucity of data did not allow a detailed analysis at the species-level, so species were grouped according to their ecological group: edge species, forest interior species, hole nesters, tree nesters, understorey nesters, ground feeders, trunk and branches surface feeders, shrub feeders, tree feeders and generalist feeders (Fuller 1995, Jokimäki & Huhta 1996). Bird species diversity, species richness, total biomass and the abundance of ecological groups were used as dependent variables in stepwise multiple regression analyses. The variables used as predictors were the three abiotic variables, canopy species richness, understorey species richness, as well as PCA scores for components one and two for habitat structure. Significance levels were Bonferroni corrected.

Associations among bird and plant or understorey species were examined using canonical correspondence analysis (CCA, Ter Braak 1986). Despite CCA is unable itself to test hypotheses, the resulting plot is a compromise solution expressing the association between species, variables and samples (Ter Braak & Verdonschot 1995). I included in the analysis only bird species that were spotted at least four times. The relative abundance of the three commonest tree species (chestnut, locust tree and oaks) and of the four commonest understorey species (elder *Sambucus nigra*, hazel *Corylus avellana*, hawthorn *Crataegus monogyna*, blackthorn *Prunus spinosa*) were used as environmental variables. The results of CCA can be presented in a diagram containing the environmental variables (here, plant and understorey species composition) plotted as arrows emanating from the center of the graph, along with points for the bird taxa (Fig. 1).

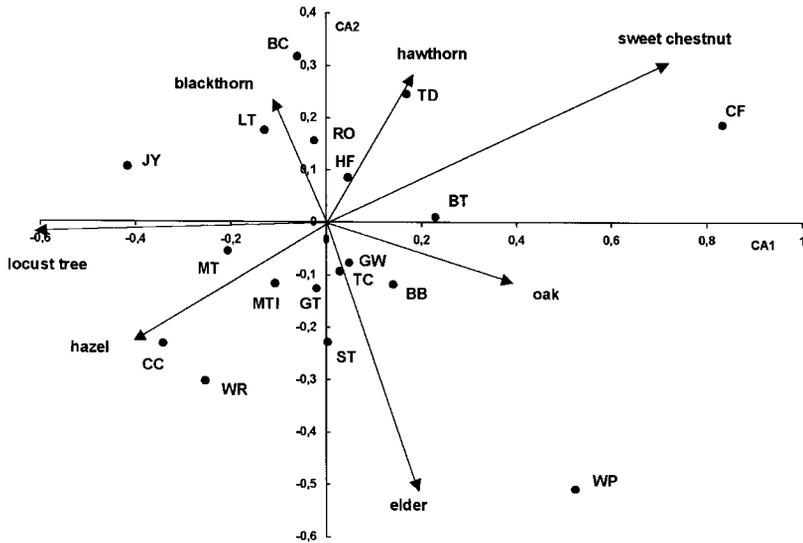


Fig. 1. Relationship between bird species and the commonest plant species, as resulted from canonical correspondence analysis. The arrows representing plant species indicate the direction of maximum change of those species across the diagram. For bird species acronyms see Appendix.

Table 1. Results of principal component analysis carried out on habitat structure data in the Val Sarmassa Nature Reserve. The highest loadings are given in bold type.

	Factor loadings	
	PC1	PC2
DBH	0.90	-0.07
canopy height	0.93	0.03
understorey height	0.44	0.41
canopy density	0.06	0.04
understorey density	-0.20	0.76
percentage of trees with climbers	0.14	0.69
eigenvalue	1.99	1.33
% total variance	33.2	22.3

Results

The first two principal component (PC1, PC2) accounted for almost 56% of the total variation in the habitat structure matrix (eigenvalues > 1) (Table 1). Canopy height and diameter at breast height of the dominant trees (DBH) showed the highest correlation with PC1 scores, which could therefore be considered as accounting for forest age. The percentage of climbers and understorey density provided the major loading on PC2, which thus accounted for structural complexity.

Thirty species of landbirds were recorded in 95 individual point-counts in the forest (Appendix). In percentage of occurrence, robin was the most frequently encountered bird, followed by great tit, blackcap and blackbird. In total numbers, robin was again the most common bird, followed by blackcap and great tit. In the forest, the mean diversity per point count was 0.5; a mean of 3.9 species was recorded. Both bird diversity and species richness

were positively correlated with PC1 (forest age) and with canopy species richness; all the other variables were excluded from the model (Table 2). Bird biomass was positively affected only by canopy species richness (Table 2).

The abundance of hole nesters, trunk and branches surface feeders and interior species was positively correlated with PC1 (forest age) and with canopy species richness. Trunk feeders were also negatively correlated with PC2 (structural complexity, also related to climber presence). Shrub feeders abundance was positively related with shrub species richness and negatively related with the distance from the forest edge. Only canopy species richness affected tree feeders, whereas no structural variable significantly affected edge species, tree nesters and generalists. Understorey nesters were related to understorey species richness.

The first two CCA axes accounted for 53.4% of the variability in the data (CA1: 31.3%, CA2: 22.1%). Chaffinch, woodpigeon, blue tit, and great spotted woodpecker appear associated with oak- or chestnut-rich plots of increasing proportion. Blackcap, long-tailed tit and robin abundance increased when blackthorn was present; wren and chiffchaff seemed to prefer hazel rich stations, whilst turtle dove appeared to use hawthorn understorey.

Table 2. Results of stepwise multiple regression analyses. The response variables were bird species diversity, bird species richness, the abundance of ecological groups of birds and bird biomass (g in weight); the explanatory variables (independent variables) were abiotic and structural parameters. Only the parameters that significantly entered in the model are listed. PC1 of structural variables could be considered a 'forest age factor', while PC2 of structural variables was related to structural complexity. Data were Bonferroni corrected.

Variable		Coefficient	SE	t-value	P	R ²	F	P
<i>Species diversity</i>	Intercept	0.30	0.07	4.50	<0.01	0.24	F _{2,92} = 14.5	<0.05
	PC1 of structural variables	0.06	0.02	2.68	<0.05			
	Canopy species richness	0.07	0.02	2.68	<0.05			
<i>Species richness</i>	Intercept	2.35	0.55	4.56	<0.01	0.22	F _{2,92} = 13.3	<0.05
	PC1 of structural variables	0.59	0.21	2.83	<0.05			
	Canopy species richness	0.43	0.15	2.94	<0.05			
<i>Interior species</i>	Intercept	1.43	0.48	3.00	<0.01	0.26	F _{2,92} = 16.4	<0.05
	Canopy species richness	0.46	0.14	3.21	<0.01			
	PC1 of structural variables	0.60	0.19	3.01	<0.01			
<i>Hole nesters</i>	Intercept	0.49	0.34	1.45	0.15	0.19	F _{2,92} = 10.5	<0.05
	PC1 of structural variables	0.37	0.10	2.75	<0.05			
	Canopy species richness	0.23	0.14	2.34	<0.05			
<i>Understorey nesters</i>	Intercept	2.28	0.48	7.51	<0.001	0.08	F _{1,93} = 5.3	<0.05
	Understorey species richness	0.32	0.14	2.30	<0.05			
<i>Trunk and branches surface feeders</i>	Intercept	-0.034	0.15	-0.23	0.82	0.20	F _{3,91} = 7.6	<0.05
	PC1 of structural variables	0.13	0.06	2.24	<0.05			
	PC2 of structural variables	-0.11	0.05	2.05	<0.05			
	Canopy species richness	0.11	0.04	2.63	<0.05			
<i>Ground feeders</i>	Intercept	1.11	0.15	7.16	<0.01	0.13	F _{1,93} = 6.9	<0.05
	PC1 structural variables	0.27	0.10	2.75	<0.05			
<i>Shrub feeders</i>	Intercept	0.52	0.16	3.36	0.01	0.16	F _{2,92} = 9.01	<0.05
	Understorey species richness	0.20	0.06	3.54	<0.01			
	Distance from the forest edge	-0.002	0.0008	-2.29	<0.05			
<i>Tree feeders</i>	Intercept	0.10	0.16	0.61	0.54	0.08	F _{1,93} = 8.26	<0.05
	Canopy species richness	0.13	0.06	2.87	<0.05			
<i>Total biomass</i>	Intercept	16.8	56	0.30	0.76	0.12	F _{1,93} = 13	<0.01
	Canopy species richness	57.5	15.9	3.61	<0.01			

Appendix. Bird species recorded during point-counts. Birds were allocated to different ecological groups, defining location (E = edge species, W = interior species), nest habit (H = hole nester, TR= tree nester, CP = understory nester) and foraging guild (C = mostly tree feeder; G = mostly ground feeder, T =mostly trunk and branches surface feeder; S = mostly shrub feeder; F = generalist feeder). Categorisation is based on H a r r i s o n (1988), F u l l e r (1995) and J o k i m ä k i & H u h t a (1996). Biomass in keeping with C r a m p (1988, 1992) and C r a m p & P e r r i n s (1993, 1994a, 1994b). Acronyms are given for species included in canonical correspondence analysis.

Species	Category	Biomass (g)	% occurrence	% total numbers
woodpigeon (<i>Columba palumbus</i>) WP	W, TR, C	504	10.5	2.6
turtle dove (<i>Streptopelia turtur</i>) TD	E, CP, G	130	4.2	1.1
hoopoe (<i>Upupa epops</i>)	E, H, G	67	1.1	0.3
wryneck (<i>Jynx torquilla</i>)	W, H, G	37	2.1	0.5
green woodpecker (<i>Picus viridis</i>)	W, H, G	177	2.1	0.5
great spotted woodpecker (<i>Dendrocopos major</i>) GW	W, H, T	76	22.1	5.8
wren (<i>Troglodytes troglodytes</i>) WR	W, CP, S	10	27.4	6.9
robin (<i>Erithacus rubecola</i>) RO	W, CP, G	18	66.3	17.7
redstart (<i>Phoenicurus phoenicurus</i>)	E, H, G	16	1.1	0.3
blackbird (<i>Turdus merula</i>) BB	W, CP, G	96	29.5	7.4
song thrush (<i>Turdus philomelos</i>) ST	W, CP, G	72	9.5	2.6
mistle thrush (<i>Turdus viscivorus</i>) MT	E, TR, G	120	6.3	1.6
blackcap (<i>Sylvia atricapilla</i>) BC	E, CP, S	19	34.7	10.0
wood warbler (<i>Phylloscopus sibilatrix</i>)	W, CP, C	9	1.1	0.3
chiffchaff (<i>Phylloscopus collybita</i>) CC	E, CP, C	8	8.4	2.4
spotted flycatcher (<i>Muscicapa striata</i>)	E, TR, C	14	2.1	0.5
long-tailed tit (<i>Aeghitalos caudatus</i>) LT	E, CP, G	8	21.1	5.5
marsh tit (<i>Parus palustris</i>) MTI	W, H, C	11	23.2	5.8
blue tit (<i>Parus coeruleus</i>) BT	W, H, C	11	24.2	6.3
great tit (<i>Parus major</i>) GT	W, H, C	18	35.8	9.5
nuthatch (<i>Sitta europaea</i>)	W, H, T	22	3.2	0.8
short-toed treecreeper (<i>Certhia brachydactyla</i>) TC	W, H, T	9	6.3	1.6
jay (<i>Garrulus glandarius</i>) JY	W, TR, F	167	16.8	4.2
hooded crow (<i>Corvus corone cornix</i>)	E, TR, F	539	1.1	0.3
starling (<i>Sturnus vulgaris</i>)	E, TR, F	55	1.1	0.3
chaffinch (<i>Fringilla coelebs</i>) CF	E, TR, G	23	13.7	3.4
greenfinch (<i>Carduelis chloris</i>)	E, TR, G	26	1.1	0.3
goldfinch (<i>Carduelis carduelis</i>)	E, TR, G	16	1.1	0.3
hawfinch (<i>Coccothraustes coccothraustes</i>) HF	W, TR, C	56	4.2	1.1
cirl bunting (<i>Emberiza cirlus</i>)	E, CP, G	26	1.1	0.3

Discussion

Both woodland structure and floral diversity influenced the broad attributes of the bird community studied, although the relative importance of structural and vegetation composition differed among ecological groups of birds.

Tree height and diameter (i.e. stand age) had a weak but constant and significant effect in most multiple regression analyses. Bird diversity, species richness, and the amount of hole nesters, interior species, trunk and ground feeders were all positively related to with stand age. In many European forests, the number of species and overall density of birds increase with forest maturation (L a c k 1939, L a c k & L a c k 1951, M o s s 1978, H e l l e & M ö n k ö n e n 1990). Stand age is positively correlated with tree volume and, in turn, with productivity of forest areas, thus its effect on bird communities (especially on interior species) can be very strong (J o k i m ä k i & H u h t a 1996). Thus, hole nester abundance increased significantly with stand age, as these species are often confined to the oldest stands of a wood because of the greater availability of holes and crevices in mature

trees (Smith et al. 1985). Trunk and branch feeders density also peaked in old stands, where invertebrate food in decaying trunks or branches is greater than young-growth. Older trees also have a greater surface area of bark to forage on, and the bark has a greater structural complexity (Nilsson 1979, Schieck et al. 1995). Trunk feeders were negatively influenced by the density of climbers, which can hide the potential food resources on trunks and therefore have an adverse effect on feeding activities. Climbers may also make it more difficult for trunk feeders to move up and down the trunk. Trunk feeders appeared to be negatively affected by understorey density, but the reason for this remains unknown.

Besides the covariation between stand age and bird abundance, another major factor affecting birds was floral diversity. Bird species diversity, richness and biomass decreased in single species woods. Most pure woods in the study site consisted of coppices of sweet chestnut or young woods of locust tree. Chestnut coppice may be deserted by species that require a vigorous shrub layer, as chestnut is typically grown in dense monoculture, which rapidly shades out the low foliage (Fuller 1995). Young locust tree wood has few holes, thus it could be avoided by hole nesters. Furthermore, there is possibly less insect food available in locust-tree woods than in mixed or pure oakwoods (Fuller 1995). The number of shrub feeders was related significantly to understorey species richness, whereas that of trunk feeders was mainly influenced by canopy richness. Again, this may be explained by the greater diversity of food, or stability of food supply (in the form of insects or berries), found in woodlands of varied vegetation composition. Different understorey nesters appeared to be associated with specific shrub species: wren and chiffchaff, for instance, preferred hazel-tree, turtle dove favoured hawthorn, whereas blackcap, robin and long-tailed tit used blackthorn understorey.

Habitat structure and plant heterogeneity should thus be considered in future forest management and nature reserve creation plans. In my study area, coppice management created a large variety of habitat types, as different growth stages are present. The bird community in the study site is clearly related to this habitat. Considering that edge effects also exist between forest compartments of different ages (far from the actual woodland edges), it is not surprising that most species recorded can be classified as edge species (Fuller 1995, Jokimäki & Huhta 1996). The high proportion of young-aged forest with a rich understorey present in the study area would certainly benefit many habitat generalists, understorey nesters and edge birds. However, we must consider that these species are already very abundant and need no special assistance. Conversely, species that require large areas of integral forest habitat, such as interior species, hole nesters and virgin forest birds (e.g. woodpeckers), are of particular concern. Since this study emphasised the importance of stand age for many ecological groups of birds, it would be prudent to retain adequate amounts of mature trees in the managed landscape.

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