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Farmland bird diversity in contrasting agricultural landscapes of southwestern Poland

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HIGHLIGHTS

- Agricultural landscapes of Poland support dense populations of breeding birds.
- High bird abundances are strongly related to a diverse network of field margins.
- Noncropped habitats are more important for biodiversity than land-use diversification.
- Density of shrubby margins is a useful predictor of overall biodiversity in farmlands.
- Preventing landscape simplification should be a priority in complex agroecosystems.

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ABSTRACT

Breeding bird communities were investigated in three contrasting agricultural landscapes of SW Poland to assess differences in abundance and determine the importance of field margins for bird populations. Counts were conducted in twelve 50-ha plots differing in landscape structure (density of all, permanent and shrubby field margins, and occurrence of high vegetation). Maps of bird distributions were used to analyze the associations of birds with four habitats: cropped fields, permanent fallows, field margins, mid-field woodlots. Ordination and classification techniques were applied to check between-plot differences in community composition. All landscapes supported high densities of total communities and farmland specialists. Species richness and bird densities were significantly related to field margin aggregations and arranged along a decreasing gradient of landscape heterogeneity: shrubby mosaic, open mosaic, open plain plots. Between-plot differences suggest that the occurrence of non-cropped habitats is more important for bird abundance than diversification of land-use. PCA and cluster analysis identified differences in species composition between the landscape types; and RDA revealed the significance of the shrubby and permanent margins for the community structure. The aggregation of shrubby margins seems to be a particularly useful predictor of bird abundance and overall biodiversity. Most species and breeding pairs were preferentially associated with margins, despite the habitat covering merely 4% of the area. The data confirmed that landscape heterogeneity with mosaic seminatural field margins is responsible for the persistence of internationally important bird populations in Poland. In such complex arable systems, preventing landscape simplification is the most effective method of biodiversity protection.

1. Introduction

Due to environmental heterogeneity, farmed landscapes belong to the most biodiversity-rich landscapes in Europe. At the same time, in many taxa dramatic declines of farmland populations have been documented (de Heer, Kapos, & ten Brink, 2005) and persist despite huge policy and financial preventive efforts, such as agri-environment schemes (AES) (Santana et al., 2014). Bird communities are commonly used to document these processes, and to quantify the health of overall farmland biodiversity. However, both the bird population metrics and extent of declines are highly uneven among regions, and those with retained traditional farming systems are of particular importance for agricultural biodiversity (Báldi & Batáry, 2011; Billeter et al., 2008; Kleijn et al., 2009; Tryjanowski et al., 2011). Therefore, it has been agreed that to protect biodiversity over larger (e.g., continental) scale conservation, methods should be better tailored to regional biodiversity indices and farming circumstances (Concepción et al., 2012; Jongman,

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2002; Tscharntke, Klein, Kruess, Steffan-Dewenter, & Thies, 2005; Winqvist et al., 2011). Unfortunately, evidence regarding bird abundance and needs (i.e., the base for reliable recommendations) is also not proportional to biodiversity resources. The bulk of ornithological data and conservation proposals come from western Europe with many declining bird populations, whereas evidence from other biogeographic regions that are disproportionately richer in biodiversity, such as Central and Eastern Europe (CEE), are still insufficient, yet growing (Báldi, Batáry, & Kleijn, 2013; Herzon & O'Hara, 2007; Mander, Mikk, & Külvik, 1999; Reif, Voříšek, Šťastný, Bejček, & Petr, 2008; Sutcliffe et al., 2015).

The present study was conducted in one of such regions, in Poland, and examined how the communities of breeding birds respond to different levels of landscape complexity. The country is particularly suitable for this kind of analyzes, given a large area of farmland (>180,000 km^2), the existing types of agriculture, and an internationally important biodiversity (Kuczyński & Chylarecki, 2012; Tryjanowski, Kuźniak, Kujawa, & Jerzak, 2009). At the same time, the agricultural land in Poland is subject to unidirectional, detrimental transformations driven by economic growth, but also by agricultural policy after entering the European Union (EU) (Sanderson, Kucharz, Jobda, & Donald, 2013). These changes are likely to increase and affect the biodiversity in a larger, regional scale; therefore, up-to-date ecological data from species-rich farmlands are required for evidence-based actions to be made.

The landscape complexity in this study has been expressed through the common presence of field margins which are an important feature of the Polish agricultural landscapes. Indeed, in birds recent country-scale evidence indicates that among nine measures of agricultural management the woody edge habitats in Poland, such as tree lines and hedgerows, were the most consistent predictor of overall species richness and richness of target groups, such as species of conservation concern and farmland specialists (Sanderson, Kloch, Sachanowicz, & Donald, 2009). Several habitat-scale studies also confirmed that field margins in Poland are inhabited by rich and diverse communities of birds and other taxa, including regular occurrence of threatened species (Łęcki, 2004; Szymański & Antczak, 2013; Wuczyński, Dajdok, Wierzcholska, & Kujawa, 2014). However, the importance of field margins in a broader landscape perspective has rarely been studied. Thus, there are insufficient data quantifying the proportion of bird communities supported by margins, and overall habitat associations of farmland birds (Herzon, Auninš, Elts, & Preikša, 2006; Skórka, Martyka, & Wójcik, 2006). Actually, this is the first study I know of that assesses the importance of field margins for bird populations in different farmlands of CEE. The under-representation of such information in recent literature also stems from the fact that many modern landscape assessments use remote sensing data which lack of detail (Hazeu et al., 2014; Kosicki & Chylarecki, 2012). Fine-scale linear landscape elements (hedgerows, forest strips, live fences, drainage ditches, little streams, roads, verges, footpaths, (Höbinger, Schindler, Seaman, Wrbka, & Weissenhofer, 2012)) and other key microhabitats are overseen in input datasets, limiting the accuracy of conclusions.

To assess the state and habitat associations of farmland birds, research on communities has principally focused either on broad scale assessments or on small-scale habitat studies. Studies at an intermediate spatial scale employing sample plots of several dozen ha are far less common (e.g. Heikkinen, Luoto, Virkkala, & Rainio, 2004). This scale allows the field work to be conducted with accuracy (e.g., using laborious but reliable mapping methods) and to count all species within the surveyed areas. As a result, there in a noticeable lack of recent studies in CEE comprising whole bird communities; most studies concentrate on selected species or ecological/taxonomic groups. Tryjanowski et al. (2009) reviewed the Polish literature on avian ecology and found merely 11 quality studies assessing the complete bird communities on sound agricultural landscape plots (>3 km^2).

The aims of this paper were to assess: (1) bird species richness and abundance in contrasting agricultural landscapes of SW Poland, (2) number of bird species, breeding density and community composition in response to the aggregation of different field margin types and, (3) the input of four major habitats in the studied landscapes to the whole bird community and the most numerous species, including the share of pairs breeding in field margins.

2. Methods

2.1. Study area

The study was conducted in diverse agricultural landscapes of the Lower Silesia region covering the SW corner of Poland. The region is not homogeneous regarding agricultural landscapes and farming intensity. Generally, farming in the Lower Silesia is more intensive than in Eastern Poland (that often resemble traditional farmlands), but not as much as in some Western European countries. The intensification processes are clearly visible in parts of the region, but many characteristics of low-intensity farming still retained in the other parts. SW Poland represents typical Central-European landscape, which has been confirmed by comparable values of indicators of land-use and agricultural production (see Wuczyński et al., 2014). These regional features allowed a comparative between-landscape study to be conducted within one geographical unit.

2.1.1. Landscape plots

Twelve study plots of ca. 50 ha each (603.2 ha). Three contrasting groups of plots were selected to reflect the prevailing types of modern arable farmland in Poland, and more generally in CEE (Fig. 1, Table 1, Appendix A):

Shrubby mosaic plots: Covered by small, privately-owned fields (0.1 ha up to 8.6 ha), a few mid-field woodlots and a few permanent fallows, and a network of linear, semi-natural field margins (described below). These heterogeneous plots reflected a model of traditional, low-intensity farming, which is disappearing in Europe but still exists in some Polish landscapes. According to recent terminology applied to agricultural landscapes, shrubby mosaic plots match the "High Nature Value Farmland Type 2" (i.e., "farmland with a mosaic of low intensity agriculture and natural and structural elements, such as field margins, hedgerows, stone walls, patches of woodland or scrub, small rivers" (Paracchini, Terres, Petersen, & Hoogeveen, 2007)).

Open mosaic plots: Similar to the shrubby mosaic plots according to ownership, land-use and field sizes, but almost lacking of high vegetation. Open mosaics are common especially in lowlands of central and eastern Poland.

Open plain plots: Intensively used, covered by a few large arable fields and, consequently, with a very low aggregation of field margins and almost devoid of other non-cropped habitats. This type of farmland is rapidly increasing after EU accession, especially in western Poland.

It is noteworthy that the open mosaic and open plain plots were combined in some analyzes. Each plot was digitally mapped using GIS, allowing for further spatial analyzes. Altogether, cropland (including 2.2% of grasslands) constituted 91.1% of the area, followed by 4.4% permanent fallows (covered by perennial vegetation), 4.0% field margins, 0.4% mid-field copses; mean area 0.36 ha, range 0.03–0.96 ha, N = 7; Fig. 1). The main crops were winter- and spring-sown cereals (ratio – ca 4:1, respectively, mainly wheat, barley, rye), oilseed rape, maize, and root plants (e.g., potatoes, sugar beets). Fallows, copses, and grasslands occurred almost exclusively

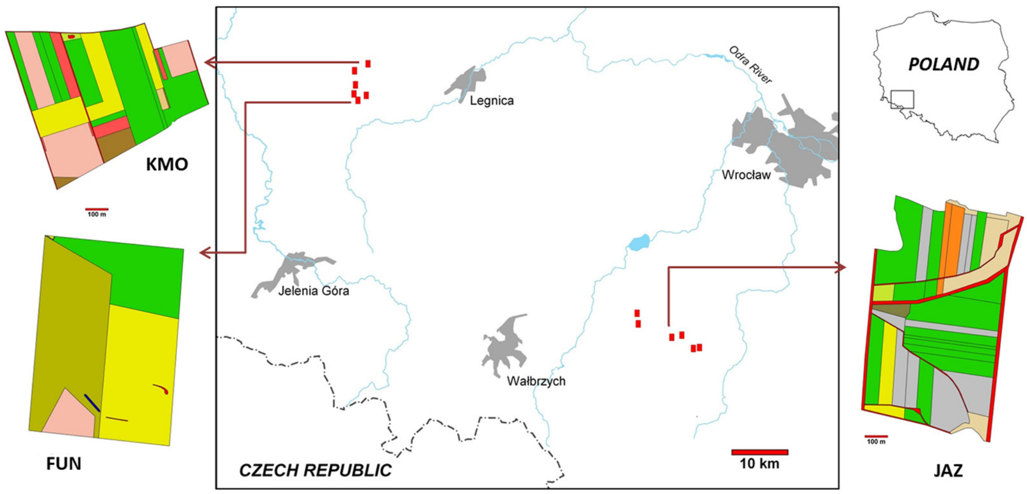

Fig. 1. Distribution of study plots against the map of SW Poland, and the outlines of example shrubby mosaic (JAZ), open mosaic (KMO), and open plain (FUN) plots. Crops and other land cover types are shown by different colors (i.e., red–permanent field margins, green–winter cereals, grey and orange–spring cereals, yellow–winter rape, pink–sugar beet, brown–potato, celadon - maize, beige–fallow). For detailed locations of the study plots, the reader is referred to the Google Earth file in the web version of the article. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

in the shrubby mosaic plots. The number of mature trees (≥30 cm diameter at breast height) was also counted to represent the occurrence of woody plants in each study plot, and totally amounted to 435 trees, mostly of deciduous species.

2.1.2. Field margins

Special attention was devoted to field margins for their common occurrence in farming landscapes and resulting importance for biodiversity. In this study, edges of all separated fields, resulting from the current land-use, were considered as field margins. No margin strips managed for conservation, which were components of agri-environment schemes in EU (Vickery, Feber, & Fuller, 2009), occurred in the studied agricultural landscape. Three not exclusive types of margins were distinguished to determine their relationship with bird diversity:

All field margins: All boundaries of separated field patches, both seasonal and permanent, well reflecting the land-use complexity.

Permanent field margins: Semi-natural habitats usually associated with human-made landscape features (roads and ditches), and covered with a lush spontaneous vegetation.

Shrubby field margins: Subset of the former group, limited to stretches with shrubs and isolated trees, including remnants of fruit tree lines and field edges adjacent to mid-field woodlots and forests adjoining the study plots.

The author also characterized the margins in terms of their vegetation structure, lengths and widths, using GeoMedia Professional 5.2 GIS software (http://www.intergraph.com).

2.2. Field procedures

Birds were surveyed using the spot (territory) mapping method (Ralph, Geupel, Pyle, Martin, & DeSante, 1993; Sutherland, 2006) in three breeding seasons: the shrubby mosaic plots were investigated in 2004 and 2005, whereas the open mosaic and open plain plots in 2007. Despite different years of counting, bird data could be compared among plots thanks to contrasting differences in habitat characteristics between the two plot groups (shrubby vs open) and minor between-year differences in shrubby mosaic plots (see below). Prior to counts, detailed maps of each study plot were generated. Land-use was further validated in the field. All field borders and some landscape features, such as semi-natural habitats

Table 1
Plot traits divided into groups (representing various types of landscapes).

Plot	Landscape	Area (ha)	Aggregation[a] of field margins [km/km^2]			No. of trees
			All margins	Permanent margins	Shrubby margins	
1 SIE	Shrubby mosaic	50.8	24.4	13.8	3.9	10
2 SIW	Shrubby mosaic	50.7	23.6	14.7	4.8	30
3 JAZ	Shrubby mosaic	49.0	26.6	11.2	6.4	54
4 SLU	Shrubby mosaic	52.6	30.9	12.3	8.0	112
5 WIS	Shrubby mosaic	48.1	24.1	14.2	9.3	134
6 WIN	Shrubby mosaic	52.9	25.0	16.5	4.3	91
7 KMO	Open mosaic	49.7	19.8	5.6	0.4	0
8 KLU	Open mosaic	50.0	17.7	3.6	0.3	1
9 KUN	Open mosaic	49.1	18.7	6.4	0.0	0
10 FMO	Open plain	50.1	2.9	1.2	0.0	0
11 FLU	Open plain	50.1	3.1	3.1	0.0	0
12 FUN	Open plain	50.2	4.2	0.7	0.1	3
Shrubby mosaic (mean ± SD)	50.7 ± 1.9	25.8 ± 2.7	13.7 ± 1.9	6.1 ± 2.2	71.8 ± 48.4	
Open (mean ± SD)	49.8 ± 0.4	11.1 ± 8.5	3.4 ± 2.3	0.1 ± 0.2	0.7 ± 1.2	
Open mosaic (mean ± SD)	49.6 ± 0.4	18.8 ± 1.1	5.2 ± 1.5	0.2 ± 0.2	0.3 ± 0.6	
Open plain (mean ± SD)	50.1 ± 0.1	3.4 ± 0.7	1.7 ± 1.3	0.0 ± 0.0	1.0 ± 1.7	
All plots (mean ± SD)	50.3 ± 1.4	18.4 ± 9.7	8.6 ± 5.7	3.1 ± 3.5	36.3 ± 49.5	

[a] Note that the term ‘aggregation’ is identical with the ‘density’ of field margins; the latter term is rarely used in this paper to avoid confusing with the density of birds.

(patches of fallows, isolated trees or shrubs), and power lines, were included in the maps. This was sufficient for precise bird mapping in the shrubby and open mosaic plots. To enhance bird mapping in the three open plain plots, these components were additionally marked in a grid of 150 m × 150 m.

All parts of each study plot were visited between April and July on five occasions; four in the morning and one in the evening, under appropriate weather conditions (no rain, fog and strong wind). The morning counts began around sunrise and were completed by 10:00 a.m. CET; some counts were extended until noon when nests were identified and controlled. The evening visit was done for censusing mainly dusk-active birds, including the Partridge (*Perdix perdix*), Common Quail (*Coturnix coturn*ix), Grasshopper Warbler (*Locustella naevia*), Blackbird (*Turdus merula*) (Cramp & Simmons, 2004). Standard conventions of the territory mapping method were used to record bird activities (Sutherland, 2006). The positions of the recorded birds were marked on a map using standard codes. Care was taken to record simultaneous territorial behavior and any other indications of breeding (e.g., found nests, social behaviors, birds carrying food, nesting materials). When counting Skylarks, the sites of taking off and landing after a song-flight were mapped to estimate the territories. In the territories assigned during the counts, nests of two field margin specialists, the Red-backed Shrike (*Lanius collurio*) and Barred warbler (*Sylvia nisoria*) were actively searched for and mapped for another project (Orłowski, Wuczyński, & Karg, 2015). The number of territories and habitat associations of the Marsh Harrier (*Circus aeruginosus*) were established based on regular (during each count) observations of adult birds and their social behaviors (e.g., between-neighbors fights, courtship, carrying gifts for a mate) (Cramp & Simmons, 2004).

2.3. Quantifying abundance of birds

After each breeding season, records were mapped. Territories were assigned in relation to the distribution of clusters of sightings. At least two registrations were taken as evidence of a particular territory, exceptionally it was one registration–in the case of certain evidence of breeding (nests) or some late migrants of irregular song activity, such as the Marsh Warbler (*Acrocephalus palustris*). In the case of the edge clusters, those that overlap the plot boundary, half of the territory was counted as belonging to the plot. Territories were then counted to calculate the population metrics used in further analyzes: (1) species richness: sum of species having any territory within the plot, (2) number of breeding pairs: sum of territories of each bird species, and (3) density: number of breeding pairs per 10 ha. The Cuckoo (*Cuculus canorus*) was accounted for in the number of species but not in the number of breeding pairs and associated analyzes, because of its unusual breeding system. For the shrubby mosaic plots, the mean number of species and breeding pairs in 2004 and 2005 was calculated and used in further analyzes, including comparisons with the open plots. Using the means was justified, since the bird indices were very similar in both seasons, especially the total number of breeding pairs in particular plots coincided. So, there was no significant difference between the median number of species in both years (23.0 and 24.5, respectively, $n = 6$, $T = 5.00$, $P = 0.249$) nor in the total number of breeding pairs (115.3 and 119.0, respectively, $n = 6$, $T = 5.50$, $P = 0.294$; Wilcoxon test for matched pairs).

Maps of bird distributions and percentages of habitat types (see above) were also used to analyze bird-habitat associations. Each territory was assigned to one of the four habitat types: crop-fields, permanent fallows, field margins, and mid-field woodlots. Usually the assignment clearly arose from clusters of sightings being located within the particular habitat. In doubtful situations halves of territories were allocated between two neighboring habitats. The data were analyzed including the total bird community and separately, the functional group of open field species and the Skylark–for particular importance of these birds in the study plots and farming landscapes in general. The species were assigned to the group based on their habitat preferences (Tryjanowski et al., 2009; Wuczyński, Kujawa, Dajdok, & Grzesiak, 2011) and indicated (Table 2).

2.4. Data analysis

Groups of sample plots (shrubby mosaic, open mosaic, open plain) were contrasted using bird population indices, defined above, and two diversity metrics: the reciprocal Simpson's index ($D_{\text{Simpson}} = 1/\sum p_i{}^2$ where *pi* is the proportion of pairs in the *i*th species) and Simpson's evenness index ($E_{\text{Simpson}} = D_{\text{Simpson}}$/number of species). The author used Simpson's index, and the associated evenness measure, because it is considered to be robust, easy to interpret, and applicable at small sample sizes (Magurran, 2004). Moreover, E_{Simpson} is useful when study areas of differing numbers of species are to be compared, because the index is insensitive to species richness. Due to small sample sizes, non-parametric tests were applied: the Mann–Whitney *U* test was used to compare between-plot differences in bird metrics, and Spearman rank correlations were used to relate bird abundances to margin aggregations. The calculations of the *U* tests and rank correlations were performed with the STATISTICA 10 package.

To examine the patterns of bird species distribution within the sample plots and the relationship with the field margins network, the ordination methods were employed using CANOCO for Windows 4.5 (Lepš & Šmilauer, 2003). Detrended correspondence analysis (DCA) was run a priori, in order to estimate the length of the compositional gradient. The resultant gradient length (e.g., 2.354 for the first axis) indicated that the linear models of PCA and RDA were appropriate (ter Braak & Šmilauer, 2002).

Principal component analysis (PCA) was employed to examine the patterns of bird species distribution in the three groups of sample plots. The results were visualized in the ordination diagram in CanocoDraw 4.0 (ter Braak & Šmilauer, 2002). To make the interpretation of diagram easier, scaling of ordination scores focused on inter-species correlations and species scores were divided by their standard deviation. Moreover, default option "centering by species" was chosen. Along with the PCA, the cluster analysis was performed to compare the plots in relation to the similarity in the composition of the avian community. Pairwise Morisita's similarity indices (Magurran & McGill, 2011) for bird abundance data were calculated and displayed as a dendrogram. Clustering algorithm was the unweighted pair group method using arithmetic averages (UPGMA). The software PAST 3.01 (http://folk.uio.no/ohammer/past) was used for cluster analysis.

Multivariate constrained ordination redundancy analysis method (RDA) was applied to relate the bird community composition to four explanatory variables (i.e., the aggregations of the three field margin types and the number of mature trees within the plot). Bird abundances were log-transformed; centering was by species only. The RDAs were used first to summarize the joint effect of the explanatory variables on bird species composition. Global Monte Carlo permutation tests of the first ordination axis and that of all canonical axes together under the full model (499 permutations) tested the significance of the model. Second run of RDAs tested the significance of individual variables separately and using the forward selection procedure (Lepš & Šmilauer, 2003). Separate testing allowed to inspect the marginal effects of all environmental variables on species composition (i.e., the independent effect of the shrubby, permanent and all field margin aggregations, and the number of trees). Forward selection revealed the conditional

Table 2
Bird abundances in the three studied types of plots. Values denote the mean (±SD and range) number of pairs breeding in the respective plot types, the total number of pairs, and total density. The open field species are marked with the asterisks.

Species	Shrubby mosaic		Open mosaic		Open plain		Total	Density (pairs/10 ha)
	Mean ± SD	Min - Max	Mean ± SD	Min - Max	Mean ± SD	Min - Max		
Skylark *Alauda arvensis**	26.0 ± 8.5	17.0–39.8	50.8 ± 6.6	47.0–58.5	41.5 ± 3.1	38.0–44.0	433.0	7.18
Yellowhammer *Emberiza citrinella*	21.0 ± 3.6	14.5–24.8	0.3 ± 0.6	0.0–1.0	0.0	0.0	127.3	2.11
Marsh Warbler *Acrocephalus palustris**	11.8 ± 7.7	2.0–25.0	3.3 ± 4.2	0.0–8.0	0.7 ± 1.2	0.0–2.0	83.0	1.38
Yellow Wagtail *Motacilla flava**	1.2 ± 1.0	0.0 - 2.5	9.5 ± 3.9	7.0–14.0	11.7 ± 13.3	3.0–27.0	70.8	1.17
Red-backed Shrike *Lanius collurio*	9.0 ± 2.2	6.3–12.5	0.0	0.0	0.0	0.0	53.8	0.89
Blackbird *Turdus merula*	6.7 ± 2.2	4.0–9.0	0.0	0.0	0.0	0.0	40.0	0.66
Whitethroat *Sylvia communis*	6.2 ± 1.4	4.5–8.0	0.0	0.0	0.3 ± 0.6	0.0–1.0	38.0	0.63
Corn Bunting *Emberiza calandra**	3.6 ± 2.1	0.0–6.3	1.2 ± 1.0	0.0–2.0	0.5 ± 0.5	0.0–1.0	26.5	0.44
Song Thrush *Turdus philomelos*	4.3 ± 2.5	2.0–8.5	0.0	0.0	0.0	0.0	25.5	0.42
Whinchat *Saxicola rubetra**	3.3 ± 2.8	0.0–6.5	0.0	0.0	0.3 ± 0.6	0.0–1.0	21.0	0.35
Blackcap *Sylvia atricapilla*	3.0 ± 3.2	0.0–7.0	0.0	0.0	0.0	0.0	17.8	0.29
Barred Warbler *Sylvia nisoria*	2.8 ± 1.2	1.3–4.3	0.3 ± 0.6	0.0–1.0	0.0	0.0	17.5	0.29
Quail *Coturnix coturnix**	0.5 ± 0.7	0.0–1.8	1.2 ± 0.8	0.5–2.0	3.0 ± 1.8	1.5–5.0	15.8	0.26
Greenfinch *Carduelis chloris*	2.0 ± 1.6	0.0–4.0	0.0	0.0	0.0	0.0	12.3	0.20
Pheasant *Phasianus colchicus*	1.9 ± 1.7	0.0–4.8	0.0	0.0	0.0	0.0	11.3	0.19
Chaffinch *Fringilla coelebs*	1.9 ± 1.9	0.0–4.3	0.0	0.0	0.0	0.0	11.3	0.19
Tree Sparrow *Passer montanus*	1.6 ± 1.3	0.0–3.8	0.0	0.0	0.0	0.0	9.5	0.16
Linnet *Carduelis cannabina*	1.3 ± 1.1	0.0–2.8	0.0	0.0	0.0	0.0	7.8	0.13
Reed Bunting *Emberiza schoeniclus*	1.1 ± 1.2	0.0–3.3	0.3 ± 0.6	0.0–1.0	0.0	0.0	7.8	0.13
Stonechat *Saxicola rubicola**	1.0 ± 0.9	0.0–2.0	0.3 ± 0.6	0.0–1.0	0.0	0.0	7.0	0.12
Grey Partridge *Perdix perdix**	0.2 ± 0.3	0.0–0.5	1.0 ± 1.0	0.0–2.0	1.0 ± 1.0	0.0–2.0	7.0	0.12
Blue Tit *Cyanistes caeruleus*	1.2 ± 1.0	0.0–2.8	0.0	0.0	0.0	0.0	7.0	0.12
Hawfinch *Coccothraustes coccothraustes*	1.1 ± 0.9	0.0–2.5	0.0	0.0	0.0	0.0	6.8	0.11
Marsh Harrier *Circus aeruginosus*	0.0	0.0	1.2 ± 0.6	0.5–1.5	0.8 ± 0.3	0.5–1.0	6.0	0.10
Garden Warbler *Sylvia borin*	1.0 ± 2.1	0.0–5.3	0.0	0.0	0.0	0.0	5.8	0.10
Starling *Sturnus vulgaris*	0.8 ± 0.8	0.0–2.0	0.2 ± 0.3	0.0–0.5	0.0	0.0	5.3	0.09
Grasshopper Warbler *Locustella naevia**	0.8 ± 0.8	0.0–2.0	0.0	0.0	0.0	0.0	4.5	0.07
Great Tit *Parus major*	0.7 ± 0.7	0.0–1.8	0.0	0.0	0.0	0.0	4.3	0.07
Chiffchaff *Phylloscopus collybita*	0.7 ± 0.7	0.0–2.0	0.0	0.0	0.0	0.0	4.3	0.07
Lesser Whitethroat *Sylvia curruca*	0.6 ± 0.7	0.0–1.8	0.0	0.0	0.0	0.0	3.8	0.06
Goldfinch *Carduelis carduelis*	0.6 ± 0.7	0.0–1.8	0.0	0.0	0.0	0.0	3.5	0.06
Serin *Serinus serinus*	0.5 ± 0.8	0.0–2.0	0.0	0.0	0.0	0.0	2.8	0.05
Dunnock *Prunella modularis*	0.4 ± 0.7	0.0–1.5	0.0	0.0	0.0	0.0	2.5	0.04
Great Spotted Woodpecker *Dendrocopos major*	0.4 ± 0.4	0.0–1.0	0.0	0.0	0.0	0.0	2.3	0.04
Icterine Warbler *Hippolais icterina*	0.3 ± 0.8	0.0–2.0	0.0	0.0	0.0	0.0	2.0	0.03
Lapwing *Vanellus vanellus**	0.1 ± 0.3	0.0–0.8	0.3 ± 0.6	0.0–1.0	0.0	0.0	1.8	0.03
River Warbler *Locustella fluviatilis*	0.3 ± 0.4	0.0–1.0	0.0	0.0	0.0	0.0	1.8	0.03
Turtle Dove *Streptopelia turtur*	0.3 ± 0.4	0.0–1.0	0.0	0.0	0.0	0.0	1.5	0.02
Woodpigeon *Columba palumbus*	0.2 ± 0.5	0.0–1.3	0.0	0.0	0.0	0.0	1.3	0.02
Great Grey Shrike *Lanius excubitor*	0.2 ± 0.3	0.0–0.8	0.0	0.0	0.0	0.0	1.3	0.02
Golden Oriole *Oriolus oriolus*	0.2 ± 0.2	0.0–0.5	0.0	0.0	0.0	0.0	1.3	0.02
Pied Wagtail *Motacilla alba*	0.1 ± 0.2	0.0–0.5	0.0	0.0	0.2 ± 0.3	0.0–0.5	1.0	0.02
Great Reed Warbler *Acrocephalus arundinaceus*	0.2 ± 0.3	0.0–0.5	0.0	0.0	0.0	0.0	1.0	0.02
Wryneck *Jynx torquilla*	0.1 ± 0.2	0.0–0.5	0.0	0.0	0.0	0.0	0.8	0.01
Collared Dove *Streptopelia decaocto*	0.1 ± 0.2	0.0–0.5	0.0	0.0	0.0	0.0	0.8	0.01
Mallard *Anas platyrhynchos*	0.1 ± 0.2	0.0–0.5	0.0	0.0	0.0	0.0	0.5	0.01
Fieldfare *Turdus pilaris*	0.1 ± 0.2	0.0–0.5	0.0	0.0	0.0	0.0	0.5	0.01
Spotted Flycatcher *Muscicapa striata*	0.1 ± 0.2	0.0–0.5	0.0	0.0	0.0	0.0	0.5	0.01
Nightingale *Luscinia megarhynchos*	0.1 ± 0.2	0.0–0.5	0.0	0.0	0.0	0.0	0.5	0.01
Cuckoo *Cuculus canorus*	+						+	
Total no of pairs	121.4 ±19.6	95.8–154	70.0 ± 9.3	63.0–80.5	60.0 ± 14.8	50.5–77.0	1118.3	
Density (pairs/10 ha)	23.9 ± 3.2	19.5–29.3	14.1 ± 1.8	12.7–16.1	12.0 ± 3.0	10.1–15.4		18.54

effects (i.e., the effect that each variable brings in addition to all the variables already selected). As before, the significance of the relationships between the environmental variables and the bird communities were determined using Monte Carlo test with 499 unrestricted permutations.

Finally, I used PAST to check the effects of the proportion of four habitat types (field margins, copses, fallows, and cropfields) on bird abundance. The effects were tested with a randomization test of goodness-of-fit, with 9999 random replicates. The test is an alternative to the more popular chi-square test, when the sample sizes are small (Sokal & Rohlf, 1995). Since the percentages of three habitats (except cropland) were small, the derived expected bird count values were also small and the randomization test was appropriate.

3. Results

3.1. Between-plot differences in bird abundances

A total of 50 bird species breeding in a mean density of 18.5 pairs/10 ha (SD ± 6.3) were recorded in the 12 study plots (Table 2, Appendix B). Pronounced between-plot differences were observed regarding both the number of species and breeding pairs (ten and three-fold min-max differences, respectively; Table 2). There was a highly significant difference between the shrubby mosaic and open landscapes regarding species richness, bird numbers and density, and species diversity ($P < 0.01$ in each case), but not species evenness (Table 3). Generally the indices of bird communities were arranged along a decreasing gradient of study sites: shrubby

Table 3
Indices of total bird communities, open farmland species, and the Skylark in the study plots. Mean values are shown (min-max in parentheses).

Variable	Shrubby mosaic plots (n = 6)	Open plots (n = 6)	P^a	Open mosaic plots (n = 3)	Open plain plots (n = 3)	P^a	All plots (n = 12)
Number of species	45 (20–36)	16 (4–9)	<0.01	13 (6–9)	10 (4–9)	0.64	50 (4–36)
Number of breeding pairs	728.3 (95.8–154.0)	390 (50.5–80.5)	<0.01	210 (63.0–80.5)	180 (50.5–77.0)	0.38	1118.3 (50.5–154.0)
Total density (pairs 10 ha^{-1})	23.9 (19.5–29.3)	13.0 (10.1–16.1)	<0.01	14.1 (12.7–16.1)	12.0 (10.1–15.4)	0.38	18.5 (10.1–29.3)
Index of diversity ($D_{Simpson}$)	9.78 (6.21–14.61)	1.87 (1.31–2.31)	<0.01	1.82 (1.74–1.90)	1.92 (1.31–2.31)	1.00	5.55 (1.31–14.61)
Evenness index ($E_{Simpson}$)	0.20 (0.28–0.35)	0.12 (0.19–0.33)	0.30	0.14 (0.19–0.32)	0.19 (0.21–0.33)	0.19	0.11 (0.19–0.35)
Share of open farmland species (% of breeding pairs)	40.0 (19.5–61.3)	97.2 (97.5–98.7)	<0.01	96.7 (95.7–98.4)	97.8 (96.2–98.7)	0.66	59.9 (19.5–98.7)
Density of open farmland species (pairs 10 ha^{-1})	9.6 (4.8–14.0)	12.7 (9.9–15.4)	0.13	13.6 (12.5–15.4)	11.7 (9.9–15.2)	0.38	11.1 (4.8–15.4)
Density of Skylark (pairs 10 ha^{-1})	5.1 (3.5–7.8)	9.3 (7.6–11.7)	<0.01	10.2 (9.5–11.7)	8.3 (7.6–8.8)	0.08	7.2 (3.5–11.7)

[a] The significance level was tested with Mann–Whitney U test.

mosaic–open mosaic–open plain. Higher values in species richness and bird abundance were noted in the open mosaic than in open plain plots (13 and 10 species; 14.1 and 12.0 pairs 10 ha^{-1}, respectively), but the differences were not significant.

The group of ten open farmland species predominated in bird communities, reaching up to 98.7% of breeding pairs in open plain plots. The group had higher, yet non-significant densities in open landscapes compared to shrubby mosaic plots (Mann–Whitney U test: Z = –1.52, P = 0.13), and in open mosaic than open plain plots (Z = –0.87, P = 0.38) (Table 3). This pattern was created mainly by the Skylarks, the most numerous of the true farmland species and of the whole bird community (38.7% of the total breeding pairs). The mean density of Skylark was significantly higher in open than in shrubby mosaic plots (Z = –2.64, P = 0.008); the difference between open mosaic and open plain plots was marginally significant (Z = –1.75, P = 0.08), with higher values in the former group.

The number of species and breeding pairs were highly correlated with the aggregation of field margins, and the correlation strength has apparently been weakly related to the subset of margins taken (all, permanent or shrubby margins) (Table 4). However, the inspection of scatterplots (Appendix C) indicated that the observed relationships were created mainly by the difference between the groups of shrubby mosaic and open plots. When limited to the sub-sample of open plots the relationships were weak.

3.2. *Bird communities among the study plots*

PCA ordination results confirmed that the three groups of sample sites were inhabited by partly different bird communities. The first PCA axis explained most (75.2%) of the total species variance and clearly separated the shrubby mosaic plots from the open plots. The eigenvalue for axis one was 0.75 and for axis two 0.10. Thus, the first axis can be identified with the gradient of the high vegetation cover, with typical open farmland species (Skylark, Yellow Wagtail-*Motacilla flava*, or in-field breeding Marsh Harrier) related to the open plots in the right site of the diagram, and all the species connected with forest and mixed habitats–on the left site (Fig. 2). The second PCA axis (10.3% of the explained variance) reflects land-use patterns and field complexity. The group of species, such as the Reed Bunting (*Emberiza schoeniclus*), Marsh Warbler, Stonechat (*Saxicola rubicola*), and the Corn Bunting *E. calandra*, tends to have larger abundance in mosaic sample plots with a lot of fallow land, whereas Yellow Wagtail, Quail, and surprisingly Partridge, were linked to uniform, intensively used agrocenoses.

Cluster analysis confirmed that bird communities clearly differed in shrubby mosaic vs open plots; both groups created separate clusters in the dendrogram produced by the analysis (Fig. 3). Within-cluster differentiation was less expressed, specifically the compositional differentiation between open mosaic and open plain plots was not observed. This might be due to the fact that the relatively rare species have little effect on the Morisita index. Overall, similar and high values of the index associated with open plots indicated that open landscapes were inhabited by bird communities of similar structure. Relatively distant position of 10 FMO reflected particularly high density of Yellow Wagtail and Quail in this site (Appendix B). In shrubby mosaics the subgroup of 6 WIN and 1 SIE was related to high numbers of several open farmland species, including Skylark, in both plots.

Redundancy analysis illustrated the importance of various field margins and mature trees for the structure of the bird community. A set of four environmental variables were significantly related to the species data; both the test on the first axis (F = 14.29, P = 0.002) and the test on all canonical axes (F = 7.39, P = 0.002) were highly significant under full model. The variance of species data accounted for by the first two axes was 75.6% (eigenvalues 0.671 + 0.085) of the total variation in the bird community, which suggests that the selected environmental variables are those responsible for the variation in species composition. A stepwise procedure allowed to directly extract the variation that is explainable by the measured characteristics of field margins and tree numbers. Separate testing revealed the significant influence of the shrubby, permanent and all field margin aggregations, and the number of trees (P < 0.01 in each case, Table 5). However, using the forward selection procedure only two variables were significant–the aggregations of the shrubby (P = 0.002) and permanent (P = 0.006) margins. Interestingly, the number of trees did not significantly increase the fit of the model (P = 0.06) suggesting that the network of well-vegetated field margins is sufficient in explaining the bird communities. The

Table 4
Spearman correlation coefficients (r_s) relating the aggregations of field margins and bird indices in the 12 study plots. Separate correlations were performed for the aggregation of all, permanent and shrubby field margins against the number of bird species and number of breeding pairs. The scatterplots illustrating these relationships are presented in Appendix C.

Aggregation of field margins (km/km^2)	N	Number of species		Number of breeding pairs	
		r_s	P	r_s	P
All FM	12	0.820	0.001	0.811	0.001
Permanent FM	12	0.742	0.006	0.818	0.001
Shrubby FM	12	0.957	<0.001	0.803	0.002

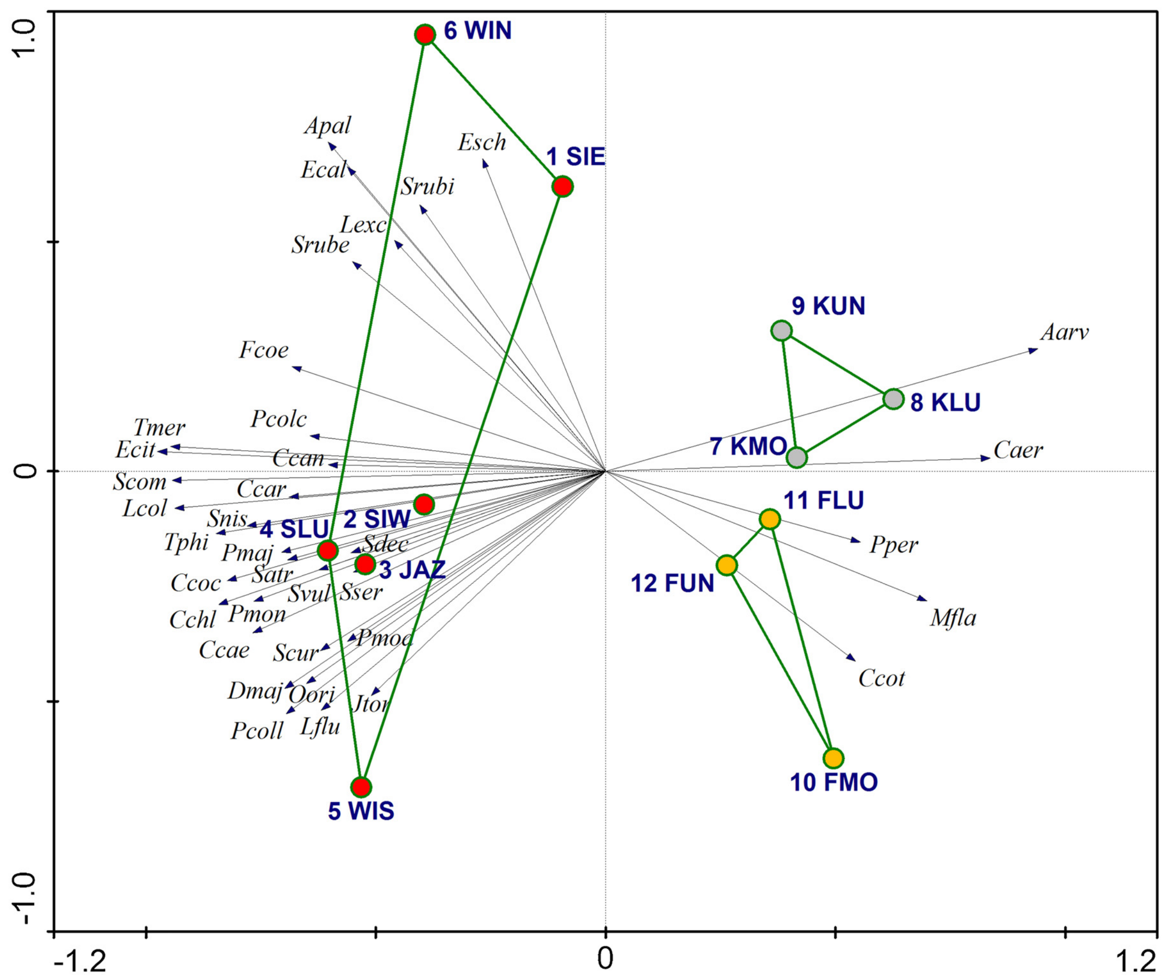

Fig. 2. PCA ordination results showing differences in breeding bird communities between the shrubby mosaic (red), open mosaic (gray), and open plain (yellow) plots enclosed in polygons. The plots are labeled as in Table 1. Species are represented by abbreviations of their Latin names. For clarity, only species that have more than 30% of their variability explained by the first two axes are displayed. The first two axes explain 85.6% (eigenvalues 0.752 + 0.104) of the total variation in the bird community. (For interpretation of the references to color in this figure legend, the reader is referred to the web version of this article.)

discrepancy between the marginal and conditional effects (Table 5) is caused by the mutual positive correlations between the aggregations of various field margins and tree numbers.

3.3. *The response of bird abundance to the proportional availability of habitats*

There was a significant relationship between the relative area of four habitat types on bird abundance with a particular importance of field margins (Fig. 4). Overall, 35% of breeding pairs were noted in this habitat (covering merely 4% of the total area), and excluding Skylark this increased to 55%. In the shrubby mosaic plots, half of the pairs (50.3%) were noted in field margins. Thirteen of 16 of the most numerous species revealed significant associations with field margins, and the Red-backed Shrike, Yellowhammer (*Emberiza citrinella*), Blackbird, and Barred Warbler may be considered margin specialists, as more than 70% of pairs bred in this habitat. The Chaffinch (*Fringilla coelebs*) and Blackcap (*Sylvia atricapilla*) were particularly dependent on mid-field woodlots and the Whinchat (*Saxicola rubetra*) was noted mostly in permanent fallows. Three true farmland species (i.e., Quail, Skylark, Yellow Wagtail) bred predominantly in cropfields, and these were the only species in which the density figures did not depart from expected.

4. Discussion

This study analyzed the breeding bird communities in typical, yet contrasting, farmland types in the central-European

Table 5
The influence of the shrubby, permanent and all field margin (FM) aggregations (km/km^2) and number of mature trees on bird species composition. Summary of the multivariate analysis, with the four variables tested separately (marginal effects), and using the forward selection procedure (conditional effects). Significance values obtained through Monte Carlo permutations.

Variable	Marginal effects			Conditional effects		
	Explained variance (%)	*F*	*P*	Explained variance (%)	*F*	*P*
Shrubby FM	67.2	20.507	0.002	67.2	20.507	0.002
Permanent FM	57.6	13.606	0.004	9.6	3.712	0.006
No. of trees	54.2	11.829	0.002	1.7	0.604	0.718
All FM	42.2	7.294	0.006	1.5	0.546	0.756

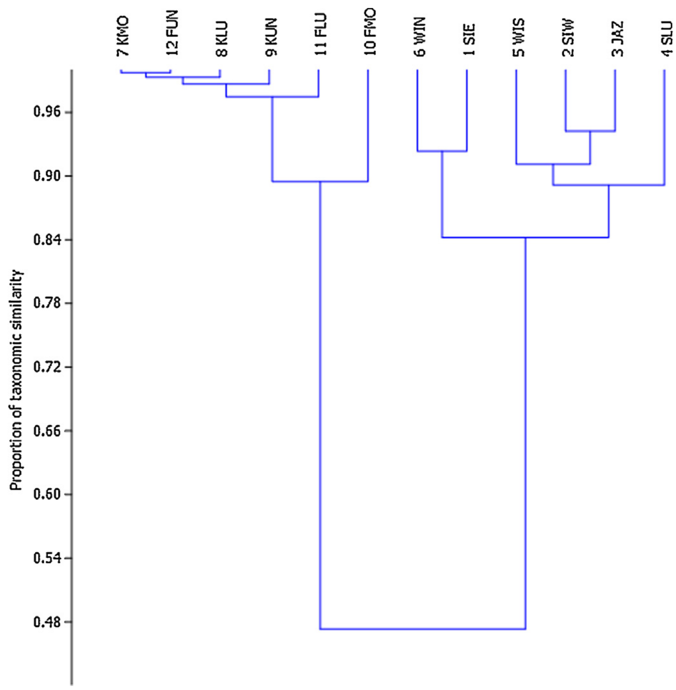

Fig. 3. Dendrogram of cluster analysis (UPGMA) using Morisita similarity index for the bird communities of the investigated study plots. The shorter connections between two plots in the diagram, the more similar the plots are. Codes of the plots defined in Table 1: 1–6–shrubby mosaic, 7–9–open mosaic, 10–12–open plain plots.

countryside shortly after EU accession. Study sites differed with the farming regimes expressed by the aggregation of field margins–a distinct landscape feature of Poland. Not surprisingly, there were significant differences between farmland types in species richness, diversity and densities of birds. An average number of species was four-fold higher in shrubby mosaic than in open plots, index of diversity was five-fold higher and bird density was twice as high. Congruent with results of this study, a positive relationship between species richness and farmland diversification have been found in many other plant and animal taxa (e.g. Fahrig et al., 2015). In contrast to the above metrics, the measure of evenness was not associated with the studied farmland types. Since E_{Simpson} reflex differences in the abundances of the species within communities and is not sensitive to species richness, it can be assumed that even in the most diverse farmlands bird communities are dominated by a few species of very high abundance, virtually open farmland species. These results also suggest that differences in species diversity are driven by differences in the number of species, rather than the evenness component of the index.

Surprisingly, the author found differences between results of this study and analogous studies in the abundance of breeding birds; regardless of farmland types, the obtained densities were usually much higher in this study. In the 11 Polish farmland bird studies conducted in areas varying in habitat structure and management intensity, the weighted mean density amounted to 9.5 pairs/10 ha (range: 4.5–15.1) (Tryjanowski et al., 2009), which is substantially less than in this study. In addition, the density of the dominant species, Skylark, which in this study averaged 7.2 pairs/10 ha, was among the highest densities recorded in Poland, and substantially exceeded most of the western European data (Kragten, Trimbos, & de Snoo, 2008; Rahman, Tarrant, McCollin, & Ollerton, 2012).

These differences could arise from regional and local attributes of the study plots. They are located in the warmest region of Poland, with fertile grounds and within arable farming interspersed with fallows and a variety of non-cropped habitats. The latter were particularly important for density figures: well-vegetated, semi-natural lines and patches did not significantly reduce the dominant field species, but had a strong positive influence on a large group of scrubland birds (Berg, 2002; Szymański & Antczak, 2013). Therefore, my data provide evidence that agricultural landscapes in Poland indeed support large bird populations, which still resist agricultural intensification. Even the most homogeneous plots that can be classified as high-intensity agriculture in CEE (although possibly of medium-intensity by western European standards) held strong populations of farmland specialists, such as Yellow Wagtail or Skylark. On the other hand, low numbers of some species, such as the Lapwing (*Vanellus vanellus*) or Partridge reflect a decreasing trend

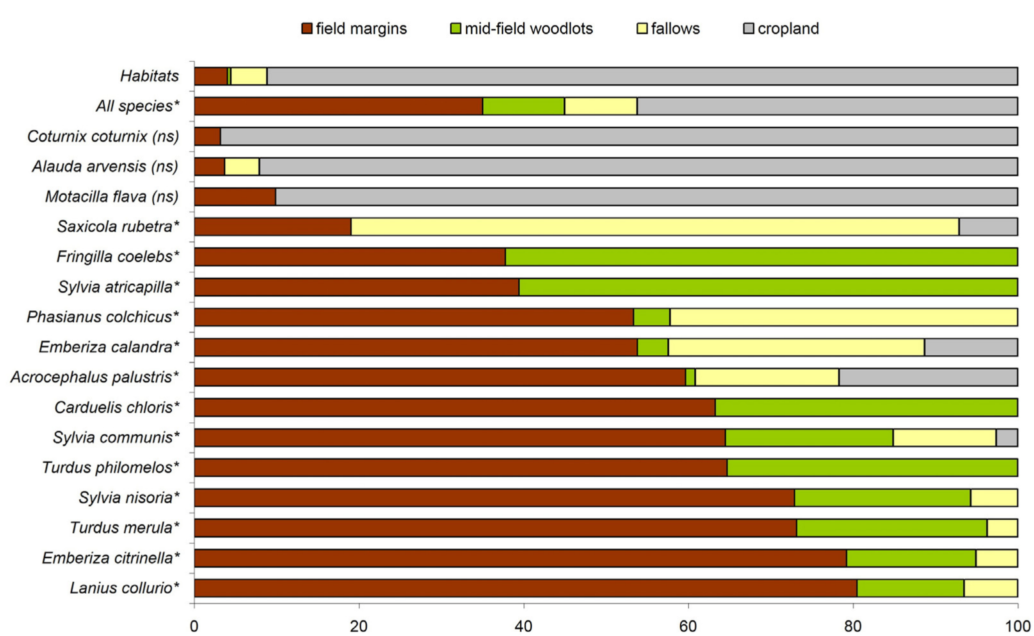

Fig. 4. Comparison of percentage shares of the four main habitat types within the study plots, the total abundance of the bird community and the abundances of 16 of the most numerous species (>10 breeding pairs; see Table 2). The species have been arranged according to the increasing share of pairs breeding in field margins. Asterisks indicate significant differences in proportions obtained in a randomization test of goodness-of-fit (d.f. = 3): ns–not significant, *$P < 0.0001$.

in their overall populations (Kuczyński & Chylarecki, 2012), which may result from a consistent worsening of farmland quality.

Landscape complexity also molded bird species composition. The bird community changed from being totally dominated by open-farmland species in open plain plots to being dominated by species of field-forest mosaic, at low proportions of non-cropped habitat patches. The number of Skylarks in open plots reached 87% of breeding pairs, but in shrubby mosaic plots the species' abundance was comparable or lower than that of the second most numerous species, the Yellowhammer. Projection of species in the PCA ordination diagram revealed that the most numerous, ecologically diverse communities were connected with shrubby mosaic plots certifying the importance of heterogeneous landscapes. These plots also supported more species recognized as threatened and of conservation concern in Europe, such as the Turtle Dove (*Streptopelia turtur*), Red-backed Shrike, Great Grey Shrike (*Lanius excubitor*), Corn Bunting, Tree Sparrow (*Passer montanus*), Linnet (*Carduelis cannabina*) (Skórka et al., 2006). This information may be important in conservation practice; considering that sites with conditions supporting priority species receive more attention than sites dominated by common species (Wuczyński et al., 2014), but see Santana et al. (2014) who showed that focusing conservation investment on flagship species does not necessarily facilitate wider biodiversity.

Open farmland bird species clearly separated the open plots from shrubby mosaic plots, as reveled in biplot of PCA. More interestingly, the positions of these species also displayed a difference between open mosaic and open plain plots, proxies for farming intensity. Skylarks showed an affinity to open mosaic plots confirming that low-intensity arable areas resembling traditional practices are more beneficial for this species than open but intensively used farmland (Eraud & Boutin, 2002; Fischer, Jenny, & Jenni, 2009). In contrast, the Quail was particularly frequent in the simplest, homogeneous landscapes, represented by open plain plots. These results are consistent with recent countrywide findings that in Polish farmlands, the Quail do not prefer traditional agriculture but are associated with large arable fields (Kosicki, Chylarecki, & Zduniak, 2013). This may suggest that this is one of just a few species that benefits from current changes in modern agriculture, although the adaptive value of such preferences is questionable (Kosicki et al., 2013), and a long-term population decrease is also noted in Poland (Kuczyński & Chylarecki, 2012). Surprisingly, most of the recorded Partridge territories (6/7) were also concentrated in open plots, and in equal numbers in open plain and open mosaic plots. This may be due to a high predation pressure in shrubby mosaic plots suggested by a much higher density of dens of the Red Fox (*Vulpes vulpes*), as compared with open plots (A. Wuczyński, personal observation) (Panek, 2013; Tryjanowski et al., 2011 and further references therein). Finally, in open plots an interesting occurrence of the Marsh Harrier was noted. This species is not particularly rare in agricultural landscapes of Poland; however, its occupation of territories in cropfields is a relatively new phenomenon since the 1980s, which is unique to western Poland (Tomiałojć & Stawarczyk, 2003). In SW Poland, the vastness of fields in open plain plots and a notable exuberance of crops such as winter barley, wheat and rape already, in April, were likely to create favorable conditions for the occurrence of the Marsh Harrier (Cardador, Carrete, & Mañosa, 2011).

The length or density of linear habitats is frequently used as a biodiversity indicator in farmlands, but its usefulness depends on the definition of habitats, on local landscape characteristics and on farming circumstances (Billeter et al., 2008; Scozzafava & De Sanctis, 2006). In this study, three measures related to linear habitats were incorporated: the aggregation of all field borders, and the aggregation of linear habitats having a semi-natural components, both permanent and their subset, shrubby field margins. Bird species richness, densities and community composition were significantly related to each of these measures. Their individual influences could not be clearly separated, since the measures were not mutually exclusive. However, the aggregation of shrubby field margins was clearly the most related variable of bird abundance, which drew the other measures. Multivariate analysis of RDA also revealed that the aggregations of the shrubby and permanent margins were better predictors of the bird community than the number of mature trees, proxy for cover of mid-field woodlots. This may suggest that in complex agricultural landscapes the length or aggregation of well-vegetated field margins act as efficient variables in describing bird communities, and this finding may be useful when seeking optimal biodiversity indicators (de Heer et al., 2005; Morelli, Jerzak, & Tryjanowski, 2014).

In contrast, the length of "all" field margins that may well describe land-use patterns, appeared less useful to describe bird indices. In open plots, bird densities and species richness were virtually not related to the margin aggregations, suggesting that even a dense mosaic of fields can not guarantee a rich bird community when the mosaic is not supplemented with shrubs, trees or other microhabitats (Tryjanowski, Sparks, Jerzak, Rosin, & Skórka, 2014). In this study, merely 4–9 breeding species were noted in open mosaics (i.e., plots having rich land-use patterns but devoid of high vegetation). Therefore, field margins with a semi-natural component and other non-cropped habitats seem to be more important for the bird communities than land-use (Berg, 2002).

The importance of field margins was also stressed by identifying the habitat associations with birds. In small area, non-cropped habitats were occupied by most breeding pairs, including most of the dominant species (except the open farmland species). Most recorded species (81%) were associated with field margins. Moreover, the habitat category of mid-field woodlots was similar to field margins, and was distinguished on account of non-linear shape. Number of breeding bird pairs in the woodlots and field margins could then be merged, increasing the relative significance of these semi-natural habitats compared to cropfields.

Altogether, these findings are consistent with earlier studies that in farming systems only a mosaic of various field margins and other marginal habitat features ensure a rich spectrum of bird communities (Wuczyński et al., 2011). The data also confirm that among various linear features, the margins partially covered with high vegetation, such as tree lines and hedgerows, play a crucial role for shaping farmland bird communities (Sanderson et al., 2009; Whittingham et al., 2009).

Small sample size (=12) was the main limitation of this study, precluding some analyzes. For example, apparent differences in bird communities between the subsamples of open mosaic and open plain plots were not confirmed in statistical tests, probably due to small sample sizes. The limitation was compensated with other methodological assumptions: relatively large landscape plots, the laborious mapping method, counting the complete bird communities. For organizational reasons I also could not avoid the counts to be conducted in different years in the shrubby and open plots. However, great differences in habitat structure between these groups of plots were probably much stronger than the year effects, since the inclusion of the year variable into statistical models was not satisfactory. It was additionally confirmed by very little between-year differences in shrubby mosaic plots. Finally, the data for this study were collected several years ago, and at present some deterioration in biodiversity values could be expected due to detrimental changes in the agriculture after EU accession (Sanderson et al., 2013). However, it is unlikely that the difference could affect the general distribution of bird communities and the conclusions presented.

The future of biodiversity-rich farmlands is still of major concern, especially in the context of the impending current reform of the Common Agricultural Policy (CAP) (ec.europa.eu/agriculture/cap-post-2013). Findings presented in this paper support earlier conclusions that in regions of heterogeneous farmland, efforts should be made first of all to protect the existing landscape diversity (Concepción et al., 2012; Kleijn et al., 2009). They may also help to optimize the agricultural landscape, especially in respect of the protection of field margins. Wuczyński et al. (2011) recorded 50 bird species breeding in field margins of SW Poland. Exactly the same figure and similar species composition was noted in the presented landscapes confirming that these species create a core of local avian fauna. Wuczyński et al. also calculated that a total length of 20–25 km of diverse permanent field margins may be sufficient to support this species number. Given that the aggregation of permanent margins in the best shrubby mosaic plots amounted to 13.7 km/km^2 (Table 1), a relatively small area of >1.5 km^2 of heterogeneous farmland would be enough to reach a theoretically complete bird community. Against this Polish baseline (grounded in real data), an aggregation of properly selected, permanent field margins not lower than 10 km/km^2 should be kept or maintained in successful ecological restoration in farmland.

In a modern, market-oriented agriculture keeping a significant proportion of non-cropped habitats is only available in relation to the current legislation and policies, such as CAP. Unfortunately, there is a fear that the new CAP will contribute little to biodiversity at the EU level (Pe'er et al., 2014). Therefore, irrespective of the initiatives based on the general structure of the reformed CAP, goodwill and wise solutions on a national level are necessary (Mante & Gerowitt, 2009). For example, the common practice of a removal of the non-cropped habitat patches, supported by direct payments, yet unjustified from the biological and practical points of view (Morandin, Long, & Kremen, 2014; Sullivan & Sullivan, 2009), should urgently be restricted by local laws and stopped. Conservation targets should be tailored to landscape, socioeconomic, and agronomic context of individual countries by incorporating local research evidence coupled with modern approaches to biodiversity protection in human-dominated landscapes (Agnoletti, 2014; Báldi et al., 2013; de Snoo et al., 2013; Hartel & von Wehrden, 2013). In the case of Poland, the measures focused on protection of the existing heterogeneous farmland structure, with a dense network of field margins in particular, are likely to be most effective for biodiversity benefits.

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Appendix A. Supplementary data

Supplementary data associated with this article can be found, in the online version, at http://dx.doi.org/10.1016/j.landurbplan.2015.11.010.

Appendix B.

A Google Earth file with locations of the study plots and example pictures is available as part of the online article.

Appendix C.

Number of breeding pairs and total density of bird species recorded in particular study plots. The open field species are marked with the asterisks.

Species	1 SIE	2 SIW	3 JAZ	4 SLU	5 WIS	6 WIN	7 KMO	8 KLU	9 KUN	10 FMO	11 FLU	12 FUN	Total	Density (pairs /10 ha)
	Shrubby mosaic					Open mosaic				Open plain				
Skylark *Alauda arvensis**	39.8	27.3	17.0	20.3	20.5	31.3	47.0	58.5	47.0	42.5	44.0	38.0	433.0	7.18
Yellowhammer *Emberiza citrinella*	14.5	22.3	21.0	24.8	23.3	20.5	0.0	1.0	0.0	0.0	0.0	0.0	127.3	2.11
Marsh Warbler *Acrocephalus palustris**	13.5	7.5	13.0	10.0	2.0	25.0	2.0	0.0	8.0	0.0	0.0	2.0	83.0	1.38
Yellow Wagtail *Motacilla flava**	2.5	0.5	2.3	0.5	0.0	1.5	7.5	14.0	7.0	27.0	3.0	5.0	70.8	1.17
Red-backed Shrike *Lanius collurio*	7.5	9.5	10.0	8.0	12.5	6.3	0.0	0.0	0.0	0.0	0.0	0.0	53.8	0.89
Blackbird *Turdus merula*	4.0	5.0	5.3	9.0	8.8	8.0	0.0	0.0	0.0	0.0	0.0	0.0	40.0	0.66
Whitethroat *Sylvia communis*	5.3	7.0	4.5	7.3	8.0	5.0	0.0	0.0	0.0	0.0	0.0	1.0	38.0	0.63
Corn Bunting *Emberiza calandra**	4.8	3.3	3.8	3.5	0.0	6.3	2.0	1.5	0.0	0.5	0.0	1.0	26.5	0.44
Song Thrush *Turdus philomelos*	2.5	4.8	2.0	8.5	5.3	2.5	0.0	0.0	0.0	0.0	0.0	0.0	25.5	0.42
Whinchat *Saxicola rubetra**	6.0	3.5	0.0	6.5	0.0	4.0	0.0	0.0	0.0	0.0	0.0	1.0	21.0	0.35
Blackcap *Sylvia atricapilla*	0.0	1.0	0.0	7.0	6.5	3.3	0.0	0.0	0.0	0.0	0.0	0.0	17.8	0.29
Barred Warbler *Sylvia nisoria*	2.5	3.8	3.3	1.3	4.3	1.5	0.0	1.0	0.0	0.0	0.0	0.0	17.5	0.29
Quail *Coturnix coturnix**	0.5	1.0	1.8	0.0	0.0	0.0	0.5	1.0	2.0	5.0	2.5	1.5	15.8	0.26
Greenfinch *Carduelis chloris*	0.0	0.8	2.5	4.0	3.5	1.5	0.0	0.0	0.0	0.0	0.0	0.0	12.3	0.20
Pheasant *Phasianus colchicus*	2.3	2.3	1.5	4.8	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	11.3	0.19
Chaffinch *Fringilla coelebs*	0.0	0.5	0.5	4.0	2.0	4.3	0.0	0.0	0.0	0.0	0.0	0.0	11.3	0.19
Tree Sparrow *Passer montanus*	0.0	2.0	0.8	1.5	3.8	1.5	0.0	0.0	0.0	0.0	0.0	0.0	9.5	0.16
Linnet *Carduelis cannabina*	1.8	2.8	0.5	2.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	7.8	0.13
Reed Bunting *Emberiza schoeniclus*	3.3	1.5	0.0	0.5	0.0	1.5	0.0	0.0	1.0	0.0	0.0	0.0	7.8	0.13
Stonechat *Saxicola rubicola**	1.0	2.0	0.0	1.0	0.0	2.0	0.0	1.0	0.0	0.0	0.0	0.0	7.0	0.12
Grey Partridge *Perdix perdix**	0.5	0.0	0.5	0.0	0.0	0.0	2.0	1.0	0.0	1.0	0.0	2.0	7.0	0.12
Blue Tit *Cyanistes caeruleus*	0.0	1.0	0.5	2.0	2.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	7.0	0.12
Hawfinch *Coccothraustes coccothraustes*	0.0	1.5	1.3	2.5	1.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	6.8	0.11
Marsh Harrier *Circus aeruginosus*	0.0	0.0	0.0	0.0	0.0	0.0	0.5	1.5	1.5	0.5	1.0	1.0	6.0	0.10
Garden Warbler *Sylvia borin*	0.0	0.0	0.0	5.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	5.8	0.10
Starling *Sturnus vulgaris*	0.0	0.0	1.5	0.3	2.0	1.0	0.5	0.0	0.0	0.0	0.0	0.0	5.3	0.09
Grasshopper Warbler *Locustella naevia**	2.0	0.5	0.0	1.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.5	0.07
Great Tit *Parus major*	0.0	0.0	0.3	1.3	1.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.07
Chiffchaff *Phylloscopus collybita*	0.0	0.8	0.5	1.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.3	0.07
Lesser Whitethroat *Sylvia curruca*	0.5	0.5	0.0	1.0	1.8	0.0	0.0	0.0	0.0	0.0	0.0	0.0	3.8	0.06
Goldfinch *Carduelis carduelis*	0.0	0.0	0.3	1.8	0.8	0.8	0.0	0.0	0.0	0.0	0.0	0.0	3.5	0.06

Species	1 SIE	2 SIW	3 JAZ	4 SLU	5 WIS	6 WIN	7 KMO	8 KLU	9 KUN	10 FMO	11 FLU	12 FUN	Total	Density (pairs /10 ha)
	Shrubby mosaic					Open mosaic				Open plain				
Serin *Serinus serinus*	0.0	0.0	0.5	2.0	0.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.8	0.05
Dunnock *Prunella modularis*	0.0	0.0	0.0	1.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.5	0.04
Great Spotted Woodpecker *Dendrocopos major*	0.0	0.5	0.0	0.8	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.3	0.04
Icterine Warbler *Hippolais icterina*	0.0	0.0	0.0	2.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	2.0	0.03
Lapwing *Vanellus vanellus**	0.8	0.0	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0	0.0	1.8	0.03
River Warbler *Locustella fluviatilis*	0.0	0.0	0.3	0.5	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.8	0.03
Turtle Dove *Streptopelia turtur*	0.0	0.5	0.0	1.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.5	0.02
Woodpigeon *Columba palumbus*	0.0	0.0	0.0	1.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.02
Great Grey Shrike *Lanius excubitor*	0.0	0.0	0.0	0.5	0.0	0.8	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.02
Golden Oriole *Oriolus oriolus*	0.0	0.0	0.3	0.5	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.3	0.02
Pied Wagtail *Motacilla alba*	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.5	0.0	0.0	1.0	0.02
Great Reed Warbler *Acrocephalus arundinaceus*	0.5	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	1.0	0.02
Wryneck *Jynx torquilla*	0.0	0.0	0.3	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.01
Collared Dove *Streptopelia decaocto*	0.0	0.0	0.3	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.8	0.01
Mallard *Anas platyrhynchos*	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.01
Fieldfare *Turdus pilaris*	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.01
Spotted Flycatcher *Muscicapa striata*	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.01
Nightingale *Luscinia megarhynchos*	0.0	0.0	0.0	0.5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.5	0.01
Cuckoo *Cuculus canorus*	+	+			+								+	
Total no of pairs	116.3	113.3	95.8	154.0	118.0	131.0	63.0	80.5	66.5	77.0	50.5	52.5	1118.3	
Density (pairs/10 ha)	22.9	22.4	19.5	29.3	24.5	24.7	12.7	16.1	13.5	15.4	10.1	10.5		18.54
No of species	23	28	28	43	29	24	9	9	6	7	4	9	50	

Appendix D.

Relationships between the aggregation (km/km^2) of all, permanent and shrubby field margins in the 12 study plots and bird indices: number of breeding pairs (left column) and number of species (right column). Spearman correlation coefficients (r_s) and associated *P*-values are also presented.

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