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Structure of avian communities in lowland coniferous forests in Opole Silesia (SSW Poland)

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Abstract: In Poland, forests comprise 31% of the total surface area, while the lowland coniferous forests comprise 51% of 94 000 km^2 afforested areas. The line transect method was employed in 2002 and 2004 to estimate population densities and dominance of all bird species breeding in a selected fragment of such forest (eight transects with 165 sections and 77.7 km in total length). In total, 54 breeding bird species were recorded. The numbers varied between 37 and 44 on the particular transect. The number of breeding pairs per 10 ha varied on each transect from 41.0 to 93.6 (x=64.8; SD=102.22). Shannon's diversity index varied between 1.2 and 1.4 on particular transects, while Simpson's diversity index varied between 0.7 and 0.9. Also Pieleau's evenness index varied slightly between 0.05 and 0.07. In overall, the differences between densities of breeding species on 8 transects were not statistically significant. The Chaffinch *Fringilla coelebs* was by far the most numerous bird species, recorded as eudominant in all eight transects and present in all 165 sections. The second to the Chaffinch was the Chiffchaff *Phylloscopus collybita*; also recorded in all sections and as a dominant in all transects. Three other species, namely the Blackbird *Turdus merula*, Willow Warbler *Phylloscopus trochilus* and Blackcap *Sylvia atricapilla* were recorded each one in more than 90% sections (N=165), and on particular transects their dominance varied between 4 and 11%. Residents comprised 57.5% of all breeding pairs. Short-distance migrants were almost twice more common than long-distance migrants. Insectivores were by far the most numerous feeding guild represented 88.9% of all breeding pairs. Overall density, cumulative dominance, diversity and evenness were unexpectedly very similar in this study (managed forest) and in natural primeval lowland coniferous forests of Białowieża.

Key words: pine forests, community ecology, population estimations.

Introduction

Coniferous forests dominated by the Scot Pine *Pinus sylvestiris* constitute a major component of forests in Central European Plain, which encompasses most of Germany, Poland, Belarus and Baltic states. Structurally these forests are also similar to the coniferous forests in the boreal zone of Fennoscandia and north-western Russia. Because of their common occurrence and homogeneousity, the lowland coniferous forests are suitable to study regional differences of their various communities (Tiainen 1980).

In Poland, forests comprise 31% of the total surface area, while the lowland coniferous forests comprise 51% of 94 000 km^2 afforested areas (Wasik 2015). They constitute, therefore, important habitat of birds. By far, there are more bird species than all other terrestrial vertebrate species in these forests (Niemi et al. 1998). In Finland, for instance, birds make up about 75% of all terrestrial vertebrates (Niemi et al. 1998).

Most Polish forests are under state management (77%), with only 19% under private management (Wasiak 2015). The lowland coniferous forests are, however, often left unfragmented in the form of large continuous blocks of several hundred to several thousand km^2 surface area, like Augustowski, Knyszyński, Piski, Nadnotecki, Dolnośląski, Stobrawski or Niemodliński Forests. Only c. 3% of Polish forests are left unmanaged as national parks and nature reserves, the biggest of which and best preserved is Białowieża National Park (Tomiałojć et al. 1984; Wesołowski, Tomiałojć 2004; Wesołowski et al. 2010).

A considerable body of literature exists on forest bird communities. Those in lowland coniferous forests in Poland were studied by Mrugasiewicz 1974; Ranoszek, Witkowski 1975; Tomiałojć 1974; Borowiec, Grabiński 1982; Tomiałojć et al. 1984; Wesołowski et al., 2010; Piotrowska, Wołk 1983; Kopij 2000ab. These studies were, however, conducted on small selected plots of mature stands and often in fragmented forests. There is a lack of thorough studies over the whole mosaic of continuous pine forests in Poland, as well as in other European countries.

The continuous pine forests are quite homogenous in regard to tree species composition and structure. They can be, however, regarded as a mosaic of plots of different age tree stands of various areas sizes ranged from a few ha to several hundred ha. Small patches of forest clearings, young tree plantations and mature stands create in such mosaic the amount of forest edge, without fragmenting the landscape. It is, therefore, untypical ecological setting different from a real forest interior and forest edge.

The purpose of this study was to 1) investigate structure of avian communities in one of such continuous coniferous lowland forests, well representing other such forests in Poland; 2) compare the communities with those in similar, but unmanaged primeval forests (Tomiałojć et al. 1984, Wesołowski et al. 2010).

Study area

The study area comprised a continuous coniferous forests, so called Niemodlin Forest, situated in Opole Silesia, SSW Poland (Fig. 1). It is administered by three forests inspectorates: Prószków Forest Inspectorate in the eastern part, and Tułowice Forest Inspectorate in the western part. A small forest fragments north of the highway are administered by Opole Forest Inspectorate. Most studies were conducted in Prószków Forest Inspectorate (transects III-VIII), with only two transects (transects I-II) designed in Tułowice Forest Inspectorate.

Prószków Forest Inspectorate with an afforested surface area of 180 km^2 comprises mainly Fresh Mixed Coniferous Forest (63.8% of all afforested surface), and Fresh Mixed Deciduous Forest (26.8%). The Alder comprises only 0.6%. The Scot Pine *Pinus sylvestris* constitutes 82.2% of the total afforested surface area, while the English Oak *Quercus robur* and Beech *Fagus sylvatica* together 8.2%. Other tree species include *Picea abies, Larix decidua*, *Betula verrucosa, Acer platanoides Acer pseudoplatanus, Fraxinus excelsior*, *Tilia cordata*, *Ulmus glabra, Carpinus betulus, Robinia pseudoaccacia*. About 79000 m^3 of the wood is harvested annually, and 173 ha is again afforested. Most tree stands are 41-60 (III class) and 81-100 (V class) years old (25.0% and 17.2% respectively). Old tree stands (VI class: age 101-120 years, and older) comprised 13.5%.

Tułowice Forest Inspectorate, with an afforested surface area of 173.6 km^2 comprises mainly so called Fresh Mixed Coniferous Forest (47.9%), Fresh Mixed Deciduous Forest (46.8% of all afforested surface), and Alder (5.3%). The Scot Pine, English Oak and Common Birch are the most common tree species (62.4%; 17.4% and 6.9% respectively of total afforested surface area). Most tree stands (42.6%) are 41-80 years old, with 14% older than 100 years. About 68 000 m^3 of the wood is harvested annually.

Methods

The line transect method (Bibby *et al*. 1992) was employed to estimate population densities and dominance of all bird species breeding in the forest. Birds were censused on transects, which run on the border lines between particular forest plots. All transects run through fresh pine forests.

Eight transects were designed for this study (Fig. 1). Their length ranged from 8 to 14.7 km (Table 1). Each transect was divided into sections. The sections were about 0.4 km long in transects I-VI and 0.6 km long in transects VII-VIII. The average length of all these sections was 0.47 km (SD = 0.09; n=165).

Birds were counted separately on each section. They were counted on each transect within a belt c. 100 m width (50 m on each side of the transect). Therefore, 1 km long transect was an equivalent of 10 ha. Each transect was surveyed thrice in the breeding season, once in each month: April, May and June. Counts were conducted in the mornings under sunny and windless weather conditions. Transects I-VI were surveyed in 2002, while transects VII-VIII in 2004. As recommended in the line transect method (Bibby et al. 1992), a breeding pair, not an individual, was a census unit.

Number of breeding pairs was estimated for each section on each transect. Maximal number of breeding pairs on whatever survey on each section was assumed as the real number of breeding pairs. The total number of breeding pairs of each species on a particular transect was calculated as the totals of maximal numbers recorded on each section within the transect.

The following guilds were distinguished: Foraging: G – granivores; I – insectivores (Lg – ground-feeders, Lb – bark-feeders, Lf – foliage-feeders); O – all others

Nesting: G – on the ground; V – in herbaceous vegetation; T – in trees or shrubs; H – in tree holes

Migration: L - long-distance migrant (wintering mostly in Africa south of Sahara); S - short-distance migrant (winter mainly in southern Palearctic region); R – resident (winter within the breeding range).

The following indices were used to characterize the diversity and evenness of the communities:

Shannon's diversity index: $H' = -\sum p_i \log p_i$, where: p_i is the proportion of breeding pairs belonging to the *i*th species

Simpson's diversity index: $D = ((\sum n(n-1))/N(N-1)$, where: n – total number of breeding pairs belonging to a given species, N – total number of breeding pairs of all species

Pileou's evenness index: $J' = (-\sum p_i \log p_i)/\log S$, where p_i is the proportion of breeding pairs belonging to the *i*th species; S – total number of species. J' varies between 0 and 1. The less variation between species in a community, the higher is J'.

Community dominance index: $DI = (n_1 + n_2)/N$, where n_1, n_2 – number of pairs of two most abundant species, N – total number of pairs of all species.

Dominance was calculated as the percentage of breeding pairs of a given species in relation to all breeding pairs of all species. Dominant species comprises 5-9.99 % of all breeding pairs recorded, eudominant –10% and more, while subdominant – 2-4.99%.

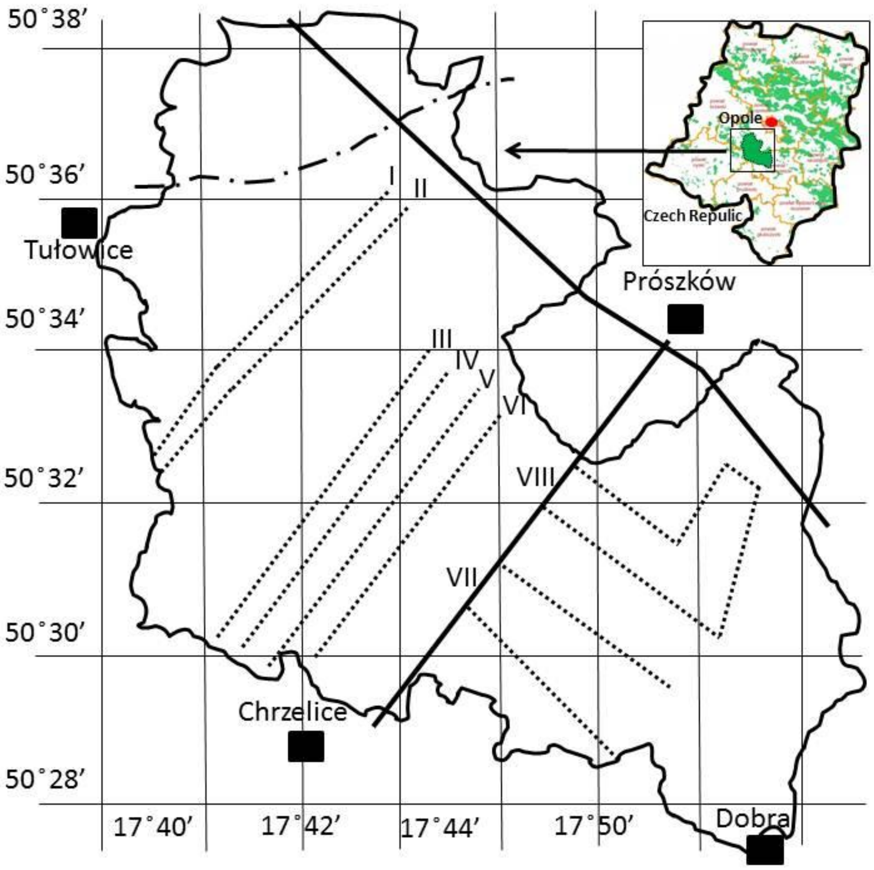

Fig 1: A map of Niemodlin Forest showing the distribution of transects. Thick continuous line – public roads, thick broken line – railway, dotted line – transects (I-VIII), black squares – main villages.

Results

In total, 54 breeding bird species were recorded. The number varied between 37 and 44 on the particular transect. The number of breeding pairs per 10 ha varied on each transect from 41.0 to 93.6 (x=64.8; SD=102.22). Shannon's diversity index varied between 1.2 and 1.4 on particular transects, while Simpson's diversity index varied between 0.7 and 0.9. Also Pieleau's evenness index varied slightly between 0.05 and 0.07 (Table 2, App.1, 2).

In overall, the differences between densities of breeding species on 8 transects, were not statistically significant ($F_{7, 424} = 0.334$, $p=0.938$).

The Chaffinch *Fringilla coelebs* was by far the most numerous bird species, recorded as eudominant in all eight transects and present in all 165 sections (Table 3, App. 1, 2). The second to the Chaffinch was the Chiffchaff *Phylloscopus collybita*; also recorded in all sections and as a dominant in all transects. Three other species, namely the Blackbird *Turdus merula*, Willow Warbler *Phylloscopus trochilus* and Blackcap *Sylvia atricapilla* were recorded each one in more than 90% sections (N=165), and on particular transects their dominance varied between 4 and 11% (Table 3, App.1, 2). The overall proportion of dominants and eudominants was 48.5%. In overall, there were 10 subdominant species comprising 32.5% of all breeding pairs. Relatively numerous were also the following species: Turtle Dove *Streptopelia turtur*, Stock Dove *Columba oeans*, Black Woodpecker *Dryocopus martius*, Golden Oriole *Oriolus oriolus*, and Raven *Corvus corax* (Table 3, App. 1, 2).

Residents were represented by 24 species and comprised 57.5% of all breeding pairs. Short-distance migrants were almost twice more common than long-distance migrants (Table 4). Insectivores were by far the most numerous feeding guild represented by 41 species and 88.9% of all breeding pairs. Granivores were represented only by four species and comprised 8% of all breeding pairs. All other guilds comprised the remaining 3.1% (Table 4). Among insectivores the most numerous was the group feeding in foliage (Table 4). Almost half of all birds nested on trees or shrubs, 28% in herbaceous vegetation and 20% in tree holes (Table 4).

Tab 1: Transects designed in pine forests near Niemodlin. H' – Shannon's Diversity Index, J' – Pielou's Evenness Index, D – Simpson's Diversity Index.

Transect number	Number of sections	Total length [km]	Number of breeding pairs	Number of species	H'	J'	D
I	22	9.1	529	38	1.31	0.83	0.93
II	22	9.5	485	37	1.28	0.82	0.93
III	22	8.8	530	44	1.38	0.84	0.94
IV	20	8.8	543	42	1.38	0.85	0.94
V	18	8.0	432	43	1.38	0.84	0.94
VI	20	8.0	599	43	1.20	0.73	0.95
VII	23	14.7	885	40	1.37	0.86	0.94
VIII	18	10.8	705	39	1.37	0.86	0.94

Tab 2: Parameters and indexes of avian assemblages in Niemodlin (managed) and Białowieża (natural) Forests.

Parameter	**Niemodlin Forest**	**Białowieza Forest**
Number of species	55	46
Number of pairs	4708	1528
Overall density	60.6	59.9
Cumulative dominance (%)	48.7	53.5
Simpson's Diversity Index (D)	0.94	0.93
Shannon's Diversity Index (H')	1.39	1.38
Pielou's Evenness Index (J')	0.80	0.83

Tab 3: Breeding bird communities in lowland coniferous forests in Niemodlin (managed) and Białowieża (natural) Forests. See the text (section 'Methods) for the explanation of guilds' abbrevaitions. Dominant species indicated with bold case.

Species	**Guilds**			**Niemodlin Forest**		**Białowieża Forest**	
	migrant	**feeding**	**nesting**	**p/10ha**	**D%**	**p/10ha**	**D%**
Fringilla coelebs	S	Ic	T	8.5	14.1	10.2	17.1
Phylloscopus collybita	S	Ic	V	5.5	9.1	4.9	8.3
Phylloscopus trochilus	L	Ic	V	4.3	7.1	0.1	0.1
Turdus merula	S	Ig	T	3.9	6.4	2.0	3.3
Erithacus rubecula	S	Ig	V	3.6	6.0	6.0	10.0
Sylvia atricapilla	S	Ic	T	3.6	6.0	4.1	6.8
Parus ater	R	Ic	H	2.8	4.7	2.8	4.6
Emberiza citrinella	R	G	T	2.7	4.5	-	-
Anthus trivialis	S	Ig	G	2.5	4.1	1.3	2.2
Turdus philomelos	S	Ig	T	2.3	3.8	3.0	5.0
Dendrocopos major	R	Ib	H	1.9	3.2	1.5	2.6
Parus major	R	Ic	H	1.9	3.1	2.4	4.0
Regulus regulus	R	Ic	T	1.6	2.6	1.9	3.2
Troglodytes troglodytes	S	Ig	V	1.4	2.3	0.7	1.2
Phylloscopus sibilatirx	L	Ic	V	1.3	2.2	3.5	5.9
Streptopelia turtur	L	G	T	1.3	2.1	-	-
Garrulus glandarius	R	O	T	1.2	1.9	0.5	0.8
Parus cristatus	R	Ic	H	1.2	1.9	1.0	1.7
Prunella modularis	S	Ic	V	0.9	1.4	2.1	3.5
Cuculus canorus	L	Ic	T	0.8	1.4	0.6	0.9
Sitta europaea	R	Ib	H	0.8	1.3	0.7	1.1
Columba palumbus	S	G	T	0.5	0.8	0.8	1.3
Sturnus vulgaris	S	Ig	H	0.5	0.8	-	-
Coccothr. coccothraustes	S	Ic	T	0.5	0.7	0.4	0.6
Dryocopus martius	R	Ib	H	0.5	0.7	0.3	0.5
Oriolus oriolus	L	Ic	T	0.5	0.7	0.3	0.4
Corvus corax	R	O	T	0.4	0.7	-	-
Columba oenas	S	G	H	0.4	0.6	0.6	1.6
Sylvia curruca	L	Ic	T	0.4	0.6	-	-
Parus caeruleus	R	Ic	H	0.3	0.6	1.0	1.7

Certhia brachydactyla	R	Ib	H	0.3	0.5	-	-
Phoenicurus phoenicurus	L	Ic	H	0.3	0.5	0.9	1.5
Sylvia communis	L	Ic	T	0.3	0.5	-	-
Certhia familiaris	R	Ib	H	0.3	0.4	1.6	2.7
Regulus ignicapillus	S	Ic	T	0.3	0.4	-	-
Muscicapa striata	L	Ic	H	0.2	0.4	0.6	1.0
Lullula arborea	S	Ig	G	0.2	0.3	-	-
Apus apus	L	Ic	H	0.2	0.3	-	-
Parus montanus	R	Ic	H	0.1	0.2	0.7	1.4
Aegithalos caudatus	R	Ic	T	0.1	0.2	-	-
Buteo buteo	R	O	T	0.1	0.1	-	-
Lanius collurio	L	Ic	T	0.1	0.1	-	-
Pyrrhula pyrrhula	S	Ic	T	0.1	0.1	0.4	0.7
Anas platyrhynchos	S	O	G	0.1	0.1	-	-
Grus grus	S	O	G	0.1	0.1	-	-
Parus palustris	R	Ic	H	0.1	0.1	0.2	0.2
Picus canus	R	Ib	H	0.1	0.1	-	-
Carduelis spinus	S	Ic	T	<0.1	0.1	0.6	1.1
Ficedula hypoleuca	L	Ic	H	<0.1	0.1	0.3	0.5
Jynx torquilla	S	Ic	H	<0.1	0.1	-	-
Turdus viscivorus	S	Ic	T	<0.1	0.1	<0.1	<0.1
Accipiter gentilis	R	O	T	<0.1	<0.1	-	-
Motacilla alba	S	Ig	G	<0.1	<0.1	-	-
Accipiter nisus	S	O	T	<0.1	<0.1	<0.1	0.1
Ficedula albicollis	L	Ic	H	-	-	1.5	2.5
Bonasa bonasia	R	G	G	-	-	0.4	0.7
Picoides tridactylus	R	Ib	H	-	-	0.3	0.5
Loxia curvirostra	R	G	T	-	-	0.3	0.5
Scolopax rusticola	S	Ig	G	-	-	0.2	0.3
Aegolius funereus	R	O	H	-	-	<0.1	<0.1
Glaucidium passerinum	R	O	H	-	-	<0.1	<0.1
Tringa ochropus	L	Ig	T	-	-	<0.1	<0.1
Strix aluco	R	O	H	-	-	<0.1	<0.1
Dendrocopos medius	R	Ib	H	-	-	<0.1	<0.1
Dendrocopos leucotus	R	Ib	H	-	-	<0.1	<0.1

Discussion

Species diversity and community structure can be affected in lowland coniferous forests by the following factors: heterogeneity and diversity of forest stand, tree stand age, landscape-scale disturbance (e.g. insect gradation, fire outbreaks), long-term and large-scale changes (e.g. climate change, change of water regime); density dependent winter mortality of both residents and migrants. Small patches of forest clearings and young tree cultivations may increase the amount of forest edge, without fragmenting the landscape. The density of forest species may increase soon after the onset of logging in surrounding areas. Also the admixture of deciduous trees in pine forests may increase bird diversity (Niemi *et al.* 1998). The variance in population density and dominance of particular species on transects may account on different ages of tree stands, and to lesser extend on the variation in food abundance, logging, nest-box installment or interactions with competitors and predators (Graczyk, Wąs 1966, 1967 1968ab; Ranoszek, Witkowski 1975; Borowiec, Grabiński 1982).

It is interesting to compare the avian communities in managed (this study) and primavel pine forests (Tomiałojć et al. 1984; Wesołowski, Tomiałojć 2004; Wesołowski et al. 2010). The avian communities in primavel pine forests were investigated by means of the mapping method (Wesołowski et al. 2010), while those in managed pine forests were conducted by means of the line transect method (this study). Since diffenet counting methods have been applied, the results are not stricktly comparable. Especially population densities of species with low vocal activity or low densities may differ, as in the line transect method less time is devoted for counting so that some pairs of those species could have passed undetected. In regard to diversity indices and population parameters, the comparison is much more accurate. The overall number of bird species recorded in primeval pine forests (N=46) was lower than that in managed pine forests (N=55), although this difference was not statistically significant (x^2=0.82; p>0.05). Other indexes such as overall density, cumulative dominance, diversity and evenness were unexpectedly very similar in both habitat types compared (Table 2).

Contrary to expectations, densities of most bird species (those breeding in densities higher than 1 pair per 10 ha) in managed lowland coniferous forests of Niemodlin were statistically similar (p>0.05) to those in natural primeval lowland coniferous forests of Białowieża (Table 3) ($F_{1, 128}$ = 0.0005, P=0.989). The preference of ecotones by some forest species have been well-documented (e.g. Borbaro et al. 2012; Kopij 2013). Four groups can be distinguished in this regard (Villard 1998): forest-interior specialists (Wood Warbler *Phylloscopus sibilatrix*), interior-edge generalists (e.g. Chiffchaff), edge specialists (e.g. Yellow Bunting), and field-edge specialists (e.g. Ortolan Bunting *Emberiza hortulana*). Ecotones are abundant in Niemodlin Forest, while in Białowieża Forest they are virtually absent. The Willow Warbler, Yellow Bunting *Emberiza citrinella* and Turtle Dove nested in quite high densities in the managed forests, but were virtually absent in the primeval forests (Table 3), while the Collared Flycatcher *Ficedula albicollis* was relatively common in the primeval forests but absent in the managed forests (Table 3). The Willow Warbler, and Yellow Bunting prefer ecotones. Somewhat difficult to explain is, however, the absence of Turtle Dove in primeval pine forests. It appears, that this species also prefers the presence of ecotones or larger open spaces in forests.

The proportions of three main migration groups were similar in managed and natural pine forests. It has been shown, however, that the proportion varies considerably in relation to the latitude. The further north, the higher proportion of long-distance migrants. While in temperate coniferous forests there are 58-63% of residents and only 13-16% long-distance migrants (Tomiałojć, Wesołowski et al. 2004, and this study), in boreal forests residents comprise 5-15%, short-distance migrants 35-65% and long-distance migrants 30-50%. In Finland, 30% species and 40% individuals winter in Africa south of Sahara, and 45% species and 48% individuals are short-distance migrants (Niemi *et al*. 1998).

Feeding guilds were similar in managed and primeval pine forests, except for bark-feeding insectivores and granivores (Table 4). The former were more numerous in primeval, while the later in the managed pine forests. The proportion of hole-nesting birds was higher in natural, while that of tree/shrub-nesting birds was higher in managed pine forests (Table 4).

Species, such as the Robin *Erithacus rubecula*, Wood Warbler and Dunnock *Prunella modularis* nested in much higher densities in primeval pine forests, while the Blackbird, Tree Pipit *Anthus trivialis*, and Wren *Troglodytes troglodytes* were more common in managed pine forests. Primeval forests have richer and denser undergrowth than managed forests, and such habitats are more suitable for Robin, Wood Warbler and Dunnock. It appears, therefore, that with the conversion of natural coniferous forests into intensively-managed ones, more bird species have increased than decreased in numbers. In general, common species became more numerous, while some uncommon species either decresed or increased.

Tab 4: Comparison of the main guilds of breeding birds in managed (Niemodlin Forest) and unmanaged forest (Białowieża Forest). None of these differences are statistically significant (x^2-test).

Guilds	Niemodlin Forest		Białowieża Forest	
	N of species	Proportion	N of species	Proportion
Migration				
Long-distance migrants	11	16.0	9	12.6
Short-distance migrants	20	26.9	20	25.6
Residents	24	57.5	17	62.8
Feeding				
Granivorous	4	8.0	4	4.1
Insectivorous				
bark	6	3.0	9	7.3
leaves	27	59.4	22	67.7
ground	8	23.7	6	22.0
Other	10	3.1	5	0.7
Nesting				
Ground	5	4.7	3	3.2
Holes	19	19.6	21	28.1
Trees/Shrubs	25	48.0	15	41.7
Herbaceous vegetation	6	28.1	6	29.0

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Appendix 1: Breeding bird assemblage in the pine forests near Niemodlin. Dominant species indicated with bold case.

Transect	Index	Frequency		Density				Dominance				Pairs - total		
		N	%	p/10ha	Min	Max	Var.	Ave.	Min	Max	Var.	N	Ave.	Var.
Fringilla coelebs	100.0	165	100.0	8.52	7.25	9.88	0.77	14.06	12.89	18.76	3.78	662	82.75	415.36
Phylloscopus collybita	64.5	165	100.0	5.50	4.95	6.50	0.29	9.07	8.09	10.59	0.55	427	53.38	136.55
Phylloscopus trochilus	50.3	148	89.7	4.29	2.50	6.02	1.63	7.07	3.83	10.65	5.59	333	41.63	58.84
Turdus merula	45.3	154	93.3	3.86	2.74	5.13	0.67	6.37	5.11	8.10	1.47	300	37.50	64.86
Erithacus rubecula	42.7	128	77.6	3.64	1.82	6.39	2.60	6.01	2.95	9.79	5.86	283	35.38	589.98
Sylvia atricapilla	42.3	158	95.8	3.60	2.63	5.00	0.55	5.95	4.60	7.42	1.00	280	35.00	74.00
Parus ater	33.1	133	80.6	2.82	2.13	3.64	0.32	4.65	3.68	6.04	0.62	219	27.38	46.27
Emberiza citrinella	31.7	122	73.9	2.70	1.97	4.43	0.78	4.46	3.28	7.18	1.52	210	26.25	49.36
Anthus trivialis	29.2	130	78.8	2.48	1.63	3.63	0.44	4.10	2.71	6.24	1.52	193	24.13	17.55
Turdus philomelos	26.9	122	73.9	2.29	0.88	2.75	0.38	3.78	1.62	4.95	1.20	178	22.25	90.79
Dendrocopos major	22.8	115	69.7	1.94	1.37	2.31	0.10	3.21	2.68	3.55	0.08	151	18.88	34.41
Parus major	22.4	95	57.6	1.90	0.50	2.87	0.63	3.14	0.93	4.75	1.60	148	18.50	148.29
Regulus regulus	18.4	97	58.8	1.57	0.88	2.00	0.13	2.59	1.62	3.16	0.20	122	15.25	38.21
Troglodytes troglodytes	16.0	85	51.5	1.36	0.75	2.22	0.19	2.25	1.39	3.40	0.49	106	13.25	36.50
Phylloscopus sibilatirx	15.7	62	37.6	1.34	0.63	2.38	0.50	2.21	1.17	3.95	1.23	104	13.00	118.86
Streptopelia turtur	14.7	68	41.2	1.25	0.44	2.84	0.73	2.06	0.76	4.60	1.55	97	12.13	48.98
Garrulus glandarius	13.7	80	48.5	1.17	0.88	1.82	0.11	1.93	1.51	2.95	0.22	91	11.38	4.27
Parus cristatus	13.7	83	50.3	1.17	0.95	1.36	0.02	1.93	1.67	2.27	0.06	91	11.38	17.13
Prunella modularis	10.0	59	35.8	0.85	0.27	1.48	0.17	1.40	0.45	2.39	0.46	66	8.25	11.93
Cuculus canorus	9.8	60	36.4	0.84	0.53	1.38	0.07	1.38	0.99	1.85	0.12	65	8.13	3.55
Sitta europaea	9.2	46	27.9	0.79	0.11	1.56	0.24	1.30	0.18	2.60	0.60	61	7.63	51.98
Columba palumbus	5.9	37	22.4	0.50	0.32	1.25	0.10	0.83	0.56	1.67	0.14	39	4.88	5.55
Sturnus vulgaris	5.4	25	15.2	0.46	0.00	0.82	0.08	0.76	0.00	1.36	0.22	36	4.50	13.43
Coccothr. coccothraustes	5.3	23	13.9	0.45	0.00	1.11	0.17	0.74	0.00	1.70	0.47	35	4.38	3.70
Dryocopus martius	5.3	33	20.0	0.45	0.00	1.13	0.11	0.74	0.00	1.50	0.20	35	4.38	9.98
Oriolus oriolus	5.3	35	21.2	0.45	0.21	1.00	0.07	0.74	0.41	1.39	0.14	35	4.38	19.13
Corvus corax	5.0	33	20.0	0.42	0.09	0.68	0.04	0.70	0.14	1.13	0.12	33	4.13	2.70
Columba oenas	4.5	27	16.4	0.39	0.00	1.36	0.21	0.64	0.00	2.21	0.57	30	3.75	16.21
Sylvia curruca	4.4	29	17.6	0.37	0.00	1.00	0.13	0.62	0.00	1.39	0.30	29	3.63	7.98

Parus caeruleus	3.9	20	12.1	0.33	0.00	0.83	0.09	0.55	0.00	1.28	0.21	26	3.25	12.50
Certhia brachydactyla	3.6	20	12.1	0.31	0.00	0.75	0.05	0.51	0.00	1.24	0.13	24	3.00	11.43
Phoenicurus phoenicurus	3.5	21	12.7	0.30	0.00	0.91	0.13	0.49	0.00	1.47	0.34	23	2.88	3.55
Sylvia communis	3.5	23	13.9	0.30	0.00	0.75	0.05	0.49	0.00	1.39	0.18	23	2.88	9.55
Certhia familiaris	3.0	20	12.1	0.26	0.11	0.37	0.01	0.42	0.19	0.62	0.02	20	2.50	1.14
Regulus ignicapillus	3.0	20	12.1	0.26	0.00	0.75	0.06	0.42	0.00	1.00	0.10	20	2.50	3.71
Muscicapa striata	2.7	18	10.9	0.23	0.00	0.56	0.03	0.38	0.00	0.85	0.08	18	2.25	4.79
Lullula arborea	2.3	13	7.9	0.19	0.00	0.63	0.04	0.32	0.00	0.83	0.07	15	1.88	2.98
Apus apus	2.1	7	4.2	0.18	0.00	1.02	0.12	0.30	0.00	1.66	0.30	14	1.75	9.07
Parus montanus	1.7	11	6.7	0.14	0.00	0.38	0.03	0.23	0.00	0.57	0.06	11	1.38	1.98
Aegithalos caudatus	1.1	7	4.2	0.09	0.00	0.27	0.01	0.15	0.00	0.46	0.04	7	0.88	2.13
Buteo buteo	0.8	5	3.0	0.06	0.00	0.27	0.01	0.11	0.00	0.45	0.03	5	0.63	1.98
Lanius collurio	0.8	5	3.0	0.06	0.00	0.25	0.01	0.11	0.00	0.46	0.03	5	0.63	0.84
Pyrrhula pyrrhula	0.8	5	3.0	0.06	0.00	0.22	0.01	0.11	0.00	0.38	0.02	5	0.63	0.55
Anas platyrhynchos	0.6	4	2.4	0.05	0.00	0.23	0.01	0.08	0.00	0.38	0.02	4	0.50	0.57
Grus grus	0.6	4	2.4	0.05	0.00	0.13	0.00	0.08	0.00	0.23	0.01	4	0.50	0.29
Parus palustris	0.6	4	2.4	0.05	0.00	0.20	0.01	0.08	0.00	0.34	0.02	4	0.50	1.14
Picus canus	0.6	4	2.4	0.05	0.00	0.23	0.01	0.08	0.00	0.37	0.02	4	0.50	0.57
Carduelis spinus	0.5	3	1.8	0.04	0.00	0.14	0.00	0.06	0.00	0.23	0.01	3	0.38	0.55
Ficedula hypoleuca	0.5	3	1.8	0.04	0.00	0.14	0.00	0.06	0.00	0.23	0.01	3	0.38	0.55
Jynx torquilla	0.5	3	1.8	0.04	0.00	0.21	0.01	0.06	0.00	0.41	0.02	3	0.38	0.55
Turdus viscivorus	0.5	3	1.8	0.04	0.00	0.13	0.00	0.06	0.00	0.23	0.01	3	0.38	0.27
Accipiter gentilis	0.3	2	1.2	0.03	0.00	0.11	0.00	0.04	0.00	0.19	0.01	2	0.25	0.21
Motacilla alba	0.3	2	1.2	0.03	0.00	0.13	0.00	0.04	0.00	0.17	0.01	2	0.25	0.21
Accipiter nisus	0.2	1	0.6	0.01	0.00	0.11	0.00	0.02	0.00	0.19	0.00	1	0.13	0.13

Appendix 2: Density (Den. = 10 p/10 ha) and dominance (Dom.) of breeding birds on each transects in pine forests near Niemodlin. Dominat species indicated with bold case.

Transect number→	I		II		III		IV		V		VI		VII		VII	
Species ↓	Den.	Dom.	Den.	Dom.	Den.	Dom.	Den.	Dom.	Den.	Dom.	Den.	Dom.	Den.	Dom.	Den.	Dom.
Fringilla coelebs	8.46	14.56	9.58	18.76	7.84	13.02	7.95	12.89	7.25	13.43	9.88	13.19	8.44	14.01	8.70	13.33
Phylloscopus collybita	6.15	10.59	4.95	9.69	5.45	9.06	5.45	8.84	5.00	9.26	6.50	8.68	5.37	8.93	5.28	8.09
Phylloscopus trochilus	5.16	8.88	4.00	7.84	4.66	7.74	6.02	9.76	5.75	10.65	4.88	6.51	2.86	4.75	2.50	3.83
Turdus merula	4.51	7.75	2.74	5.36	4.55	7.55	3.30	5.34	4.38	8.10	5.13	6.84	3.54	5.88	3.33	5.11
Erithacus rubecula	2.97	5.10	2.21	4.33	2.95	4.91	1.82	2.95	2.38	4.40	3.25	4.34	5.37	8.93	6.39	9.79
Sylvia atricapilla	3.74	6.43	3.79	7.42	4.09	6.79	2.84	4.60	2.63	4.86	5.00	6.68	3.27	5.42	3.70	5.67
Parus ater	2.75	4.73	2.74	5.36	3.64	6.04	2.27	3.68	2.13	3.94	3.50	4.67	2.45	4.07	3.24	4.96
Emberiza citrinella	1.98	3.40	2.11	4.12	3.07	5.09	4.43	7.18	2.38	4.40	3.63	4.84	1.97	3.28	2.69	4.11
Anthus trivialis	3.63	6.24	2.53	4.95	2.61	4.34	2.05	3.31	3.00	5.56	3.13	4.17	1.63	2.71	2.04	3.12
Turdus philomelos	2.75	4.73	2.53	4.95	1.82	3.02	2.27	3.68	0.88	1.62	2.38	3.17	2.72	4.52	2.50	3.83
Dendrocopos major	1.98	3.40	1.37	2.68	1.82	3.02	2.05	3.31	1.63	3.01	2.25	3.01	2.04	3.39	2.31	3.55
Parus major	1.98	3.40	1.58	3.09	1.59	2.64	1.25	2.03	0.50	0.93	1.63	2.17	2.86	4.75	2.87	4.40
Regulus regulus	1.54	2.65	1.37	2.68	1.48	2.45	1.36	2.21	0.88	1.62	2.00	2.67	1.90	3.16	1.76	2.70
Troglodytes troglodytes	1.10	1.89	1.58	3.09	1.25	2.08	1.02	1.66	0.75	1.39	1.38	1.84	1.36	2.26	2.22	3.40
Phylloscopus sibilatirx	0.77	1.32	0.63	1.24	1.14	1.89	0.91	1.47	0.75	1.39	0.88	1.17	2.38	3.95	2.31	3.55
Streptopelia turtur	0.44	0.76	0.63	1.24	1.14	1.89	2.84	4.60	1.00	1.85	2.38	3.17	0.75	1.24	1.30	1.99
Garrulus glandarius	0.88	2.27	0.95	1.86	0.91	2.26	1.82	2.03	0.88	2.08	1.38	1.67	1.22	1.69	1.30	1.84
Parus cristatus	1.32	1.51	0.95	1.86	1.36	1.51	1.25	2.95	1.13	1.62	1.25	1.84	1.02	2.03	1.20	1.99
Prunella modularis	0.66	1.13	1.16	2.27	0.45	0.75	1.48	2.39	0.88	1.62	1.25	1.67	0.27	0.45	1.02	1.56
Cuculus canorus	0.77	1.32	0.53	1.03	1.02	1.70	0.91	1.47	1.00	1.85	1.38	1.84	0.68	1.13	0.65	0.99
Sitta europaea	0.66	1.13	0.53	1.03	0.23	0.38	0.11	0.18	0.50	0.93	0.88	1.17	1.56	2.60	1.20	1.84
Columba palumbus	0.33	0.57	0.32	0.62	0.45	0.75	0.68	1.10	0.38	0.69	1.25	1.67	0.34	0.56	0.46	0.71
Sturnus vulgaris	0.33	0.57	0.00	0.00	0.45	0.75	0.11	0.18	0.63	1.16	0.75	1.00	0.82	1.36	0.46	0.71
Coccothr. coccothraustes	0.55	0.57	0.21	0.41	0.00	0.75	0.00	0.55	0.88	1.39	0.13	1.34	0.54	0.56	1.11	0.57
Dryocopus martius	0.22	0.38	0.00	0.00	0.45	0.75	0.34	0.55	0.50	0.93	1.13	1.50	0.61	1.02	0.37	0.57
Oriolus oriolus	0.33	0.95	0.21	0.41	0.45	0.00	0.34	0.00	0.75	1.62	1.00	0.17	0.34	0.90	0.37	1.70
Corvus corax	0.66	1.13	0.32	0.62	0.68	1.13	0.57	0.92	0.50	0.93	0.50	0.67	0.27	0.45	0.09	0.14

Columba oenas	0.00	0.00	0.00	0.00	0.45	0.75	1.36	2.21	0.63	1.16	0.63	0.83	0.00	0.00	0.37	0.57
Sylvia curruca	0.22	0.38	0.11	0.21	0.68	1.13	0.00	0.00	0.75	1.39	1.00	1.34	0.27	0.45	0.19	0.28
Parus caeruleus	0.00	0.00	0.11	0.21	0.11	0.19	0.34	0.55	0.00	0.00	0.50	0.67	0.54	0.90	0.83	1.28
Certhia brachydactyla	0.00	0.00	0.11	0.21	0.23	0.38	0.23	0.37	0.25	0.46	0.38	0.50	0.75	1.24	0.28	0.43
Phoenicurus phoenicurus	0.11	0.19	0.00	0.00	0.80	0.57	0.91	0.74	0.38	1.39	0.38	0.33	0.00	0.45	0.09	0.43
Sylvia communis	0.11	0.19	0.00	0.00	0.34	1.32	0.45	1.47	0.75	0.69	0.25	0.50	0.27	0.00	0.28	0.14
Certhia familiaris	0.22	0.38	0.32	0.62	0.11	0.19	0.23	0.37	0.25	0.46	0.25	0.33	0.27	0.45	0.37	0.57
Regulus ignicapillus	0.00	0.00	0.11	0.21	0.34	0.57	0.34	0.55	0.25	0.46	0.75	1.00	0.07	0.11	0.37	0.57
Muscicapa striata	0.11	0.19	0.00	0.00	0.23	0.38	0.23	0.37	0.00	0.00	0.25	0.33	0.34	0.56	0.56	0.85
Lullula arborea	0.11	0.19	0.11	0.21	0.11	0.19	0.11	0.18	0.25	0.46	0.63	0.83	0.00	0.00	0.37	0.57
Apus apus	0.00	0.00	0.11	0.21	0.11	0.19	1.02	1.66	0.13	0.23	0.25	0.33	0.00	0.00	0.00	0.00
Parus montanus	0.00	0.00	0.00	0.00	0.34	0.57	0.34	0.55	0.13	0.23	0.38	0.50	0.00	0.00	0.09	0.14
Aegithalos caudatus	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.25	0.46	0.13	0.17	0.27	0.45	0.00	0.00
Buteo buteo	0.11	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.27	0.45	0.00	0.00
Lanius collurio	0.00	0.00	0.00	0.00	0.11	0.19	0.00	0.00	0.25	0.46	0.25	0.33	0.00	0.00	0.00	0.00
Pyrrhula pyrrhula	0.22	0.38	0.11	0.21	0.11	0.19	0.11	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Anas platyrhynchos	0.00	0.00	0.00	0.00	0.23	0.38	0.11	0.18	0.13	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Grus grus	0.00	0.00	0.11	0.21	0.00	0.00	0.11	0.18	0.13	0.23	0.00	0.00	0.07	0.11	0.00	0.00
Parus palustris	0.11	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.20	0.34	0.00	0.00
Picus canus	0.00	0.00	0.00	0.00	0.11	0.19	0.23	0.37	0.13	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Carduelis spinus	0.00	0.00	0.11	0.21	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.23	0.00	0.00
Ficedula hypoleuca	0.00	0.00	0.00	0.00	0.11	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.23	0.00	0.00
Jynx torquilla	0.00	0.00	0.21	0.41	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.17	0.00	0.00	0.00	0.00
Turdus viscivorus	0.11	0.19	0.11	0.21	0.00	0.00	0.00	0.00	0.13	0.23	0.00	0.00	0.00	0.00	0.00	0.00
Accipiter gentilis	0.11	0.19	0.00	0.00	0.00	0.00	0.11	0.18	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Motacilla alba	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.13	0.17	0.00	0.00	0.09	0.14
Accipiter nisus	0.00	0.00	0.00	0.00	0.11	0.19	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Number of breeding pairs	529	100	485	100	530	100	543	100	432	100	599	100	885	100	705	100