Acta Zoologica Academiae Scientiarum Hungaricae 46 (2), pp. 103–114, 2000

RELATIONSHIPS BETWEEN THE ABUNDANCE OF BREEDING BIRDS IN WESTERN POLAND AND THE STRUCTURE OF AGRICULTURAL LANDSCAPE

KUJAWA, K.[1] and P. TRYJANOWSKI[2]

[1]*Research Centre for Agricultural and Forest Environment of Polish Academy of Sciences Field Station, Szkolna 4, 64–003 Turew, Poland, e-mail: ortolan@priv7.onet.pl*
[2]*Department of Avian Biology and Ecology, Adam Mickiewicz University Fredry 10, 61–701 Poznan, Poland, e-mail: ptasiek@main.amu.edu.pl*

The relationships between bird abundance and landscape structure were studied in nine plots located in an agricultural landscape in W Poland. Numbers of bird species per plot ranged from 3 to 31, densities from 3.8 to 32.8 pairs/10 ha. Habitat parameters, as percentage of tree cover ranged from 0 to 14.5%, meadows from 0 to 48.5%, habitat diversity (H') from 0.004 to 1.07, density of forest – field ecotones from 0 to 144 m/ha, density meadows and crop field ecotones from 0 to 38 m/ha, and ecotones between crop fields – from 0 to 245 m/ha. The number of bird species per plot increased most significantly with tree cover (r^2=0.63 in linear regression); the density of breeding pairs also increased linearly with tree cover (r^2=0.85 in linear regression). Tree cover was also the main factor influencing the density or species number of particular nesting-guilds with the exception of the density of ground-nesters, which was not significantly related to any 'habitat' variable. The relationships between wood cover and species number appeared to be non-linear, showing higher slope values at smaller values of wood cover. Protection of high bird abundance in western Poland is strongly linked with the preservation of margin habitats, especially woodlots, which provide nesting opportunities for most of the species occurring in farmland in W Poland.

Key words: breeding bird community, agriculture, management implications, Poland

INTRODUCTION

In an agricultural landscape the communities of birds in margin habitats (especially hedges and small woods) have been shown to differ from cultivated areas in their higher species richness and population densities (BEZZEL 1982, FLADE 1994). However, differences in the richness of bird communities at the landscape scale are not easily explained by research on particular landscape elements since the different elements are mutually interactive in their modification of the structure of bird communities. Thus, for example, population densities of species characterising open habitats are negatively correlated with the presence and quality of woodland/crop field ecotones (OELKE 1968, BERG & PART 1994, KUJAWA 1994). Bird species associated with woods in agricultural landscape depend not only on the percentage cover of such areas, but also on their degree of

fragmentation (CIESLAK 1985, KUJAWA 1997), and locations with respect to one another (LACK 1988) as well as to the surrounding landscape (BELLAMY *et al.* 1996). In consequence, many authors (SCHIFFERLI *et al.* 1985, BASTIAN *et al.* 1989, BROWN & STILLMAN 1993, BUCKLAND & ELSTON 1993) showed that the abundance of breeding birds could be explained by very few variables characterising farmland. Among these, the most important were variables describing non-farmed, patchily distributed habitats – woods, shrubs or marshes (their percentage cover or relative length). In Poland research based on precisely measured features of landscape structure and entire communities of breeding birds is needed. Admittedly, some studies have considered differences in the richness of communities in relation to landscape structure, but the characterisation has either been a purely descriptive one, or presenting only the percentage shares of different elements (GÓRSKI 1988, JERMACZEK & TRYJANOWSKI 1990, KOT 1990, KUJAWA 1994, TRYJANOWSKI 1999).

The aim of the study was to reveal the relationships between farmland structure and the abundance of breeding birds, i.e. how do the amount of tree cover, meadows, the density of habitat edges and the diversity of agricultural land affect the structure of avian communities.

MATERIALS AND METHODS

Study area

The work was performed in the Wielkopolska region (W Poland), which is one of the most transformed parts of Poland due to the development of agriculture. The woods are mostly intensively used, and cover up to 20% of the whole area. The main crops are wheat, rye, sugar beet, potatoes, corn and rape. The abundance of breeding birds as well as the landscape structure were studied on nine sampling plots (with an area of 24–56 ha) located 10–60 km from Poznan.

Four study plots (T1, T2, T3, T4) are located within the General D. Chlapowski Landscape Park, c. 40 km S of Poznan and within a 5 km radius of the village of Turew (52°04'N, 16°49'E). This area is located on the Koscianska Plain (KONDRACKI 1988), at 70–90 m a.s.l. Arable land takes up 66% of the area, with the remaining agricultural land (c. 9% of the total) being meadow or pasture. The most characteristic feature of the Turew area is differentiated hedges and small woods of which the oldest have existed for about 170 years. The dominant planted species is *Robinia pseudacacia*. Its variously aged stands are mixed with *Quercus robur*, *Fraxinus excelsior*, poplars (*Populus* spp.), *Ulmus campestris*, *Acer platanoides* and *Pinus silvestris*.

Another three plots (S, P1 and P2) are located near Poznan, directly next to a built-up area (52°31'N, 16°48'E). The plots represent the typical intensively used farmland in the Poznan Lakeland (KONDRACKI 1988), 80–90 m a.s.l. The prevalent majority of the neighbourhood of our plots were arable fields and woodlots were limited to small clumps, lanes and hedges at the village edges. In the lower, wet part of the study area the trees are mainly limes (*Tilia* spp.), maples (*Acer* spp.), *Quercus robur*, *Alnus glutinosa* and poplars, whereas higher parts in very dry places are dominated by *Pinus silvestris* with undergrowth of *Sambucus nigra*.

Two further plots (W1 and W2) are located in the western part of the Wielkopolska Region, almost 70 km W from Poznan, in the Zbaszyn Trench (52°07'N, 16°04'E), 70–80 m a.s.l. The plots were typically agricultural, the arable fields amounting to 80 % of the area, but several kilometres

Table 1. Landscape ecological variables of the nine study plots in W Poland

Plot	S	P1	P2	W1	W2	T1	T2	T3	T4
Area (ha)	55	36	54	24	32	35	38	55	46
Crop (%)	97.0	87.4	99.1	94.8	98.4	61.1	37.0	93.0	97.4
Wood (%)	1.8	3.0	0.0	4.0	0.7	13.7	14.5	7.0	0.2
Grass (%)	0.0	0.0	0.0	0.0	0.0	18.1	48.5	0.0	2.3
Other (%)	1.2	9.6	0.9	1.2	0.9	7.1	0.0	0.0	0.0
Woodedge (m/ha)	13	28	0	17	29	65	144	82	3
Cropgrass (m/ha)	0	0	0	2	0	38	22	0	29
Cropcrop (m/ha)	44	40	60	89	50	0	4	0	245
Diversity (H')	0.16	0.44	0.004	0.23	0.09	1.07	1.00	0.25	0.13

to the west there are large complexes of pine forest. In the fields there are still mostly deciduous trees, located mainly in wet parts of the area and along the roads.

The comparative characteristics of the study plots are given in Table 1.

Methods

The study was carried out in 1994. For each plot, topographical maps and aerial photographs were used to determine the following variables describing habitat heterogeneity: 1. grass, wood, other – the cover (expressed as a proportion – from 0 to 1) of main habitat types other than crop fields, respectively – natural grasslands, woods and others combined (e.g. small built-up areas, roads, wasteland etc.); 2. diversity – the Shannon diversity index H':

$$H' = -\sum_{i=1}^{n} p_i \ln (p_i)$$

where n is the number of habitats and p_i – the proportion of the *i*-th habitat; 3. woodedge – the amount of wood edges per unit area of plot (in m/ha); 4. cropcrop, cropgrass – the ecotones between crop fields and between crop fields and grasslands, respectively, expressed as a proportion of total ecotones length divided by plot size (m/ha).

The densities of bird populations were estimated using the combined version of the mapping method (TOMIALOJC 1980). The method involved 8–10 (mostly 9) censuses per plot between April and June, beginning half an hour before sunrise and ending 4–5 hours later depending on the weather and bird activity. For more exact mapping, points of reference were designated and marked in woods with a shortage of natural orientation points. The numbers of pairs of *Buteo buteo*, *Strix aluco*, corvids and *Sturnus vulgaris* were determined on the basis of the numbers of nests found. *Cuculus canorus* was excluded from the analyses due to its non-territorial breeding behaviour, which makes the density estimation unreliable. The birds breeding on the study plots were grouped into nesting-guilds according to TRYJANOWSKI (1999).

Statistical analysis of relationships between landscape structure and abundance of birds on the study plots was carried out using simple regression and forward stepwise multiple regression. The dependent variables were the number of species and the density of bird populations (according to whole community or to nesting-guilds), while the independent variables were the ones describing plot structure. The variables expressed as proportions were transformed with the arcsine (x) function for normalised values of the proportional type (ZAR 1984). After transformations the distribution of all variables did not differ from normal (Kolmogorov-Smirnov test, $P>0.05$). All statistics were carried out using SPSS/PC statistical package (NORUSSIS 1986).

RESULTS

On the study plots a total of 39 breeding bird species were recorded, its actual value ranged from 3 to 31 on the study plots (Appendix). The bird communities showed clear differences according to different values of habitat parameters (Table 2). Before performing the multiple stepwise regression analysis, the relationships between 'habitat' variables and 'bird' parameters were checked by Pearson correlation. It was shown that three 'habitat' variables were significantly linked with most of the ten analysed 'bird' variables: habitat diversity (H'), tree cover, and the amount of forest ecotones. On the other hand, they were markedly inter-correlated (Table 3). The presence of inter-correlated variables makes the interpretation of regression results unreliable (ROBERSTON *et al.* 1993), thus for further analyses the number of these variables should be reduced as much as possible. We excluded diversity as a 'secondary' habitat measurement, it is a function of its components (including tree cover) and is highly correlated with other variables, only with one exception. In addition, we also excluded plot size, which was not correlated with any 'bird' variable. Summing up, for the stepwise regression, the following 'habitat' variables were taken as independent: tree cover (wood), grassland cover (grass), other margin habitats (other), amount of the ecotones between crop fields (cropcrop) and amount of ecotones between crop fields and grasslands (cropgrass).

Table 2. Structure parameters of breeding bird communities of studied plots

PLOT	S	P1	P2	W1	W2	T1	T2	T3	T4
Total									
Species number	16	14	3	10	23	31	31	25	7
Pairs/10 ha	9.8	8.9	3.8	15.4	15.0	29.7	32.8	16.7	12.8
Species in nest-guilds									
Hole-nesters	2	3	0	3	0	6	7	7	0
Lowly nesting spp.	3	2	0	6	3	5	7	2	1
Highly nesting spp.	4	3	0	9	1	11	9	8	1
Ground-nesters	6	5	3	4	5	8	7	7	5
Density in nest-guilds									
Hole-nesters	0.4	1.1	0.0	1.6	0.0	5.1	8.2	4.7	0.0
Lowly nesting spp.	2.0	1.1	0.0	5.3	2.5	13.4	13.0	6.1	0.5
Highly nesting spp.	1.3	1.1	0.0	4.4	0.8	12.9	11.7	6.2	0.2
Ground-nesters	7.1	5.8	3.8	6.3	12.1	9.3	8.4	4.7	12.3

Multiple stepwise regression analysis with farmland variables showed that 'bird' variables were most significantly linked with tree cover, with the exception of the number of ground nesting species (Table 4). The results of stepwise regression analysis are in most cases exactly the same as the results of correlation coefficient analysis. For explaining the between-plots variation of the species number the most significant variable was woods, which explained 63% ($P<0.01$) of the variation observed (Table 4). Total density of breeding birds was dependent mainly also on woods, explaining 85% ($P<0.001$) of the variation observed.

The variation of species number between plots of ground nesting species depended in 59% on variable woods ($P<0.05$), while no variable was found at $P<0.05$ for bird density. Also, for the species, which build open nests lowly above the ground, the most important factor was woods. The number of species was dependent on this variable in 48% ($P<0.05$), and the density of low nesting species was linearly dependent on woods (95%, $P<0.001$). The number of species nesting in tree-holes was related in 88% on woods, and their density – in 94% ($P<0.001$) on the same variable. Also the density of highly nesting species was very strongly dependent on woods (in 99%, $P<0.001$). The same variable was the

Table 3. Pearson correlation coefficients between 'bird' on 'habitat' parameters. Explanations of habitat variables – see text; ns – non-significant. * – P<0.05. ** – P<0.01. *** – P<0.001

	Crop	Wood	Grass	Other	H'	Wood-edge	Crop-grass	Crop-crop
Total sp. number	-0.75*	0.82**	0.63 ns	0.17 ns	0.76*	0.83**	0.37 ns	-0.66 ns
Total density	-0.89**	0.93***	0.84 ns	0.06 ns	0.89**	0.84**	0.68*	-0.37 ns
Species number of hole nesters	-0.79*	0.89**	0.60*	0.18 ns	0.76*	0.86**	0.29 ns	-0.65 ns
Number of lowly nesting species	-0.73*	0.74*	0.68*	0.05 ns	0.70*	0.63 ns	0.32 ns	-0.38 ns
Number of highly nesting species	-0.72*	0.86**	0.52 ns	0.18 ns	0.75*	0.66 ns	0.39 ns	-0.51 ns
Species number of ground-nesters	-0.71*	0.80*	0.54 ns	0.22 ns	0.75*	0.72*	0.55 ns	-0.47 ns
Density of hole-nesters	-0.90**	0.96***	0.84**	0.03 ns	0.84**	0.96***	0.46 ns	-0.56 ns
Density of lowly nesting species	-0.90**	0.98***	0.79*	0.13 ns	0.91**	0.83**	0.60 ns	-0.54 ns
Density of highly nesting species	-0.90**	0.99***	0.77*	0.17 ns	0.92**	0.82**	0.61 ns	-0.54 ns
Density of ground-nesters	-0.08 ns	0.01 ns	0.17 ns	-0.07 ns	0.13 ns	0.00 ns	0.55 ns	0.46 ns

most important for the number of species in this guild, but together with grassland, explaining 90% of the variability. All the results are collected in Table 4. Summing up, the results of the step-wise regression are very similar to the results of correlation coefficient analysis and they indicate a decisive role of wood habitats for explaining the between-plots variation of bird density and abundance.

The analyses presented shows that in most cases (except the density of ground-nesters) the relationships between 'habitat' variables and species number

Table 4. The results of the forward stepwise multiple regression of 'bird' on 'habitat' variables

Variable	Coefficient	SE	t	P
Number of species (r^2=0.63, P<0.01)				
Const	10.29	2.84	3.6	<0.01
Woods	150.0	38.98	3.8	<0.01
Density of birds (r^2=0.85. P<0.001)				
Const	8.30	1.700	4.9	<0.01
Woods	156.5	23.34	6.7	<0.001
Number of species nesting on the ground (r^2=0.59, P<0.01)				
Const	4.43	0.468	9.5	<0.0001
Woods	22.53	6.424	3.5	<0.01
Density of species nesting on the ground (r^2=0.25, P<0.1)				
No variables were entered	–	–	–	–
Into model	–	–	–	–
Number of species nesting lowly in vegetation (r^2=0.48, P<0.05)				
Const	1.70	0.772	2.2	<0.1
Woods	30.49	10.60	2.9	<0.01
Density of species nesting lowly in vegetation (r^2=0.90, P<0.001)				
Const	0.427	0.509	0.8	ns
Woods	89.47	6.987	12.8	<0.0001
Number of species nesting highly in vegetation (r^2=0.90, P<0.001)				
Woods	117.75	16.82	7.0	<0.001
Grass	-17.39	6.83	2.5	<0.05
Density of species nesting highly in vegetation (r^2=0.99, P<0.0001)				
Woods	86.64	3.486	24.9	<0.0001
Number of species nesting in tree-holes (r^2=0.88, P<0.0001)				
Woods	53.92	6.68	8.1	<0.0001
Density of species nesting in tree-holes (r^2=0.94, P<0.0001)				
Woods	48.68	3.932	12.4	0.0001

(r = 0.74–0.89) are weaker than those between the 'habitat' variables and bird density (r = 0.93–0.99) (Table 3 and 4). It seems that the difference is caused by non-linear relationships between the species number (total or within nest-guilds) and woods (Fig. 1), which cannot be well fitted to linear equation.

DISCUSSION

The avifauna of the plots studied may be regarded as typical for that occurring in agricultural landscapes of West Poland (JERMACZEK & TRYJANOWSKI 1990, KUJAWA 1994, TRYJANOWSKI 1999). The following species are characteristics for this community: *Motacilla flava*, *Acrocephalus palustris* and this community is dominated by *Alauda arvensis*. On the other hand, we recorded remark-

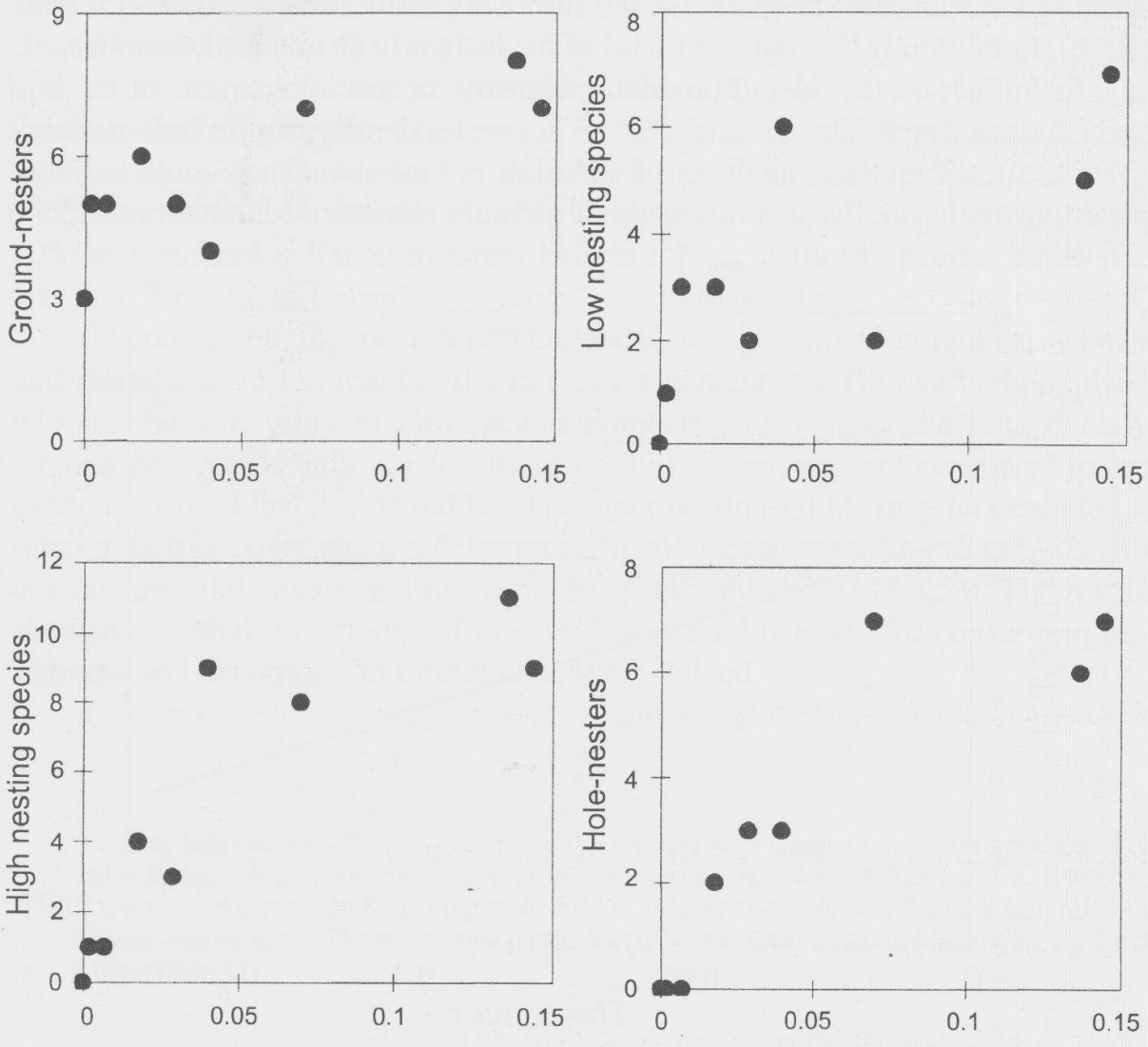

Fig. 1. Relationships between tree cover (transformed by arcsine function) and species number in the nest-guilds

able between-plots variation in bird density, as well as number of species. Our results showed that differences in the bird communities, as well as in the nesting-guilds in the agricultural landscape, may be explained by reference to a small number (1–2) of variables characterising the landscape structure. It is clear from the results that tree cover plays a decisive role in the forming of bird communities in agricultural landscapes. BONGIORNO (1982), SCHIFFERLI *et al.* (1985), O'CONNOR & SHRUBB (1986), FUCHS & SCHIFFERLI (1989) and BERG & PART (1994) obtained similar results.

However, the results from Ireland (LYSAGHT 1989) do not point to a positive relationship between the overall density of linear hedges and the number of species, and population density. Calculated on the basis of data found in the cited work, the Spearman's rank correlation coefficients, r_S were even negative – with respective values of -0.15 and -0.20 ($P>0.05$). This unexpected result may be linked to limited variation in the density of hedges (from 122–157 m/ha). The same explanation may be given for the surprising result obtained by BULL *et al.* (1976). In this study the removal of 1/3 of the hedges in an area had no noticeable negative effect on the overall population density, or species richness of the bird communities despite the obvious decline in species density, e.g. in hole-nesters.

As a consequence, analyses of variation in bird abundance could be interpreted at two spatial scales: (a) scale of a single element of landscape, and (b)

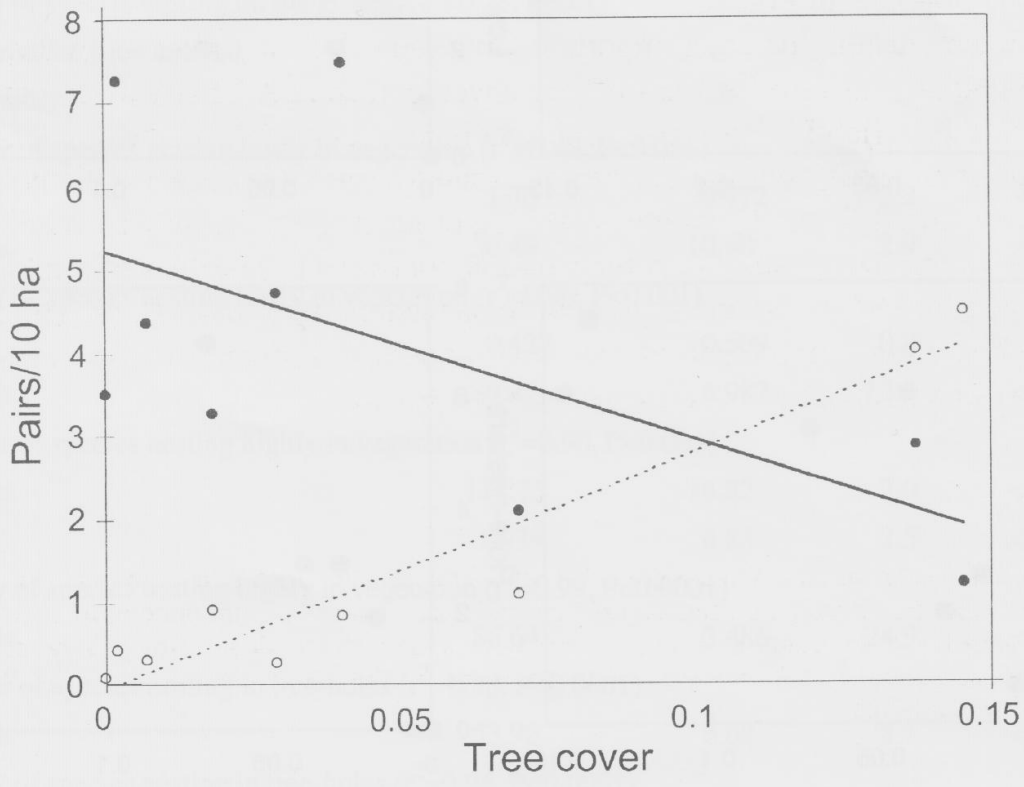

Fig. 2. Relationships between tree cover (transformed by arcsine function) and two ground-nesters: *Emberiza citrinella* (circles) and *Alauda arvensis* (filled circles)

scale of the whole landscape. Our results show that there was a possibility to explain variability in bird abundance depending on a landscape parameter. The strong correlations between landscape parameters and bird abundance used in our study suggest that if we analyse sufficiently long series of plots, the effect of singular variables on birds may be overlooked.

The density of ground-nesters was the only 'bird' parameter, which was not dependent on any measured 'habitat' variables. The reason is the diverse relationships between some ground-nesting species and 'habitat' variables. For example the density of some species, e.g. *Emberiza citrinella* increases with tree cover, but that of some others, e.g. *Alauda arvensis* decreases (Fig. 2). Thus, even though the number of ground-nesting species increases with tree cover, the density did not.

In the present study, total density of breeding birds was markedly lower than in many other studies in Great Britain, which were carried out in areas with similar percentage of tree cover (O'CONNOR & SHRUBB 1986). This is an unexpected result, because the intensity of British farming is higher than the Polish one, so one may rather expect a reverse relation. Probably it may be linked with the very long (5000 years) history of British farming, which provided enough time for forest species to adapt to altered habitats (O'CONNOR & SHRUBB 1986). Very long transition from the forest to field system may also explain why up to 80% of farmland avifauna in Great Britain represent forest species, while it is less than 30–50% in Poland.

In conclusion, the most important landscape element affecting bird richness and abundance in farmland is the tree cover percentage. This variable explains 63% of the variability in bird species numbers and 85% of the total density. Among nest-guilds only the density of ground-nesters was not correlated to any of the measured 'habitat' variables. The other nesting-guilds may be predicted in relation to tree cover and the determination coefficient regarding to total density amounted to 0.94–0.99, and regarding to species number 0.48–0.90. The results showed essential importance of marginal woodland habitats for conserving bird richness and abundance in farmland of West Poland.

*

Acknowledgements – We are grateful to the farmers who granted us regular access to their land and supplied valuable information on farmland management. We are grateful to Z. KOSINSKI, A. SURMACKI, and especially R. J. FULLER and three anonymous reviewers for their helpful comments on an earlier draft. The study was partly found by the Committee for Scientific Research (No. 6 PO4G 046 11).

REFERENCES

BASTIAN, O., HUMMITZSCH, P. & SCHRACK, M. (1989) Beziehungen zwischen Landschaftsstruktur und Artenvielfalt der Avifauna in der Agrarlandschaft nördlich von Dresden. *Zool. Abhandl.* **45**: 53–73.

BELLAMY, P. E., HINSLEY, S. A. & NEWTON, I. (1996) Factors influencing bird species numbers in small woods in south-east England. *J. Appl. Ecol.* **33**: 249–262.

BERG, A. & PART, T. (1994) Abundance of breeding farmland birds on arable and set-aside fields at forest edges. *Ecography* **17**: 147–152.

BEZZEL, E. (1982) *Vögel in der Kulturlandschaft.* Ulmer Verlag, Stuttgart, 350 pp.

BONGIORNO, S. (1982) Land use and summer bird populations in northwestern Galicia, Spain. *Ibis* **124**: 1–20.

BROWN, A. F. & STILLMAN, R. A. (1993) Bird-habitat associations in eastern Highlands of Scotland. *J. Appl. Ecol.* **30**: 31–42.

BUCKLAND, S. T. & ELSTON, D. A. (1993) Empirical models for the spatial distribution of wildlife. *J. Appl. Ecol.* **30**: 478–495.

BULL, A. L., MEAD, C. J. & WILLIAMSON, K. (1976) Bird-life on a Norfolk Farm in relation to agricultural changes. *Bird Study* **23**: 163–182.

CIESLAK, M. (1985) Influence of forest size and other factors on breeding bird species number. *Ekol. Pol.* **33**: 103–121.

FLADE, M. (1994) *Die Brutvogelgemeinschaften Mittel- und Norddeutschlands.* IHV-Verlag, Eching, 879 pp.

FUCHS, E. & SCHIFFERLI, L. (1980) Comparative censuses in Swiss farmland. Pp. 107–113. *In* OELKE, H. (ed.): *Bird Census Work and Nature Conservation, Proc. VI. Intern. Conf. Bird Census Work.* Göttingen.

GÓRSKI, W. (1988) Birds breeding in the farmland of the Damnica Plateau (NW Poland). *Acta orn.* **24**: 29–61.

JERMACZEK, D. & TRYJANOWSKI, P. (1990) Breeding bird communities in the farmland of Ziemia Lubuska and Western Wielkopolska (Western Poland) with the consideration of arable fields. *Lub. Przegl. Przyr.* **1–3**: 3–26.

KONDRACKI, J. (1988) Geografia fizyczna Polski. [Physical geography of Poland]. PWN, Warszawa, 464 pp.

KOT, H. (1990) The effect of suburban landscape structure on communities of breeding birds. *Pol. Ecol. Stud.* **14**: 235–261.

KUJAWA, K. (1994) Influence of land-use change within agricultural landscapes on the abundance and diversity of breeding bird communities. *In* RYSZKOWSKI, L. & BAAZY, S. (eds): *Functional Appraisal of Agricultural Landscape in Europe.* ZBSRiL PAN, Poznan, pp. 183–196.

KUJAWA, K. (1997) Relationships between the structure of mid-field woods and their breeding bird communities. *Acta orn.* **32**: 175–184.

LACK, P. C. (1988) Hedge intersections and breeding bird distribution in farmland. *Bird Study* **35**: 133–136.

LYSAGHT, L. S. (1989) Breeding bird populations of farmland in mid-west Ireland in 1987. *Bird Study* **36**: 91–98.

NORUSIS, M. J. (1986) *SPSS/PC+. Advanced statistics.* SPSS, Chicago. 482 pp.

O'CONNOR, R. J. & SHRUBB, M. (1986) *Farming and birds.* Cambridge Univ. Press, Cambridge, 284 pp.

OELKE, H. (1968) Wo beginnt bzw. wo endet der Biotop der Feldlerche? *J. Orn.* **109**: 25–29.

OBORNE, P. (1984) Bird numbers and habitat characteristics in farmland hedgerows. *J. Appl. Ecol.* **21**: 63–82.

ROBERSTON, P. A., WOODBURN, M. I. A., NEUTEL, W. & BEALEY, C. E. (1993) Effects of land use on breeding pheasant density. *J. Appl. Ecol.* **30**: 465–477.

SCHIFFERLI, L., BLUM, H. & NAEF-DAENZER, B. (1985) Einfluss der Landschaftsstruktur auf die Zahl der Brutvogelarten im aargauischen Reusstal. *Orn. Beob.* **82**: 251–264.

TOMIALOJC, L. (1980) The combined version of the mapping method. Pp. 92–106. *In* OELKE, H. (ed): *Bird Census Work and Nature Conservation, Proc. VI. Intern. Conf. Bird Census Work*, Göttingen.

TRYJANOWSKI, P. (1999) Effect of habitat diversity on breeding birds: comparison of farmland bird community in the region of Wielkopolska (W Poland) with relevant data from other European studies. *Pol. J. Ecol.* **47**: 153–174.

ZAR, J. H. (1984) *Biostatistical analysis*. Prentice-Hall, Englewood Cliffs, New Jersey, 365 pp.

APPENDIX

List of species breeding on the study plots.
Abbreviations: PR – number of pairs, PL – number of plots

Species	PR	PL
Alauda arvensis	145.5	9
Fringilla coelebs	62	5
Emberiza citrinella	48.5	9
Motacilla flava	42.5	8
Sturnus vulgaris	26.5	6
Carduelis carduelis	22.5	7
Passer montanus	17.5	5
Parus major	15.5	4
Parus caeruleus	14.5	4
Turdus merula	13.5	5
Hippolais icterina	12.5	4
Miliaria calandra	12	5
Sylvia atricapilla	11	4
Carduelis cannabina	9	6
Motacilla alba	9	7
Turdus philomelos	9	4
Carduelis chloris	8.5	3
Sylvia communis	8.5	6
Acrocephalus palustris	7.5	4
Luscinia megarhynchos	6.5	2
Emberiza hortulana	5.5	3
Certhia brahydactyla	4.5	2
Phylloscopus collybita	4.5	3
Sylvia borin	4.5	3

Species	PR	PL
Oriolus oriolus	4	4
Emberiza schoeniclus	3.5	3
Anas platyrhynchos	3	2
Buteo buteo	3	2
Coccothraustes coccothraustes	3	1
Columba palumbus	3	3
Muscicapa striata	3	2
Passer domesticus	3	2
Sitta europaea	2.5	3
Anthus trivalis	2	2
Erithacus rubecula	2	1
Perdix perdix	2	2
Pica pica	2	1
Saxicola rubetra	2	2
Sylvia curruca	2	2
Turdus pilaris	2	1
Streptopelia decaocto	1.5	2
Dendrocopos major	1	1
Galerida cristata	1	1
Lanius collurio	1	1
Phylloscopus trochilus	1	1
Serinus serinus	1	1
Strix aluco	1	1
Luscinia luscinia	0.5	1

Revised version received 21st April, 2000, accepted 30th June, 2000, published 24th July, 2000