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Formation of bird communities in the forest sample plots undergoing the action of industrial pollution in the Ojców National Park

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Abstract. In 1973-1990 counts of birds were carried out in two permanent sample plots in the territory of the Ojców National Park, undergoing degradation owing to the action of industrial pollution: in fresh oak-pine forest *Pino-Quercetum*, where the process of remodelling of the stand was under way (Plot I) and in a more stable deciduous forest *Tilio-Carpinetum* and *Pino-Quercetum* var. *Fagus silvatica* (Plot II). The numbers of breeding species ranged from 18 to 25 ($\bar{x}$=21.4, SD=±2.13, v=9.95) in the oak-pine forest and from 15 to 23 ($\bar{x}$=18.41, SD=±1.97, v=10.70) in the deciduous forest. In the deciduous stand the density of nesting birds was changing to a relatively small extent ($\bar{x}$=76.82 pairs/10 ha, SD=±5.73, v=7.46), whereas in the withering pine forest it fell by about one-third in 1973-1978 and from 130-107 to a level of 61-81 ($\bar{x}$=70.42, SD=±6.68, v=9.48) in 1979-1990. Considerably larger structural changes brought about by the degradation of the stand owing to industrial pollution have been found in the bird community of the oak-pine forest than in that of the deciduous forest.

Key words: birds, censuses, long-term research, changes in bird communities, industrial pollution, Ojców National Park, South Poland.

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I. INTRODUCTION

The work presented is the fruit of a 18-year study undertaken to establish qualitative and quantitative changes in the bird communities in two forest sample plots varying in respect of their biotopes, situated within the range of the influences of industrial pollution. The study was carried out in the Ojców National Park, in the region where the harmful action of industry upon nature is particularly well seen (KAMIENIECKI & SZCZĘSNY 1972; GRESZTA 1975; GRODZIŃSKA 1978, 1980, 1985; ŚWIEBODA 1980; ZĄBECKI 1984). The studies were monitoring in nature, permitting the ascertainment how the bird communities of various forest associations react to these kinds of environmental changes.

The avian fauna of the Ojców National Park was studied in 1964-1977 (BOCHEŃSKI & OLEŚ 1977), however, so far no ecological study of the ornithofauna focussed on bioindicative problems have been unfolded here.

I wish to thank heartily to the Management of the Ojców National Park for making it possible for me to carry out my study in the Park, to Mr Józef PARTYKA, the Deputy Director of the Park, for giving me access to the data concerning the level of pollution with industrial fumes and dust, to the Management of the Institute of Systematic and Evolution of Animals for full support and various assistance in the realization of this work, to Prof. Z. BOCHEŃSKI for instruction given to me during this work and to Prof. Z. GŁOWACIŃSKI for valuable directions and help in preparing the material.

II. STUDY AREA AND METHOD

The Ojców National Park (ONP) is situated in the southern part of the Kraków-Wieluń Jurassic Ridge (50°20'N, 19°50'E), covering a total area of 1590 ha. It includes the valleys of two streams: the Prądnik and Sąspówka, together with the adjacent slopes and part of the upland. A considerable part of the Park, 1257 ha, is occupied by forest communities. The main species going to the making of the forest are: pine – 32% of the forest area, fir – 24%, beech – 20% and spruce – 10% (Plan urządzenia, 1972). The isolation of deadwood in ONP, mainly of coniferous species, i.e. fir, pine and spruce, was found as the sixties (GOETEL et al. 1971; CAPECKI & TUTEJA 1977). In the latest 20 years this process has not been brought to a stop but, on the contrary, we can observe a distinct retreat of coniferous trees, notably fir trees from the stand (ZĄBECKI 1984, 1991; GĄDEK 1990). At present half the coniferous stands of ONP are damaged to a high degree and the other half to a very high degree (ZĄBECKI & WIERUS, in press). In its further consequence this leads to a change in the plant associations: the decline of the association *Pino-Quercetum*, which occupied a half of the Park area in 1959-1961 (MEDWECKA-KORNAŚ & KORNAŚ 1963) and the expansion of sycamore maple wood *Phyllito-Aceretum* and epilithic beech woods *Dentario glandulosae-Fagetum* (MICHALIK 1991). A sample plot (Plot I) was founded in 1973 in the environment that was undergoing the greatest transformations, namely, in the fresh oak-pine forest *Pino-Quercetum*. In 1974 a comparative plot (Plot II) was established in a deciduous stand with a small admixture of coniferous trees and so in an environment in which the presumable changes in the stand would not have been so intense as in the stand with prevailing conifers (Fig. 1).

Plot I, situated on the upland, 4 ha in area at first (1973-1975), was extended to 10 ha in 1976. It was grown over by pines about 70-80 years old and singly by spruce, fir, beech and oak. Some trees, mainly pines, making up the crown layer, were already dry at the time when this investigations was started. The understorey present in 60% of the plot area, with its cover often reaching 100%, consisted mainly of young fir and spruce, as well as hazel, black-berried, red-berried elder and buckthorn. Young firs and spruces, in particu-

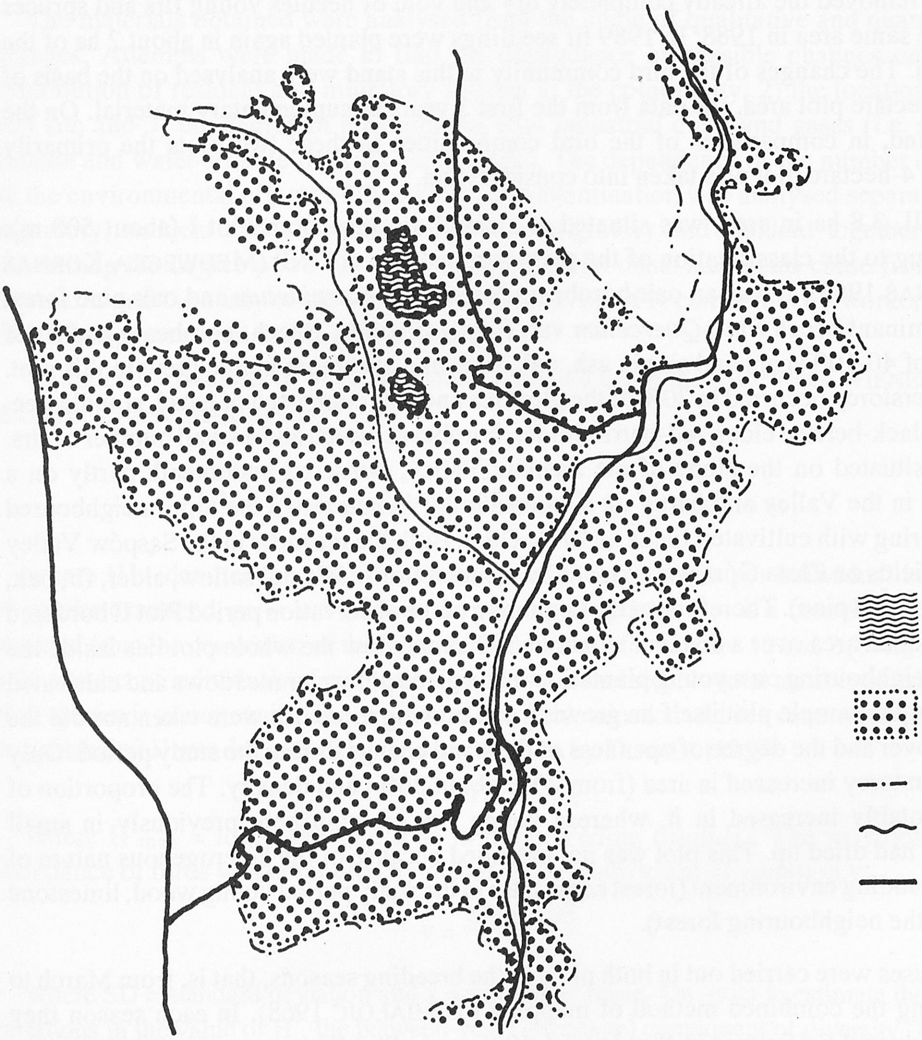

Fig. 1. A diagramatic map of a part of ONP, showing the situation of the sample plots; a – sample plots, b – wooded area, c – boundary of ONP, d – streams, e – roads.

lar, grew in abundant thick clumps, covering even patches several ares in area. Owing to the further continuous withering of the pines, which formed the crown layer, in the course of investigation the stand was becoming increasingly open, thinner. Nearly all the young coniferous trees going into the making of the understorey had also dried up. In 1990 in a half of the sample plot, i.e. about 5 ha, there grew scarcely 85 young coniferous trees below 2.5 m in height. None of them had a thick crown, whereas most of them were characterized by their deformed trunks. The following growing and nursing measures were taken in the sample plot in the study area period: in 1975 alder, fir, oak, lime and sycamore maple were planted in an area of about 1 ha, but except for several alders all the seedlings perished. In 1987 part of the dry trees were removed from a half of the sample plot (about 5 ha) and so were removed the already completely dry and void of needles young firs and spruces from the same area in 1988. In 1989 fir seedlings were planted again in about 2 ha of the plot area. The changes of the bird community in this stand were analysed on the basis of the 10-hectare plot area, the data from the first 3 years as suplementary material. On the other hand, in comparisons of the bird communities in these two plots the primarily founded 4-hectare plot was taken into consideration.

Plot II, 3.8 ha in area, was situated at a small distance from Plot I (about 500 m). According to the classification of the plant associations of ONP (MEDWECKA-KORNAŚ & KORNAŚ 1963), it was an oak-hornbeam forest *Tilio-Carpinetum* and oak-pine forest with dominant beech *Pino-Quercetum* var. *Fagus silvatica*. Beech, hornbeam and fir of the age of 40-100 years and singly ash, oak, lime and sycamore maple grew in this plot. The understorey occurred in 20% of the plot area and was composed of hazel, spindle tree, rowan, black-berried elder, red-berried elder, hornbeam, beech and a small number of firs. Plot II, situated on the slope of the Sąspów Valley, bordered underneath partly on a meadow in the Valley and partly on a wood similar in nature. At the top it neighboured on a clearing with cultivated fields on Złota Góra. Both the meadow in the Sąspów Valley and the fields on Złota Góra were gradually wooded from 1974 on (sallow, alder, fir, oak, larch, lime and pine). Therefore, at the beginning of the observation period Plot II bordered upon an open area over a distance of about 300 m and now the whole plot lies inside the forest (neighbouring on a young plantation in the place of former meadows and cultivated fields). In the sample plot itself no growing and nursing measures were taken nor did the crown cover and the degree of openness of the stand change during the study period. Only the understorey increased in area (from 20 to about 30%) and density. The proportion of rowan notably increased in it, whereas young firs growing here previously in small numbers had dried up. This plot was not extended because of the heterogenous nature of the surrounding environment (forest edge, later in the study period young wood, limestone rocks in the neighbouring forest).

Censuses were carried out in both plots in the breeding seasons, that is, from March to July, using the combined method of mapping (TOMIAŁOJĆ 1968). In each season they were conducted 6-10 times in Plot I and 4-10 times in Plot II.

The counts of birds were carried out from the end of March to mid-July (in very belated spring in 1980 or 1983 the counts were started in mid-April). Assessment took 2-6 hrs each time in Plot I and 1-3 hrs in Plot II. The species are placed in the class of breeding birds if their nests were found, or their behaviour indicated the presence of the nests, or if they were observed at least three times at the same place during the counts (exceptionally at 2 counts at the time when these birds should have incubated eggs or feed chicks). Birds whose territories lay partly in the sample plot and partly outside it (e.g. pairs whose nests were situated several metres from the plot boundary), were counted as 0.5 pair. Apart from the birds recognized as breeding in a given season, the remaining species observed in the sample plots were distinguished as visiting (in Tables I and II, showing the results of observations, are marked with the symbol "+"). These were mainly birds nesting in the neighbourhood of the study area and birds whose breeding territories were larger than the sample plot or nomadic species recorded only in a small number of inspections.

The materials obtained were analysed from the angle of qualitative and quantitative changes. Attempts were made to find the dependence of possible changes on 1) the contribution of resident and migratory species to the community, 2) the location of the nest site and 3) the degree of air pollution with industrial dusts and gases (i.e. sulphur dioxide and water-soluble fluorine compounds). The dependence of the number of birds on the environmental effects of the industrial contamination was analysed separately for migratory, resident and all nesting birds (i.e. migratory and resident together). Data concerning the degree of air pollution with industrial dusts and gases came from measurements and the study of the abiotic environment of OPN carried out by workers of the Park Management and SANEPID in Cracow.

The species diversity of birds (H') was calculated using the SHANNON-WIENER index (LLOYD, ZAR & KARR 1968):

$$H' = \sum_{i=1}^{S} p_i \log_2 p_i \approx C/N \{N \log_{10} N - \sum n_i \log_{10} n_i \}$$

where H' – denotes the size of information expressed in bits per individual in the set of species examined, $p_i \approx n_i/N$, S – is the number of species, C – is a constant (3.321928) obtained from the convertion of the logarithms the bases of which are 10 and 2 (b=2), and n_i – is the number of individuals of each species in the set examined, N – total number of individuals of all species in a community. The structure of species domination within a community (evenness or equitability) J' was determined by the formula given by TRAMER (1969):

$$J' = H'/H'_{max}$$

where $H'_{max} = \log_2 S$ (H' and S as in the preceding formula). The variation of the abundance of birds was computed by means of the coefficient of variation v:

$$v = \frac{SD \times 100}{\bar{x}}$$

where SD = standard deviation and $\bar{x}$ = arithmetic mean. On order to estimate the annual variations in the value of H', the between-year (interstage) component of diversity (DIV_{diff}) was calculated on the basis of the index given by JÄRVINEN and VÄISÄNEN (1976):

$$DIV_{diff} = H'_{TOT} - H'$$

where H'_{TOT} represents diversity throughout the period of a succession phase and H' is the average annual diversity.

For qualitative comparisons of bird communities SØRENSEN's (1948) index was applied:

$$QS = \frac{2c}{(a + b)} \times 100$$

where QS denotes the similarity between sets (communities), a – is the number of species in one set, b – the number of species in the other set and c – the number of species common to both sets under comparison.

Table I

Counts of birds in Plot I (in 1973-75 – 4 ha, in 1976-90 – 10 ha) in fresh oak-pine forest (*Pino-Quercetum*). Figures denote the number of breeding pairs, + – species observed but not nesting in the plot

Species	Number of pairs in consecutive years																					Mean No of pairs/10 ha (1973-1990)
	Area – 4 ha						Area 10 ha															
	No of pairs			Pairs/10 ha			No of pairs															
	1973	1974	1975	1973	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Erithacus rubecula (LINNAEUS, 1758)	6	4.5	6	15	11.2	15	12	14	9	10	8	7	7	9	8	6	7	11	10	9	8	9.79
Fringilla coelebs LINNAEUS, 1758	5	4.5	5	12.5	11.2	12.5	12	10	7	10	7	7	6	7	8	7	12	11	10	8	9	9.29
Sylvia atricapilla (LINNAEUS, 1758)	4	5.5	5.5	10	13.7	13.7	8	10.5	4	6	6	8	7	6	7	5	8	6	5	7	6	7.61
Phylloscopus collybita (VIEILLOT, 1817)	3.5	3.5	4	8.7	8.7	10	10	7	7	6	5	4	6	7	5	6	7	5	4	5	3	7.61
Turdus philomelos C. L. BREHM, 1831	4.5	3.5	4	11.2	8.7	10	10	8	6	5	9	7	2	2	2	2	5	3	5	4	4	5.77
Parus major LINNAEUS, 1758	4	3	3.5	10	7.5	8.7	6	5.5	5	7	4	6	7	5	6	2	7	4	4	4.5	4	5.73
Phylloscopus sibilatrix (BECHSTEIN, 1793)	3.5	2.5	1	8.7	6.2	2.5	3	3	7	7	4	8	8	5	2	6	5	8	4	4	6	5.41
Prunella modularis (LINNAEUS, 1758)	3	4	4	7.5	10	10	8	7	7	5	4	3	3	3	2	3	4	2.5	1	2	3	4.72
Turdus merula LINNAEUS, 1758	3	3.5	4	7.5	8.7	10	8	8	4	3	6	4	5	3	3	1	1	3	3	1	4	4.62
Parus ater LINNAEUS, 1758	1	2	1	2.5	5	2.5	4	4	6	3	3	2	3	3	2	2	3	1.5	2	3	3	3.03
Certhia familiaris LINNAEUS, 1758	2	2.5	2	5	6.2	5	3	3	2	2	3	3	2	3	3	2	4	1	2	1.5	1	2.87
Parus palustris LINNAEUS, 1758	1	1	1.5	2.5	2.5	3.7	5	5	3	2	1	5	2	4	3	3	1	0.5	1	1	1	2.57
Regulus regulus (LINNAEUS, 1758)	0.5	1	1	1.2	2.5	2.5	+	4.5	2	1	2	2	3	2	2	1	3	4	4	4	2	2.15
Pyrrhula pyrrhula (LINNAEUS, 1758)	1	1	1	2.5	2.5	2.5	1	2	1	2	1	2	1	2	1	2	2	1	1	2	3	1.75
Sitta europaea LINNAEUS, 1758	+	0.5	+	+	1.2	+	1	1	1	1	1	1	3	1	2	3	3	1	2	3	2	1.51
Parus montanus CONRAD, 1827	1	1	1	2.5	2.5	2.5	2	2	2		1	3	2	1	2	1	1			1		1.42
Sylvia borin BODDEART, 1783	1	1	2.5	2.5	2.5	6.2	4	3	3	1		1		1	+	1				+		1.40
Parus caeruleus LINNAEUS, 1758	1	1	1	2.5	2.5	2.5	1	1	+			2	+	4	2	2			1	1	1	1.25
Picoides major (LINNAEUS, 1758)	+	+	+	+	+	+	+	2.5	2	+	1	2	2	2	2	1	+	1	1	1	1	1.03
Carduelis chloris (LINNAEUS, 1758)	+	+	1	+	+	2.5	2	2	2	2	1	+		1					2	2		0.92
Troglodytes troglodytes (LINNAEUS, 1758)			+			+	1		+		1	+	+	1	2	1	2	1	2	2	1	0.78
Coccothr. coccothraustes (LINNAEUS, 1758)							1	+			1	2	2	1	+	1	+	1.5	1	1	+	0.64

Emberiza citrinella LINNAEUS, 1758	1	1	1	2.5	2.5	2.5	2	2.5				2	2		+				+	+		0.64
Anthus trivialis (LINNAEUS, 1758)		1	1		2.5	2.5	+		+			+				1	1	2	2	1	+	0.50
Columba palumbus LINNAEUS, 1758	1		+	2.5		+	1	1.5	2	1		+	1									0.50
Muscicapa striata (PALLAS, 1764)	1		1	2.5		2.5	2					+	1		+			+	+		1	0.50
Garrulus glandarius (LINNAEUS, 1758)	0.5	+	+	1.2	+	+	+	+	1	1	2	+	2	1	+	+	+	+	+	+	+	0.46
Ficedula hypoleuca (PALLAS, 1764)	1	1	+	2.5	2.5	+	1	+	1	+	+	+				+			1	+	+	0.44
Pernis apivorus (LINNAEUS, 1758)									1	1	1	+										0.17
Phylloscopus trochilus (LINNAEUS, 1758)							2				1						+		+			0.17
Buteo buteo (LINNAEUS, 1758)								+					+	+	+	1	+	+	+	1	+	0.17
Parus cristatus LINNAEUS, 1758	1	+	+	2.5	+	+		+														0.14
Phoenicurus phoenicurus (LINNAEUS, 1758)	0.5	+		1.2	+		+															0.07
Sylvia communis LATHAM, 1787		0.5			1.2																	0.07
Accipiter gentilis (LINNAEUS, 1758)											+											
Streptopelia turtur (LINNAEUS, 1758)											+											
Cuculus canorus (LINNAEUS, 1758)										+	+	+	+				+	+	+			
Picus viridis LINNAEUS, 1758																			+			
Dryocopus martius (LINNAEUS, 1758)																	+	+				
Picoides minor (LINNAEUS, 1758)		+			+													+				
Hippolais icterina (VIEILLOT, 1817)												+	+									
Sylvia curruca (LINNAEUS, 1758)							+			+												
Regulus ignicapillus (TEMMINCK, 1820)										+											+	
Ficedula albicollis (TEMMINCK, 1815)																	+		+			
Oriolus oriolus (LINNAEUS, 1758)								+	+		+	+										
Corvus corone LINNAEUS, 1758									+			+	+									
Corvus corax LINNAEUS, 1758										+		+	+								+	
Serinus serinus (LINNAEUS, 1766)			+			+	+															
Carduelis carduelis (LINNAEUS, 1758)							+												+			
Carduelis spinus (LINNAEUS, 1758)														+								
Loxia curvirostra LINNAEUS, 1758									+	+	+			.							+	
Total: species observed	27	28	29	27	28	29	32	29	29	27	28	35	29	25	25	25	26	25	31	27	28	28.06
breeding species	24	22	21	24	22	21	25	22	23	20	23	21	22	23	19	23	18	18	22	23	19	21.40
breeding pairs	51	49	52	127.5	122.5	130	110	107	85	76	73	81	77	74	64	60	76	64	68	69	63	84.83

Table II

Counts of birds in Plot II (3.8 ha) in the forest associations *Tilio-Carpinetum* and *Pino-Quercetum* var. *Fagus silvatica* in 1974-1990. Figures denote the number of breeding pairs, + – species observed but not nesting in the plot

Species	Number of pairs in consecutive years																	Mean No of pairs
	1974	1975	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985	1986	1987	1988	1989	1990	
Fringilla coelebs LINNAEUS, 1758	3	3	3	3	4	3	3	3	4	3	4	3	4	5	4	3	4	4.21
Erithacus rubecula (LINNAEUS, 1758)	2.5	2	3	3	3	3	3	3	4	2	3	4	4	3	4.5	3	3	3.79
Parus major LINNAEUS, 1758	2	2	3	3	1	2	3	3	3	3	2	2	3	3	3	3	2	3.07
Turdus merula LINNAEUS, 1758	2	3	2	3	2	1	2	2	1	2	1	3	1	2	+	1	1	2.07
Sitta europaea LINNAEUS, 1758	1	2	+	2	1	2	2	2	1	2	2	2		2	3	2	3	2.07
Phylloscopus sibilatrix (BECHSTEIN, 1793)	1	1		+		1	1	4	1	2	1	1	2	2	1.5	3	2.5	1.71
Sylvia atricapilla (LINNAEUS, 1758)		2	1	1	1	1	2	2	1	1	2	2	2	2	1	1	2	1.71
Turdus philomelos C. L. BREHM, 1831	1.5	2	1	1	2	1	1	1		1	3	2	2	1	1	2	1	1.69
Parus palustris LINNAEUS, 1758	2	2	2	3	2	+	1	2	1	1	1	1	1	1	1	1	1	1.64
Phylloscopus collybita (VIEILLOT, 1817)	1	2	1	1		2	1	1	2	1	1	1	2	1	1	1	1	1.43
Certhia familiaris LINNAEUS, 1758	1	1	1	1	1	1	1	2		1	2		1	1	1	2	2	1.36
Anthus trivialis (LINNAEUS, 1758)	1	2	1	1	1	2	1	1	1	1	1		2	2	+	1	1	1.36
Parus ater LINNAEUS, 1758	1	1	1	+	1	1	1	1	2	2	1	1	1		1	1	1	1.29
Parus caeruleus LINNAEUS, 1758	2	1	1	2	1		1	2	+	2			1	+	1	1	1	1.29
Muscicapa striata (PALLAS, 1764)		2	1	1		1	1	2		1	1	1			1		1	0.93
Coccothr. coccothraustes (LINNAEUS, 1758)				1	1		1	1	1	+	1	2		1	1	1	1	0.86
Parus montanus CONRAD, 1827	1	1		+	1	1	1		1	1	1	1			+			0.64
Picoides major (LINNAEUS, 1758)	+		+	+	1	+	1	1	+	1	1	+	+	0.5	1	1	1	0.61
Pyrrhula pyrrhula (LINNAEUS, 1758)	+	+	+	+	1		+	+	1	1	1	+	1	1	1	1	+	0.57
Emberiza citrinella LINNAEUS, 1758		1	1	0.5	1	1	+	+	1		+		1					0.46
Garrulus glandarius (LINNAEUS, 1758)	+			+	1	1	1	1		1	+	+	+	+	+		+	0.36
Prunella modularis (LINNAEUS, 1758)	1	1	1	1						+								0.29

Carduelis chloris (LINNAEUS, 1758)	1	+	1	+	1	1		+						+		+		0.29
Troglodytes troglodytes (LINNAEUS, 1758)	+	+	+	+	1	+	+			1	+	+	+	0.5	1	+		0.25
Jynx torquilla LINNAEUS, 1758										1	1			1				0.21
Sylvia borin BODDAERT, 1783	1		1	+	1			+					+	+			+	0.21
Ficedula albicollis (TEMMINCK, 1815)									+				+		1	1	1	0.21
Sturnus vulgaris LINNAEUS, 1758	1	1	+					+	1		+	+						0.21
Lanius collurio LINNAEUS, 1758	+		1	0.5		1	+	+	+				+					0.19
Regulus regulus (LINNAEUS, 1758)							1	+								1	+	0.14
Turdus viscivorus LINNAEUS, 1758					1													0.07
Sylvia communis LATHAM, 1787		1							+				+					0.07
Ficedula parva (BECHSTEIN, 1794)					1									+				0.07
Oriolus oriolus (LINNAEUS, 1758)	1							+	+				+			+		0.07
Accipiter gentilis (LINNAEUS, 1758)									+									
Buteo buteo (LINNAEUS, 1758)	+	+	+	+			+	+	+	+	+	+	+		+	+	+	
Columba palumbus LINNAEUS, 1758	+	+												+				
Cuculus canorus (LINNAEUS, 1758))		+	+	+			+	+	+	+			+		+			
Picus canus GMELIN, 1788				+														
Dryocopus martius (LINNAEUS, 1758)											+					+		
Picoides minor (LINNAEUS, 1758)		+						+		+					+			
Hippolais icterina (VIEILLOT, 1817)									+									
Sylvia curruca (LINNAEUS, 1758)				+														
Phylloscopus trochilus (LINNAEUS, 1758)				+			+				+			+	+		+	
Certhia brachydactyla C. L. BREHM, 1820																	+	
Pica pica (LINNAEUS, 1758)										+								
Corvus corone LINNAEUS, 1758											+							
Carduelis carduelis (LINNAEUS, 1758)			+	+														
Carduelis spinus (LINNAEUS, 1758)															+			
Total: species observed	24	26	26	32	23	21	27	28	28	26	28	21	25	25	28	24	25	25.71
breeding species	19	20	18	18	23	18	20	18	17	21	19	15	15	17	18	19	18	18.41
breeding pairs	27	33	26	29	31	27	29	34	27	31	30	27	28	29	29	30	29.5	29.21

III. RESULTS

The results of the counts of bird carried out in two sample plots in 1973-1990 are presented in Tables I and II.

1. Number of species

The number of species observed in the sample plots ranged from 25 to 35 in Plot I (Table I, Fig. 2A) and from 21 to 32 in Plot II (Table II, Fig. 2B). The number of species (S) nesting in Plot I fluctuated between 18 and 25 ($\bar{x}$ = 21.4, SD=± 2.13, v = 9.95) and in Plot II between 15 and 23 ($\bar{x}$ = 18.41, SD=± 1.97, v = 10.70). The species compositions of the birds nesting in the two plots were very similar (high SØRENSEN's index QS = 84% in comparing the bird communities from areas similar in size, that is, originally established 4-hectare Plot I and whole 3.8-hectare Plot II). Out of the total number of 40 species acknowledged as breeding in the plots studied, as many as 28 nested in both plots; another 5 species (*Pernis apivorus*, *Buteo buteo*, *Columba palumbus*, *Phoenicurus phoenicurus* and *Parus cristatus*) nested exclusively in Plot I and 7 (*Jynx torquilla*, *Turdus viscivorus*, *Ficedula parva*, *Ficedula albicollis*, *Oriolus oriolus*, *Lanius collurio* and *Sturnus vulgaris*)

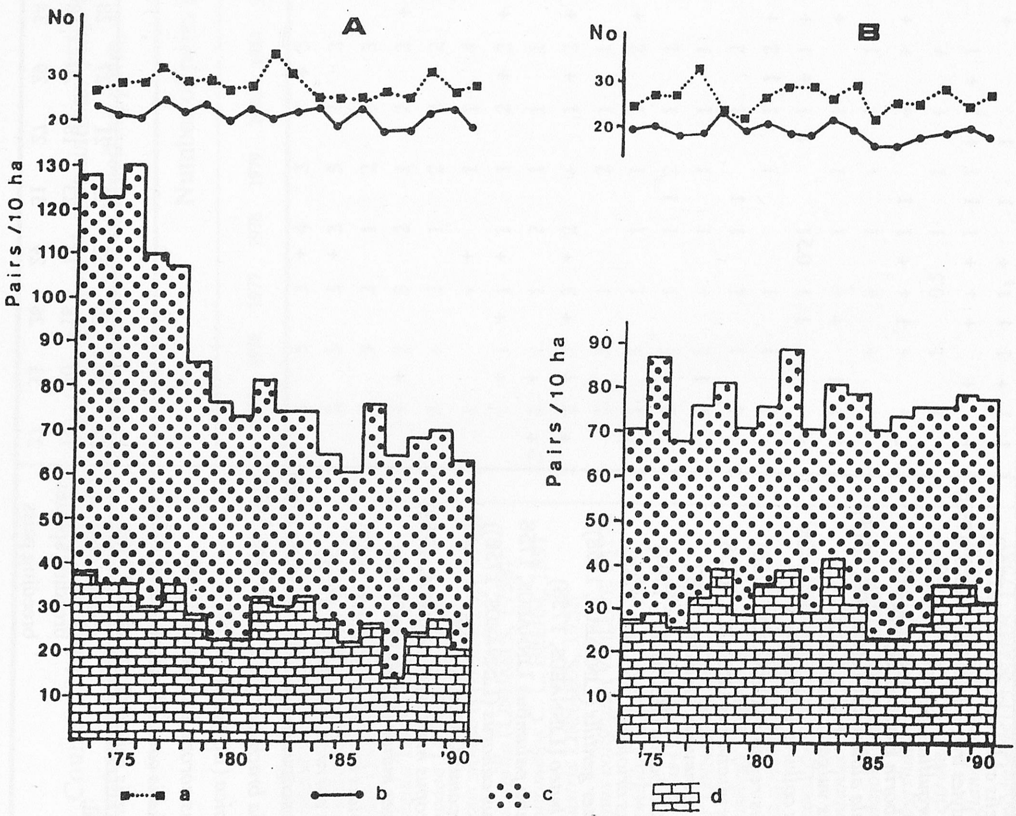

Fig. 2. Changes in the number of species and breeding pairs occurring in various types of ONP forest. A – Plot I, B – Plot II, a – number of species observed, b – number of breeding species, c – migratory birds, d – resident birds.

in Plot II. No significant changes were observed in the species composition of the birds occurring in Plot I after a lapse of years. As regards the species nesting regularly in Plot I (at least in three consecutive seasons), only *Sylvia borin* does not breed here at present. It however nests at a distance of several tens of metres from the sample plot in the same forest complex. Some changes were found in the avian species composition in the deciduous stand (Plot II): in the eighties two new species (*Jynx torquilla* and *Ficedula albicollis*) settled in it and three other species, nesting regularly in the seventies, now do not occur at all (*Prunella modularis*) or only visit rarely (*Sylvia borin*, *Emberiza citrinella*); similarly, the species which previously nested irregularly at the edges (*Sylvia communis*, *Phylloscopus trochilus* and *Lanius collurio*), do not occur here any more. The disappearance of these last species is however connected with the afforestation of the areas nieghbouring upon Plot II, and so it is caused by the change of the ecotone over a part of the plot border and does not constitute transformations of the bird community of the deciduous tree stand.

2. Number of breeding pairs

The densities of birds occurring in two sample plots did not change to the same extent. In the stand with prevailing coniferous trees (Plot I) a fall in the density of breeding pairs was noted in the second half of the seventies (mainly 1976-1978). It is probable that during the first years of investigation (1973-1975) the calculation of the density of birds in the plot, expressed by the number of pairs per 10 ha, was charged with an error owing to the small size of the area. Nevertheless, despite the possibility of errors in the estimation of the density in 1973-1975, there is no doubt as to the existence of a tendency for the abundance of birds to fall in the oak-pine forest until 1979 (Fig. 2A). This decrease may be defined by the equation: $y = 156.42 - 7.14\ x$ ($r = -0.729$, $0.05>p>0.02$). Only fluctuations in the abundance were observed in this plot in 1979-1990, the mean density ($\overline{x}$) being 70.42 pairs/10 ha (SD=± 6.68, v = 9.48). At the same time in the stand of deciduous trees only fluctuations in abundance were found throughout the period of study and the mean density of bird ($\overline{x}$) was 76.82 pairs/10 ha (SD=± 5.73, v = 7.46).

In both plots the density of birds was independent of the number of species. The coefficients of correlation between the number of species and that of breeding pairs are low (for Plot I $r = 0.338$, $p>0.1$; for Plot II $r = 0.424$, $0.1>p>0.05$).

3. Changes in the abundance of particular species

The decrease in the abundance of birds in Plot I results from a fall in the density of most species nesting on the plot. Out of the 9 species distinguished as dominant in 1973-1976, only *Fringilla coelebs* and *Phylloscopus sibilatrix* maintained their numbers at the same level, whereas the remaining species (i.e. *Erithacus rubecula*, *Turdus merula*, *Turdus philomelus*, *Sylvia atricapilla*, *Prunella modularis*, *Phylloscopus collybita* and *Parus major*) decreased in number to a larger or smaller extent. And so did the density of the remaining non-dominant species treated jointly (Fig. 3). The decrease of the density of birds nesting in the oak-pine forest seems to be permanent, for it has lasted, with small swings, for as long as 11 years. In the years when the abundance of birds in the oak-pine forest was undergoing a reduction the density of the same species in the deciduous stand was not subjected to changes (Fig. 3). Similar directions of changes in density were found

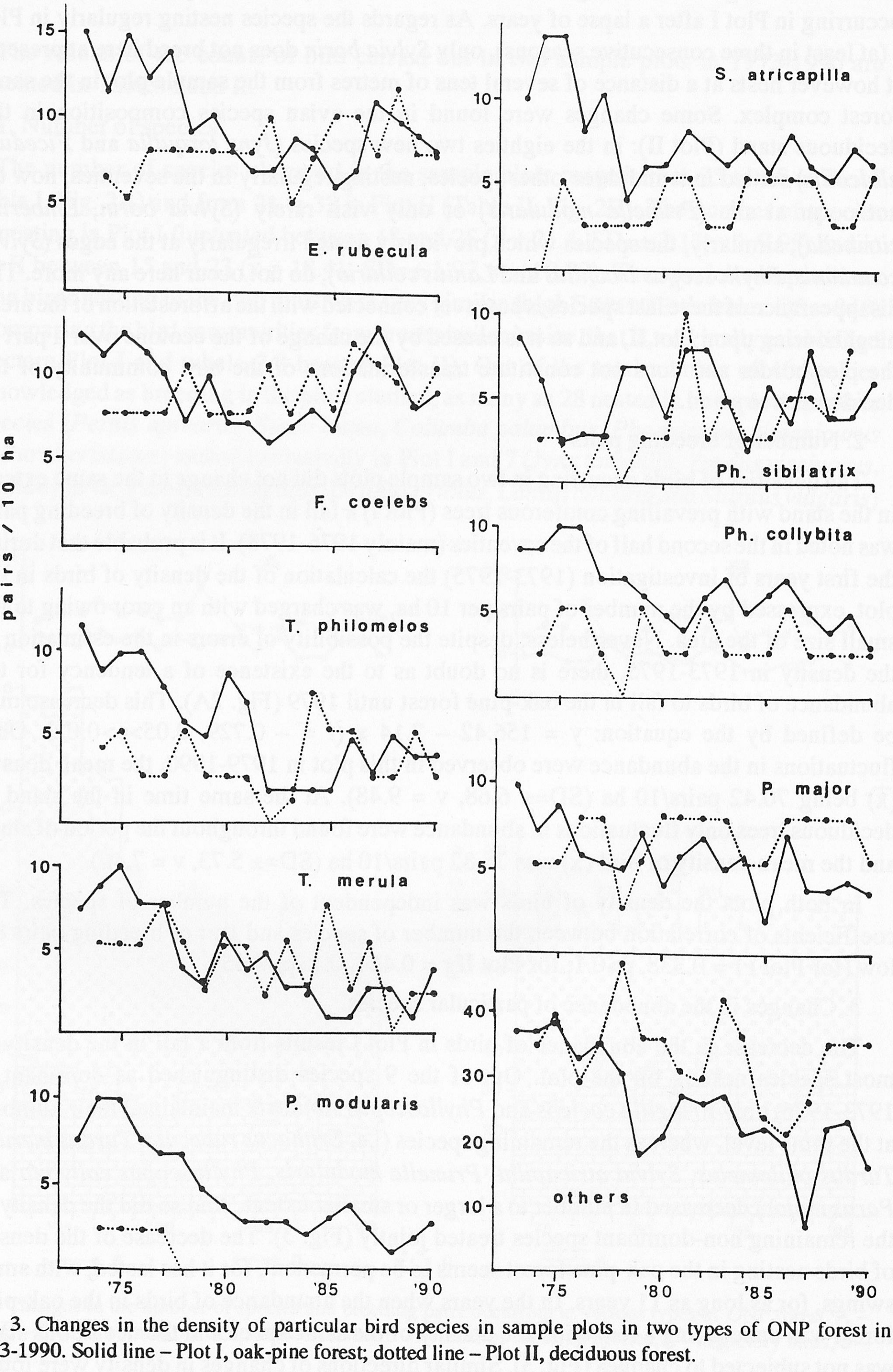

Fig. 3. Changes in the density of particular bird species in sample plots in two types of ONP forest in 1973-1990. Solid line – Plot I, oak-pine forest; dotted line – Plot II, deciduous forest.

only in three species: a decrease was observed in the Blackbird and Dunnnock (in the Dunnock it was tantamount to its withdrawal from the deciduous stand), and in the Willow Warbler there was an increase in abundance in both environments studied.

4. Changes in abundance relative to the birds' places of nesting

In the withering oak-pine forest (Plot I) the numbers of birds placing their nests in the understorey decreased to the highest degree. The reduction of the number of birds nesting in the shrub layer to less than a half was due to a fall in the abundance of several species, mainly Song Thrushes, Blackbirds, Dunnocks and *Sylvia* warblers. The birds building their nest on the ground and in tree-holes decreased in number to a smaller degree. Only the density of birds nesting in tree crowns was not changed (Fig. 4A). At the same time none of the groups being discussed changed in respect of abundance perceptibly (Fig. 4B) in the deciduous stand (Plot II). It is also worthy of emphasis that the total number of birds nesting in the oak-pine forest was to a high degree correlated with the number of individuals of each group distinguished, i.e. of birds nesting on the ground, in the understorey, in tree crowns and tree-holes. Simultaneously, in the deciduous stand there was a correlation only between the total number of nesting birds and the number of birds nesting in tree-holes (Table III).

5. Relationship between the numbers of breeding birds and those of resident and migratory birds

Bird density fluctuations in both types of forests in breeding seasons in 1980-1990 were brought about by the changes in the number of resident species remaining in OPN over winter (Fig. 2A and B). The correlation between the density of breeding birds and the numbers of resident species was fairly distinct in both plots, being greater in the oak-pine forest ($r = 0.776$, $p<0.001$) than in the stand of broad-leaved trees ($r = 0.623$, $0.01>p>0.005$). At the same time, however, the short-lived leaps in abundance, covering

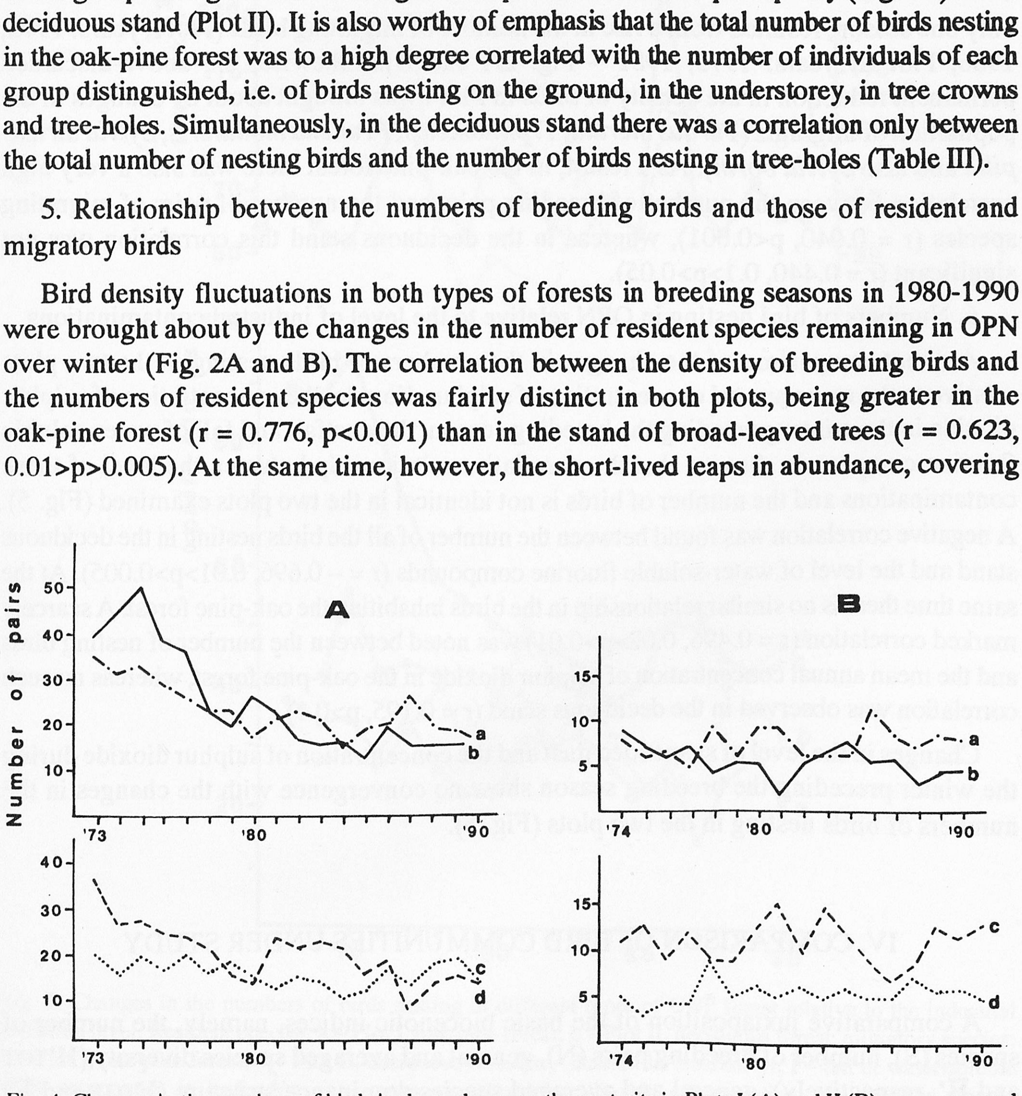

Fig. 4. Changes in the numbers of birds in dependence on the nest-site in Plots I (A) and II (B); a – on ground, b – in undergrowth, c – in tree crowns, d – in tree-holes.

Table III

Relationship between the number of nesting birds and the nesting site expressed by coefficient of corelation r

Nesting site	Plot I	Plot II
on ground	0.823 ($p<0.001$)	0.061 ($p>0.1$)
in undergrowth	0.960 ($p<0.001$)	0.259 ($p>0.1$)
in tree crowns	0.641 ($p<0.001$)	0.034 ($p>0.1$)
in tree holes	0.827 ($p<0.001$)	0.691 ($0.005>p>0.001$)

only one season, resulted from a rise in the number of migrating birds (Plot I, years: 1975, 1986; Plot II: years: 1975, 1981 – Fig. 2A and B). Likewise, the above-discussed permanent reduction in the density of birds in Plot I was brought about by changes in the population of migrants (*Turdus merula*, *T. philomelos*, *Prunella modularis*, *Sylvia atricapilla* and also *Sylvia borin*). As a result, in the oak-pine forest there was also a very high correlation between the number of breeding pairs and the number of pairs of migrating species ($r = 0.040$, $p<0.001$), whereas in the deciduous stand this correlation was not significant ($r = 0.440$, $0.1>p>0.05$).

6. Numbers of bird nesting in OPN relative to the level of industral contaminations

A direct comparison of the changes in the numbers of birds nesting in the two plots relative to the mean annual concentration of sulphur dioxide, the concentration of sulphur dioxide in the winter preceding the breeding season, the dustfall and fall of water-soluble fluorine compounds showed that the correlative relationship between the level of these contaminations and the number of birds is not identical in the two plots examined (Fig. 5). A negative correlation was found between the number of all the birds nesting in the deciduous stand and the level of water-soluble fluorine compounds ($r = -0.696$, $0.01>p>0.005$). At the same time there is no similar relationship in the birds inhabiting the oak-pine forest. A scarcely marked correlation ($r = 0.496$, $0.02>p>0.01$) was noted between the number of nesting birds and the mean annual concentration of sulphur dioxide in the oak-pine forest, whereas no such correlation was observed in the deciduous stand ($r = 0.195$, $p>0.1$).

Changes in the level of suspended dust and the concentration of sulphur dioxide during the winter preceding the breeding season show no convergence with the changes in the numbers of birds nesting in the two plots (Fig. 5).

IV. COMPARISON OF BIRD COMMUNITIES UNDER STUDY

A comparative juxtaposition of the basic biocenotic indices, namely, the number of species (S), number of breeding pairs (N), general and averaged species diversity (H'_{TOT} and $\bar{H}'$, respectively), general and averaged species dominance structure (J'_{TOT} and $\bar{J}'$) and between-year component diversity (DIV_{diff}), is given in Table IV.

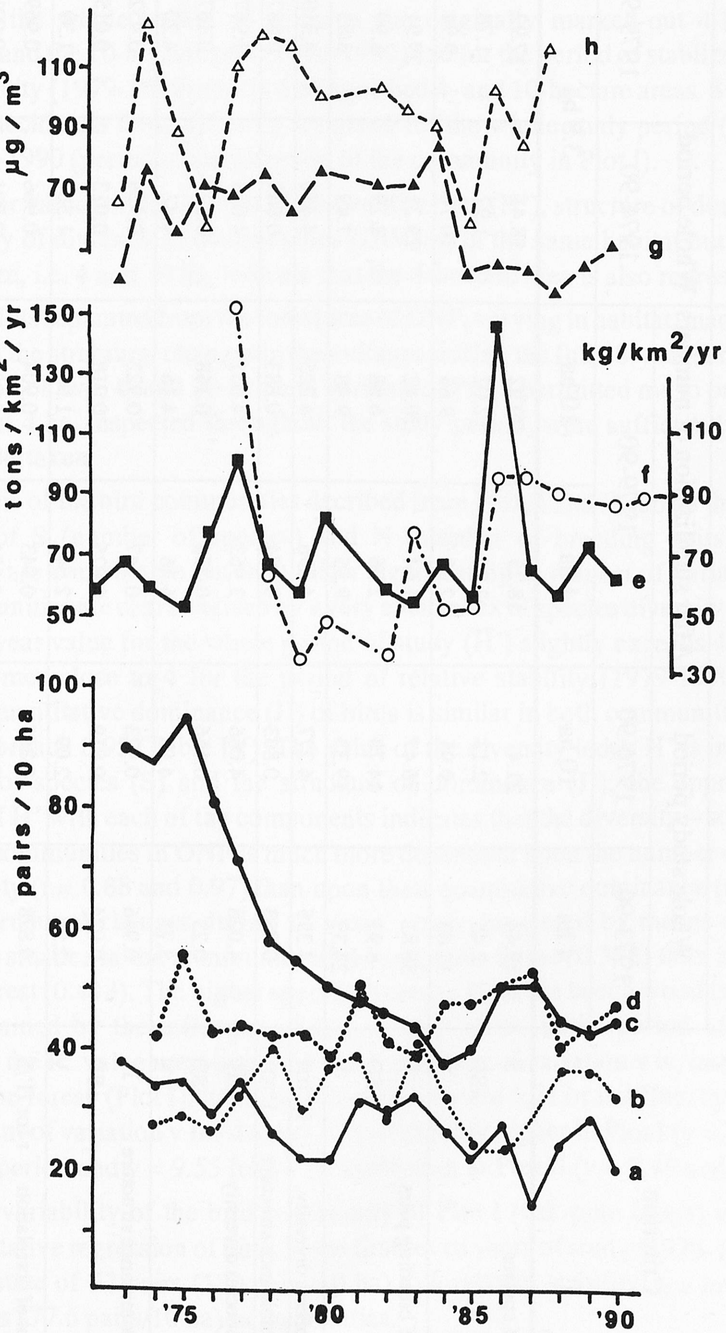

Fig. 5. Changes in the numbers of birds nesting in different types of ONP forest relative to the industrial pollution level. Resident species: a – Plot I, oak-pine forest; b – Plot II, deciduous forest; migratory species: c – Plot I, oak-pine forest; d – Plot II, deciduous forest; e – dustfall in tons/km^{2}yr; f – fall of water-soluble fluor compounds in kg/km^2/yr; g – mean annual sulphur dioxide concentration; h – sulphur dioxide concentration in winter preceding the breeding season.

Table IV

A comparative review of biocenotic indications for the bird communities studied in the ONP

Criterion		Plot I				Plot II	
		Whole study period		After stabilization of numbers		Whole period	
		1973-90	1976-90	1979-90		1974-90	1979-90
		4 ha	10 ha	4 ha	10 ha	3.8 ha	
Number of species	$\bar{S}$	19.44	21.4	18.25	20.92	18.41	17.92
	±SD	2.46	2.13	2.26	2.02	1.97	1.78
	V	12.63	9.95	12.39	9.66	10.70	9.94
Number of breeding pairs	$\bar{N}$	36.81	76.47	31.04	70.42	29.21	29.91
	±SD	8.97	14.78	2.96	6.68	2.19	1.99
	V	24.37	19.33	9.55	9.48	7.49	6.83
General species diversity	H'_{TOT}	4.355	4.277	4.296	4.225	4.456	4.310
General dominance structure	J'_{TOT}	0.863	0.863	0.884	0.883	0.869	0.887
Average species diversity	$\bar{H}'$	4.028	4.066	3.963	4.031	4.013	3.967
	±SD	0.23	0.166	0.256	0.168	0.177	0.167
	V	5.71	4.08	6.46	4.16	4.42	4.20
Average dominance structure	$\bar{J}'$	0.946	0.923	0.947	0.922	0.956	0.952
	±SD	0.024	0.019	0.025	0.018	0.013	0.015
	V	2.54	2.09	2.64	1.92	1.36	1.39
Coefficient of correlation	r for H'/S	0.878 $p<0.001$	0.865 $p<0.001$	0.943 $p<0.001$	0.904 $p<0.001$	0.966 $p<0.001$	0.969 $p<0.001$
Coefficient of correlation	r for H'/J'	0.511 $0.05<p<0.002$	0.491 $0.1<p<0.05$	0.866 $p<0.001$	0.556 $0.05<p<0.002$	0.747 $p<0.001$	0.808 $p<0.001$
Between-year component diversity	DIVdiff	0.338	0.211	0.333	0.194	0.443	0.343

The data concerning the oak-pine forest (Plot I) are taken into account in the following variants: for the whole period of study in the originally marked-out 4-hectare plot (1973-1990) and the 10-hectare plot (1976-1990) and for the period of stabilization of this birds community (1979-1990) also in distinguished 4- and 10-hectare areas. Similarly, the data for the deciduous forest (Plot II) are given for the whole study period (1974-1990) and for 1979-1990 (period of stabilization of the community in Plot I).

The similar values of the indices of species diversity (H'), structure of dominance (J') and especially of diversity of communities (DIV_{diff}) in the same habitat but in the areas varying in size, i.e. 4 and 10 ha, indicate that the 4-hectare area is also representative.

The two plots separated from the forest area of ONP, varying in habitat, made it possible to investigate the structural changes in the avifauna during the full 18-year series of study. The separation of two, 4- and 10-hectare, variants of Plot I permitted me to prove that the areas of about 4 ha, inspected throughout the study period, were sufficiently reliable in the study undertaken.

An analysis of the bird communities decribed from Plots I and II shows that in respect of the size of S (number of species) and N (number of breeding pairs) these two communities are comparable but they differ significantly in respect of variability scale. These communities are characterized by a very even index of species diversity (H'), whose mean many-year value for the whole period of study ($\overline{H}'$) slightly exceeds 4 bits in both cases and comes close to 4 for the period of relative stability (1979-1990). Also the structure of quantitative dominance (J') of birds is similar in both communities, its mean values ($\overline{J}$) approach 0.95 (Table IV). The value of the diversity index H' is influenced by the number of species (S) and the structure of dominance (J'); the appraisal of the correlation of H' with each of the components indicates that the diversity – so interpreted – of the two communities in ONP is much more dependent upon the number of species in the community ($r = 0.88$ and 0.97) than upon their quantitative dominance ($r = 0.51$ and 0.75). The structural changes during 18 years' study, measured by means of the index DIV_{diff} were smaller in the community of the oak-pine forest (0.388) than in that of the deciduous forest (0.443). The higher species diversity H' in the beech wood in 1974-1990 may be explained by the influence of the ecotone in the initial period of study. The variability of the H' value measured with the coefficient of variation v is, instead, greater in the oak-pine forest (Plot I); it is, respectively, 4.41 and 5.71 or it differs by about 23%. The coefficient of variation v for density is considerably higher in Plot I ($v = 24.37$ for the whole study period and $v = 9.55$ for 1979-1990) than in Plot II ($v = 7.49$ and 6.83).

The high variability of the bird community of Plot I (oak-pine forest) was due to a strong quantitative regression of birds in the first seven years of study (1973-1979), which reduced the state of 52 pairs (130 pairs/10 ha) to a relative stability at a lower level of about 31 pairs (77.6 pairs/10 ha) in the eighties.

Strong factors reducing the bird populations appeared in ONP in the seventies; they were connected with rapid changes in the structure of forest (mainly with the dropping-out of coniferous trees and shrubs) and indirectly with the industrial air pollution. It is a very interesting fact that the bird communities in Plot II (deciduous forest) did not yield to degradation, showing higher ecological resistance than did the bird communities of the oak-pine forest. Adequate surveys (Fig. 2) show that it was mainly migratory birds that contributed to the quantitative regression of birds in Plot I. On the other hand, a comparison with the community in Plot II indicates that the cause of that regression did not lie outside the study area (winter quarters, passages) but within its range, in the actual type of the habitat. In other words, under today's conditions prevailing in ONP the bird communities are more exposed to degradation in coniferous forests than in deciduous ones, the differences in this endangerment being significant.

V. COMMENTS

The bird community of the deciduous forest of ONP does not depart from the communities in beech woods in different regions of Poland in respect of its species composition and density. This can be seen from KIEŚ's (1991) comparison of JACCARD's and RENCONEN's coefficients calculated for the bird communities of beech woods, including Plot II of the present study. The density of birds in the deciduous stand (oak-hornbeam forest with dominant beech) in ONP, being one of the higher densities in beech woods and oak-hornbeam woods in Poland (KIEŚ 1991 and literature quoted by him; GŁOWACIŃSKI 1975), in the light of MARGALEF's (1968) and ODUMS's (1969) theory of ecosystem development may evidence the ageing of this plant community. This is also shown by the settling of new bird species belonging to the group of treeholer. A certain overestimation of the density may however result (at least partly) also from the error caused by the small size of the sample plot.

The possibility of such an error demands great cautiousness in the interpretation of the results concerning the absolute numbers of birds of the whole community or particular species calculated for an area unit. On the other hand, however, the deformation resulting from the smallness of the area is of little significance, especially in a case of long-lasting monitoring investigations, as evidenced by the similar values of S and N for 4- and 10-hectare plots in the coniferous habitat (Table IV).

The bird communities, living in coniferous or mixed coniferous-deciduous forests, that is, in coniferous stands or mixed stands with prevailing conifers, observed in other regions of Poland (among other authors, ŚLIZOWSKI 1991 and papers quoted by him; GŁOWACIŃSKI 1975, 1990; TOMIAŁOJĆ 1974; TOMIAŁOJĆ et al. 1984), had similar numbers of species and, for the most part, considerably lower levels of density of pairs than in ONP. Only the bird community of a wet oak-pine forest near Legnica makes an exception (TOMIAŁOJĆ 1974); its density, higher than that in ONP, that author explained by "rich cover for nests". And so the bird communities in different types of stands in ONP, despite the above-described distinct changes in the environment, are not poorer than the communities of similar environments of other regions of Poland and as regards the density of nesting birds, they are frequently richer.

The highly significant correlation of the changes in the sizes of bird communities in the oak-pine forest with the number of migratory birds in them, as well as the fall in the number of this very group of birds until 1979 might suggest that the causes of these changes and the fall in number found themselves outside the territory of the ONP. Bad living conditions in the winter quarters and an increase in the morality rate on the passage routes may be responsible for the decreasing size of the breeding population of migratory birds (LOSKE & LEDERER 1987, TERBORGH 1992). Nevertheless, in the deciduous stand in ONP no decrease was found in the number of migrants analogous to that in coniferous forests; neither is there a correlation between the total number of nesting pairs and the number of migrants. This provides evidence for the fact that the number of nesting birds and the decrease of the number of migrants in the oak-pine forest in ONP are not connected with the rise in their mortality during migrations and at winter quarters. The changes in the numbers of migrants only in one plot and the upward trend in the numbers, among other birds, of Blackbirds and Dunnocks in Poland (TOMIAŁOJĆ 1990), and so the birds responsible for a lasting decrease in the number of birds nesting in the oak-pine forest in ONP in 1975-1979, make us seek the causes of those changes in the deterioration of living conditions in the environment itself, i.e. in the changing oak-pine forest.

The environment in which birds live in ONP is heavily contaminated with industrial gases and dusts (GRODZIŃSKA 1985, PARTYKA 1986; PARTYKA, BIEDERMAN 1987-89). Despite such a high air pollution no direct influence of it on the abundance of birds can be seen, for its negative influence on the number of birds should have its reflection in analogous changes in both plots. The lack of changes in the number of birds living in one of the plots under study, the entire lack of correlation between the number of birds and the level of some contaminations (suspended dust, concentration of sulphur dioxide in the winter preceding the breeding season) or the correlation found in only one type of stands (fluorine compounds, mean annual concentration of sulphur dioxide) evidence that these contaminations at the level occuring in ONP do not directly limit the numbers of birds. The correlation found between the number of birds and the level of fluorine compounds in Plot II or the mean annual concentration of SO_2 in Plot I is therefore an apparent (random) correlation. The lack of direct dependence of the number of birds on the environmental contamination (at the level that it reaches on the ONP region) is also indicated by the high density of birds in both sample plots. It approaches or exceeds the density levels found in relatively little contaminated environments, such as the Babia Góra region (KIEŚ 1991; ŚLIZOWSKI 1991), Gorce (GŁOWACIŃSKI 1990), Bieszczady (CICHOŃ & ZAJĄC 1991 or Białowieża Forest (TOMIAŁOJĆ et al. 1984).

A comparison of the biocenotic indices (S, N, H', J') of the bird communities of ONP with these indices for various forest associations of Niepołomice Forest (GŁOWACIŃSKI 1975), Gorce Mts (GŁOWACIŃSKI 1990), Białowieża Forest (GŁOWACIŃSKI 1990 on the basis of TOMIAŁOJĆ et al. 1984) and the Bieszczady (CICHOŃ & ZAJĄC 1981) shows that the former bird communities ought to be referred to mature deciduous and oak-pine forests. However, the values of the coefficient of variation (v) of species diversity (H') and the between-year component of diversity (DIV_{diff}) of the avian communities come nearest to phase III of succession (15 – 19-year thicket) and are somewhat lower than phase IV (a wood 95 years old) (GŁOWACIŃSKI 1990). Thus the stability of both the bird communities studied in ONP is lower than in maturing forests. Consequently, it may be expected that the process of alterations in the bird communities of the ONP forests will continue and the relative balance in 1979-1990 may have been apparent balance.

The above-presented changes in the bird community only in one plot (i.e. the drastic reduction of its abundance by one-third) in the period of changes occurring in the plant association of this plot, lead to the conclusion that the main factor limiting the occurrence and abundance of birds in the structure of vegetation. This is also suggested by the fact that the greatest changes in abundance were found in the group of birds associated with the understorey and so with the layer of plants that had most changed its physiognomy and value. The transformation of the understorey in the oak-pine forest of ONP, consisting in the elimination of young coniferous trees from it, brought about the reduction of the abundance of the bird species which most readily built their nests in young dense coniferous trees, namely, thrushes, *Sylvia* warblers and Dunnock (BOCHEŃSKI 1968, 1985, TOMEK 1980). The withering and elimination just of such young trees from the understorey caused a considerable reduction of places suitable for building and effective screening a nests. Towards the end of the eighties the species under discussion placed their nests in much worse places, i.e. worse hidden and screened. The increase of losses caused by the predation of nests built in coniferous trees, found in ONP (from 41% in 1974-1975 to 64% in 1989-1990 – TOMEK in press) was the result of the worse cover of nests and so a further effect of the drying-up of young coniferous trees.

Finally, one supposition more. The foregoing considerations shows that the change in the structure of vegetation connected with the withering of coniferous trees, chiefly in the shrub layer, bears main resposibility for the decrease in the number of birds in Plot I (oak-pine forest). Above all, Blackbirds and Dunnocks but also Song Thrushes and Robins responded to it. These four species forage chiefly on the ground, in litter. It is therefore possible that their food base is also reduced by air pollution. There are no direct evidences for that because appropriate studies have not been carried out in ONP. An indirect proof of that is the quantitative state of another species, that is of Bullfinch, also nesting mainly in young coniferous trees in ONP (BOCHEŃSKI & OLEŚ 1981), but having a different food base. Throughout the 18-year period of investigation it was present in both plots at a similar, unchanging level, showing no downward tendencies at all. This problem however remains open, since its solution would call for research work of a team of specialists in various fields.

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