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ORIGINAL ARTICLE

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Effects of management intensity and orchard features on bird communities in winter

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Abstract The knowledge and conservation of diminishing valuable habitats in agricultural landscapes are of key importance in saving declining farmland biodiversity. One of these habitats is the traditional orchard whose role in supporting birds is still poorly known, especially in winter. We counted birds in 106 orchards differing in management intensity (abandoned, traditional, and intensive) during December 2009 and January 2010 in Wielkopolska, western Poland and measured site characteristics and composition of surrounding landscapes for every orchard. Old abandoned and traditionally managed orchards had significantly higher bird species richness than intensive ones. Irrespective of orchard type, bird species richness as well as density were positively influenced by the cover of unmown herb layer in orchards and tree diversity. Tree and fruit densities positively affected bird species richness and density mainly in abandoned orchards while in other orchard types the effect of these variables was less pronounced. Land cover diversity in a landscape had a positive effect on species richness and density mostly in abandoned orchards and we believe that this effect reflects the elevated utilization of such orchards by birds from the surrounding landscape. Thus, abandoned, as well as traditionally managed orchards seems to be especially important habitats that offer food source and refuge for wintering birds and should be protected. We propose to diversify fruit production by planting various tree species, leaving part of the herb layer unmown and several trees unharvested in intensive orchards in order to improve suitability of modern orchards for birds.

Keywords Apple · Ecosystem services · Farmland · Fruit · Landscape · Poland

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Introduction

Agricultural intensification and changes in farming practice has led to the fragmentation and loss of seminatural habitats, the disappearance of field margins, as well as midfield woods and hedges and, in effect, the formation of large monoculture crop fields (Meeus 1990; Burel and Baudry 1995; EEA 2010). European farmland biodiversity, in a result, declined (Thomas et al. 2004; Donald et al. 2006). Therefore, conservation and knowledge of diminishing valuable habitats in agricultural landscapes are of key importance for saving endangered farmland biodiversity (Wenzel et al. 2006; Tryjanowski et al. 2011).

Among these habitats, orchards deserve special attention. Old traditional orchards belong to species-rich High Nature Value farming systems in Europe (Cooper et al. 2007). They constitute a refuge for many arthropod and breeding bird species that are attached to woody habitats and do not occur in intensive open agricultural landscapes (Herzog 1998; Bailey et al. 2010). Some specific features of orchards make them of key importance for farmland biodiversity on local, as well as landscape scales. Planting orchards is a long-lasting tradition in temperate areas and they belong to perennial crops, therefore, this is a reason why orchards are regarded as a highly stable, predictable habitat for many organisms (Brown and Welker 1992; Kozár 1992). The multi-strata design of orchards and the presence of adjacent weeds and hedges contribute to diversity of arthropods and birds (Rands 1986; Kwiatkowska 1989; Simon et al. 2010). In addition, a high abundance of flowers and fruits constitute an excellent source of food for pollinating insects. On a landscape scale, orchards may contribute to plant diversity in the adjacent agricultural areas and in turn to an increase of breeding and foraging habitats for many animal species in crops (Boller et al. 2004). A century ago, in the agricultural landscapes of central Europe, there were strong traditions of maintenance of small orchards adjacent to households. However, during the last few decades they have been widely abandoned in favor of larger monocultures because of their relatively low economic value (Jermaczek and Jermaczek 2003). In the current European agricultural landscape, orchards are dominated by large, intensively managed orchards aimed at maximizing fruit production. As a consequence, these new orchards are heavily sprayed with insecticides and have very few herbaceous plants or hedges. Studies on avifauna in intensive orchards are limited and authors mainly report on the influence of pesticides on the reproductive rate of passerines (e.g., Bouvier et al. 2005) or, rarely, on bird diversity (Rösler 2003; Genghini et al. 2006; Wiącek and Polak 2008; Bouvier et al. 2011; MacLeod et al. 2012). Moreover, the relative effects of abandonment, traditional management as well as modern intensive management of orchards on bird and other organism communities is poorly recognized (Tryjanowski et al. 2009, 2011). Bird species richness and abundance in orchards may depend not only on the management of the orchard but also on the surrounding landscape composition (Krebs et al. 1999; Benton et al. 2003). However, there are only a few studies on the influence of orchard characteristics and their surroundings on bird communities (Agerberg 2007; Wiącek and Polak 2008; Bailey et al. 2010).

Winter is a critical period for many sedentary bird species because of the marked decline of resources and harsh weather conditions (Brown and Roth 2002; Skórka and Wójcik 2005; Arizaga et al. 2012). In many orchards some fruits are left, so they may constitute a good source of food for birds trying to survive winter in farmland (Skórka et al. 2006). Moreover, these habitats are also hibernation sites for many insect species (Harwood et al. 1992; Lys and Nentwig 1994) that may constitute food resource for birds which consequently contribute to natural pest control (Tryjanowski et al. 2009). Therefore, the presence of diverse bird species in winter may also be beneficial for orchards and adjacent farmland from economical point of view. However, as far as we are aware, there are a lack of studies of birds wintering in different orchard types in central Europe, thus their importance for conservation of birds during winter is not recognized.

In this paper, we investigated how the management of orchards (intensive, extensive, abandoned), characteristics of orchards (e.g., area, density of trees and fruits) and diversity of land cover in a landscape influence bird species richness and density during winter.

Materials and methods

We selected 106 orchards from the area covering 24,000 km^2 located in the Wielkopolska district in western Poland. Poland is the largest apple producer in Europe, and Wielkopolska is one of its leading districts (Bański 2008). Between the middle of December 2009 and the middle of January 2010 one visit was paid to each orchard to survey birds. Birds were surveyed during favorable weather conditions (no snowfall or rainfall, wind below 4 m s^{-1}) between 8:00 and 14:00. The maximal distance between orchards was 197 km and minimal 1 km. Orchards were randomly assigned to observers, however they specified how many orchards were able to survey (mean = 5 orchards per observer, range 1–12 orchards). Observers walked randomly in the orchard. The walks in orchards followed a zig-zag pattern in order to cover the entire area of orchard visually and aurally. Observers walked alone both on the edge and in the interior of orchards. In most of the orchards, it was very easy to encompass the entire area of orchard visually because trees were without leaves. It was also very easy to follow movements of birds in order to not count them twice. The duration of the survey was proportional to the orchard size (Schoereder et al. 2004) with 20 min spent per 1 ha but no shorter than 10 min in the smallest orchards.

We considered detectability of birds to be high in our surveys. First, winter in Poland is a period when deciduous trees do not carry leaves. Thus, visibility is high. Secondly, orchards, even the abandoned ones, are structurally very simple habitats. There is usually a very low number of shrubs inside, trees have many branches cut, and trees are planted in rows what makes birds easy to detect there. Thirdly, birds in winter are more mobile and gather in flocks. These flocks often contain different species and this social behavior of birds may lead to their increased detectability. For example, many tits, woodpeckers, and nuthatches form multi-species flocks, which occupy small areas throughout the winter (Alatao 1982; Matthysen 1990). Finally, we also performed analysis on calculated number of species to correct for imperfect detection (for the details see, "Statistical analyses").

We measured the following environmental variables potentially affecting bird species richness (number of species) and density (number of individuals ha^{-1}):

1. type of orchard: intensively managed, extensively managed, or abandoned;
2. orchard area (ha);
3. tree density (number of trees ha^{-1});
4. tree species diversity index;
5. fruit density (fruits ha^{-1}). Calculated from both fruits hanging on trees and laying on the ground;
6. cover of unmown herb layer within the orchard (%);
7. covers (%) of agricultural fields;
8. grasslands;

9. forests;
10. orchards;
11. human settlements within a 500-m radius of the orchard boundary. All these land covers types were correlated between each other therefore, we combined them in a land cover diversity index.

The above variables may be assigned to four main groups of factors: orchard management scheme (variable 1), structural complexity of orchards (2, 3, 4), food resources (5, 6), and diversity of surrounding landscape (7). Abandoned orchards were usually located next to abandoned human settlements. Obviously, no specific management was applied in this orchards (no pesticide use, no tree protection from frost, no use of fertilizers). Fruits were collected mostly by occasional visitors. In traditionally managed orchards, fruit production was of low intensity, mostly to fulfill needs of owners. No pesticide use was applied there, but trees were protected from low temperatures, painted with lime to preclude some pests and the herb layer was occasionally cut. Usually, most of the fruits were harvested when ripe. Intensively managed orchards were easily distinguishable as herb layer was usually mown a few times per year, branches were regularly cut and pesticide was applied in high supply during the fruit growth (10–14 sprayings per season). We excluded direct effect of pesticides on birds during winter because the grace period was shorter than time lasting between the last spraying and our winter surveys. However, pesticides may have indirect effect since it may influence the number of hibernating insects in trees. Information on pesticide usage was gathered from interviews with orchard owners.

Environmental variables 2 and 7–11 were calculated with ImageJ software or directly in the field with the use of a GPS. We used high-resolution images freely available in National Data Base Geoportal (http://maps.geoportal.gov.pl/webclient/). Variables 1, 3, 5, and 6 were determined during field surveys. All trees were counted in the small- and medium-sized orchards but in the larger ones, the number of trees was estimated by multiplying number of rows with trees and number of trees counted in one row. Tree species in orchards were determined during field surveys and during interviews with owners. We also counted all fruits (mostly apples) left on trees and on the ground in small orchards. In the large orchards, the number of fruits was estimated by random selection of trees located along transects throughout the orchard where fruits (both on trees and under them) were counted and then interpolated for the entire orchard. At least 10 % of all trees had to be surveyed for this purpose. Both tree and fruit densities are presented in number of individuals per hectare. Tree diversity and land cover diversity indices were expressed by Simpson reciprocal diversity index ($1/D$) (Simpson 1949). The value of this index has 1 as the lowest possible figure. This figure would represent a composition containing only one tree species or only one land cover type. The higher the value, the greater the fruit tree species diversity or land cover diversity in the surrounding of orchards. In case of land cover diversity, the value of this index was positively correlated with forest cover ($r^2 = 0.106$, $p < 0.001$), grassland cover ($r^2 = 0.192$, $p < 0.001$), orchard cover ($r^2 = 0.206$, $p < 0.001$) and cover of human settlements ($r^2 = 0.044$,$p = 0.032$) in a 500-m radius from the orchard boundary. The variables describing land cover were strongly correlated between each other and land diversity index allowed to compile them into one variable.

Earlier studies showed that the landscape structure played a role for bird species richness and density (Söderström and Pärt 2000; Herzon and O'Hara 2007) and we choose the radius of 500 m because it described close proximity of orchards. Management recommendations are much easier to incorporate at such small (local) spatial scale than at larger ones (Mouysset et al. 2011). We also did not count all small landscape features (e.g., singular trees or shrubs) because at the scale of study and in so many orchards it was simply infeasible to collect such data. Moreover, our models (see "Results") generally explained quite large proportion of variation in the species richness and density, thus we probably included most of the meaningful variables.

The basic characteristics of investigated orchards are summarized in Table 1. For correlation coefficients between all continuous environmental variables used in the analyses, see Supplementary material.

Statistical analyses

We used one-way analysis of variance to compare features of abandoned, traditionally and intensively managed orchards. The stepwise forward regression with selection of variables based on Akaike information criterion (Burnham and Anderson 2002) was used to find those ones that affected species richness and bird density. In models, we introduced all fixed effects and all interactions between orchard type and continuous variables. These interactions tested if species richness and density of birds was differentially affected by the same environmental variables in the three orchard types. Log10 transformation was used to normalize data distributions and to remove the effect of outlying observations (Quinn and Keough 2002) in explanatory and dependent variables. The explanatory continuous variables were standardized to allow direct comparison of their function slopes (betas).

We also performed additional analyses on factors affecting bird species richness and density with generalized linear models (GLM) because dependent variables were count data (Supplementary material). When we used Poisson error variance in GLM we found that the results suffered from the substantial overdispersion, especially when analyzing bird densities (overdispersion parameter = 36). Thus, we analyzed bird densities with the GLM with the negative binomial error variance. Basically, GLM with Poisson and binomial error variance distributions produced similar results to that received from stepwise regression and these results are presented in the Supplementary material.

Analysis of variance and stepwise regression and GLM with Poisson and negative binomial error variances was performed in JMP 9 and SPSS 19 software.

Bird surveys often suffer from low detectability of species (Elphick 2008). As we explained above, we did not believe it was a serious problem in our study but we also calculated number of species with different methods that account for imperfect detectability, all implemented in the software Spade (available from: http://chao.stat.nthu.edu.tw/softwareCE.html). The bias-corrected Chao 1 estimate (Shen et al. 2003; Chao 2005; Chao et al. 2006) was chosen because other methods did not calculate number of species from small samples. There was a strong positive correlation between observed and estimated number of species and statistical models based on these two data sets gave similar results (see, Supplementary material for results of the stepwise regression analysis made on estimated number of species and for some cautions on the possible biases when interpreting these results).

Canonical ordination was used to relate the density of the individual bird species to the environmental variables using the CANOCO 4.5 package. Since the length of the longest gradient in DCCA was short (2.01) we used redundancy analysis (RDA) for this ordination. We used forward selection of variables in RDA to find out which variables significantly affected bird species communities in orchards.

Results

Features discriminating different orchard types

Traditionally managed and abandoned orchards were smaller, had lower tree density and orchard cover in the landscape than intensive ones (Table 1). Traditionally managed and abandoned orchards also had greater unmown cover of the herb layer, higher cover of human settlement and generally higher land cover diversity in the landscape than intensively managed orchards (Table 1).

Factors affecting bird species richness

In total, 39 bird species and 2,325 individuals were noted in all orchards (Table 2). Species richness was highest in abandoned orchards and lowest in intensive ones (Table 3; Fig. 1). Independently of orchard type, species richness was positively related to orchard area (beta = 1.099 ± 0.305), the unmown cover of the herb layer (beta = 0.826 ± 0.317), tree density (beta = 0.550 ± 0.245), tree diversity (beta = 0.583 ± 0.253), and land cover diversity (beta = 0.076 ± 0.028) (Table 3).

Factors affecting density of birds

We did not find statistically significant differences in density of birds between three orchard types during

Table 1 Basic characteristics (mean ± SE) of orchards and their landscapes by orchard type

Variable code	Orchard type			ANOVA test and *p* value*
	Abandoned (A) $n = 38$	Extensive (B) $n = 45$	Intensive (C) $n = 23$	
Area	0.47 ± 0.05	0.42.0 ± 0.06	2.85 ± 0.36	$\mathbf{F_{(2,103)} = 21.59; < 0.001}$ **C > A and B**
TreeDen	201.8 ± 26.1	270.5 ± 37.6	824.6 ± 100.1	$\mathbf{F_{(2,103)} = 9.90; < 0.001}$ **C > A and B**
TreeDiv	1.7 ± 0.1	1.6 ± 0.1	1.6 ± 0.1	$F_{(2,103)} = 0.03; 0.970$
NotMown	90.7 ± 2.0	55.9 ± 4.2	28.5 ± 3.5	$\mathbf{F_{(2,103)} = 24.17; < 0.001}$ **A > B > C**
FruitDen	1,234.5 ± 405.3	1,350.6 ± 372.4	525.7 ± 530.2	$F_{(2,103)} = 0.869; 0.422$
AppleTree	66.2 ± 5.8	64.7 ± 4.9	51.9 ± 10.1	$F_{(2,103)} = 0.17; 0.314$
OrchCov	3.8 ± 0.9	3.4 ± 0.9	13.3 ± 1.3	$\mathbf{F_{(2,103)} = 11.73; < 0.001}$ **C > A and B**
GrassCov	9.7 ± 2.2	4.9 ± 1.0	10.2 ± 1.4	$F_{(2,103)} = 1.59; 0.207$
ForCov	13.1 ± 2.1	12.3 ± 2.2	8.9 ± 1.0	$F_{(2,103)} = 0.14; 0.869$
Build	21.2 ± 2.3	25.9 ± 2.3	9.3 ± 1.2	$\mathbf{F_{(2,103)} = 4.49; 0.013}$ **A and B > C**
LandDiv	2.29 ± 0.15	1.88 ± 0.11	1.85 ± 0.12	$\mathbf{F_{(2,103)} = 3.090; 0.050}$ **A > B and C**

Results in *bold* are statistically significant ($p < 0.05$)

Area orchard area (ha), *TreeDen* tree density (number of trees/ha), *TreeDiv* tree diversity index, *NotMown* percentage cover of orchard herb layer that was unmown, *FruitDen* density of fruits/ha; *AppleTree* percentage share of apple trees in orchards, *OrchCov* percentage cover of orchard within 500 m from the orchard, *GrassCov* percentage cover of grassland within 500 m, *ForCov* percentage cover of forest within 500 m, *Build* percentage cover of buildings within 500 m, *LandDiv* land cover diversity index

* Significant differences in post hoc Tukey test

Table 2 List of bird species and their abundance in surveyed orchards

No.	Species	Abandoned $n = 38$	Extensive $n = 45$	Intensive $n = 23$	Total $n = 106$
1	Fieldfare *Turdus pilaris*	74	222	326	622
2	Tree Sparrow *Passer montanus*	147	229	124	500
3	Great Tit *Parus major*	133	145	21	299
4	Yellowhammer *Emberiza citrinella*	33	135	88	256
5	European Greenfinch *Carduelis chloris*	26	46	71	143
6	Blackbird *Turdus merula*	58	19	26	103
7	Blue Tit *Cyanistes caeruleus*	41	31	4	76
8	Chaffinch *Fringilla coelebs*	6	1	46	53
9	House Sparrow *Passer domesticus*	17	36	0	53
10	Hawfinch *Coccothraustes coccothraustes*	10	5	7	22
11	Eurasian Collared Dove *Streptopelia decaocto*	5	17	0	22
12	Eurasian Siskin *Carduelis spinus*	0	20	0	20
13	Corn Bunting *Emberiza calandra*	5	14	0	19
14	Long-tailed Tit *Aegithalos caudatus*	18	0	0	18
15	Brambling *Fringilla montifringilla*	8	4	6	18
16	Eurasian Jay *Garrulus glandarius*	9	4	1	14
17	Magpie *Pica pica*	8	5	1	14
18	Marsh Tit *Poecile palustris*	9	4	0	13
19	Linnet *Carduelis cannabina*	11	0	0	11
20	Redpoll *Carduelis flammea*	0	3	7	10
21	Mistle Thrush *Turdus viscivorus*	3	6	0	9
22	Great-spotted Woodpecker *Dendrocopos major*	5	3	0	8
23	Goldfinch *Carduelis carduelis*	2	0	5	7
24	Reed Bunting *Emberiza schoeniclus*	0	5	2	7
25	Eurasian Bullfinch *Pyrrhula pyrrhula*	2	5	0	7
26	Pheasant *Phasianus colchicus*	1	0	5	6
27	Willow Tit *Poecile montanus*	5	0	0	5
28	Common Buzzard *Buteo buteo*	0	2	2	4
29	Eurasian Nuthatch *Sitta europea*	2	2	0	4
30	Crested Tit *Lophophanes cristatus*	3	0	0	3
31	Sparrowhawk *Accipiter nisus*	1	1	0	2
32	Rough-legged Buzzard *Buteo lagopus*	0	0	2	2
33	Carrion Crow *Corvus corone*	2	0	0	2
34	Middle Spotted Woodpecker *Dendrocopos medius*	2	0	0	2
35	Robin *Erithacus rubecula*	1	1	0	2
36	Goshawk *Accipiter gentilis*	0	0	1	1
37	Green Woodpecker *Picus viridis*	0	1	0	1
38	Starling *Sturnus vulgaris*	0	0	1	1
39	Eurasian Wren *Troglodytes troglodytes*	1	0	0	1

Table 3 Final general linear models testing effects of orchard characteristics on bird species richness and density

Variable code	Species richness			Density		
	df	*F*	*p*	*df*	*F*	*p*
OrchType	2	3.347	**0.039**	2	2.108	0.127
Area	1	12.994	**< 0.001**	1	35.200	**< 0.001**
NotMown	1	6.784	**0.011**	1	7.756	**0.006**
FruitDen	1	–	–	1	4.699	**0.033**
TreeDen	1	4.837	**0.030**	–	–	–
TreeDiv	1	5.275	**0.024**	–	–	–
LandDiv	1	12.212	**< 0.001**	1	34.808	**0.031**
Area × OrchType	2	2.001	0.112	–	–	–
TreeDens × OrchType	–	–	–	2	8.99	**0.011**
LandDiv × OrchType	2	2.592	0.071	2	3.101	**0.050**
FruitDen × OrchType	–	–	–	2	3.297	**0.041**

Result of the forward stepwise procedure based on the Akaike criterion. Significant effects are emboldened. Model for species richness explained 35 % of variation and model for density explained 45 % of variation. For explanations of the variable codes, see Table 1. Results in bold are statistically significant ($p < 0.05$)

winter (Table 3; Fig. 1). Independently of the orchard type, bird density was positively related to unmown cover of herb layer (beta = 0.444 ± 0.159) but negatively by orchard size (beta = −0.947 ± 0.160; Table 3). There were significant interactions between orchard type and tree density, land cover diversity in the

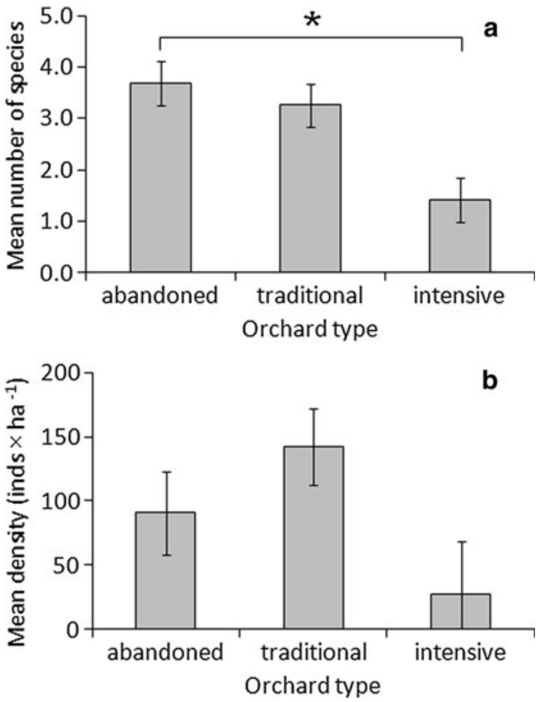

Fig. 1 Species richness (**a**) and density (**b**) of birds wintering in orchards of different types. Means with standard errors are presented. *$p < 0.050$

surrounding landscape, and fruit density (Table 3). The relationship between tree and bird densities was strong and positive in abandoned orchards (beta = 0.648 ± 0.312, p = 0.048), weaker and nonsignificant for traditionally managed orchards (beta = 0.226 ± 0.206, p = 0.533, n.s.), and a negative relationship in intensively managed ones (beta = −0.650 ± 0.370, p = 0.102, n.s.). The relationship between land cover diversity and bird density was the strongest and positive for abandoned orchards (beta = 0.659 ± 0.265, p = 0.015), weaker and nonsignificant for intensive orchards (beta = 0.524 ± 0.308, p = 0.092) but slightly negative for traditionally managed orchards (beta = −0.248 ± 0.265, p = 0.352). Similarly, the relationship between fruit and bird densities was strong and positive in abandoned orchards (beta = 0.514 ± 0.256, p = 0.048), attenuated in intensively managed ones (beta = 0.423 ± 0.382, p = 0.271), and the relationship was slightly negative in traditionally managed orchards (beta = −0.096 ± 0.247, p = 0.698).

Species response to environmental variables

First and second canonical axes of the RDA explained 22 % of the variation in species composition in the studied orchards, of which 83 % was explained by environmental factors (Fig. 2). Forward selection of environmental variables showed that tree density, tree diversity, orchard area, and abandoned orchards had significant effects on the composition of bird communities (Table 4). Tree diversity positively affected Great Tit *Parus major* and Blue Tit *Cyanites caeruleus*. Tree density positively affected densities of House Sparrow *Passer domesticus*. Cover of unmown vegetation, fruit density within orchards and diversity of surrounding habitats positively affected several seed-eating species such as Tree Sparrow *Passer montanus* and Yellowhammer *Emberiza citrinella*, and many other species that are usually omnivorous during winter (like Blackbird *Turdus merula*, Fieldfare *T. pilaris*, Mistle Thrush *T. viscivorus*, Eurasian Nuthatch *Sitta europea*, Great-spotted Woodpecker *Dendrocopos major*; Fig. 2). Densities of most species were lower in large intensive orchards (Fig. 2).

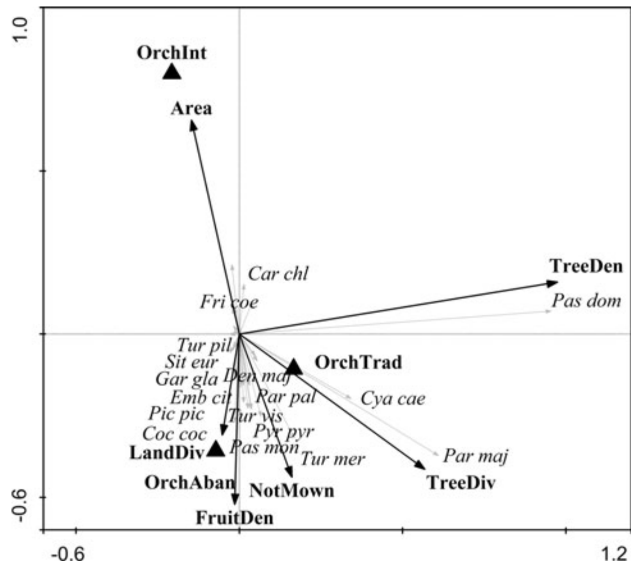

Fig. 2 RDA ordination of the species in relation to environmental variables in the studied orchards. Species are identified by abbreviated scientific names presented in Table 1. Species occurring in less than five orchards have been omitted. *OrchIn* intensively managed orchard. For explanation of other variable codes see Tables 1 and 2

Table 4 Results of forward selection analysis of environmental variables in RDA, explaining patterns in bird community structure in the orchards during winter

Variable code	*F*	*p*
TreeDen	**23.34**	**0.002**
TreeDiv	**2.44**	**0.004**
Area	**1.62**	**0.030**
OrchAban	**1.40**	**0.048**
FruitDen	1.30	0.102
LandDiv	1.38	0.086
NotMown	1.05	0.396
OrchTrad	0.88	0.618

The analysis was performed using Monte Carlo tests with 499 permutations. Variables are ordered according to their stepwise inclusion into the model. Statistically significant effects are in *bold* ($p < 0.05$). For further explanation, see Table 1

OrchAban abandoned orchards, *OrchTrad* orchard traditionally managed

Discussion

Our study revealed that the type of orchard management had an important impact on wintering bird communities and abandoned orchards had significantly higher bird species richness than intensive ones. Furthermore, our study underlines the importance of various orchard characteristics such as area, cover of unmown herb layer, tree diversity and density, as well as the diversity of the surrounding landscape for species richness and density of birds wintering in orchards.

The importance of orchards for birds, mostly during the breeding season, has already been identified (e.g., Bouvier et al. 2005; Wiącek and Polak 2008). It was shown that orchards constitute a breeding habitat for many farmland bird species linked with small mid-field woods (e.g., Chaffinch, Fieldfare, Hawfinch) (Kwiatkowska 1989; Wiącek and Polak 2008). Our results indicate the same stay true also for wintering species. To the best of our knowledge, there is a lack of studies on birds wintering in orchards in central Europe. In western Europe, Rey (2011) showed that olive orchards in Spain maintain high densities of frugivorous birds during winter. However, winter climatic conditions are substantially different in the Iberian Peninsula from that noted in central Europe. Studies in North America indicated the importance of the abundance of fruit trees for some wintering and migrating frugivorous bird species (Kwit et al. 2004; Foster 2007). Our study suggests that orchards may be important for many other bird groups such as seed-eating passerines and insectivores. Considering the strong decline of many common farmland birds in Europe (Donald et al. 2006) orchards may be one of the key habitats providing refuges, food resources, and, eventually, may improve winter survival of some species (Skórka et al. 2006; Tryjanowski et al. 2011).

Effect of the orchard management on wintering birds

The differences between orchard types illustrate changes in management that took place through recent decades in central Europe (Bański 2008). In our study area, the intensive orchards were larger, had higher tree density, a lower cover of unmown herb layer, a higher cover of orchards, and lower cover of human settlements in their landscapes than traditional ones. These results illustrate current and common in Europe process of farmland management intensification: planting large, one-age, dense monocultures that are often poor in food sources during winter and with a low diversity of surrounding habitats (Geiger et al. 2010). The negative impact of such intensive management of orchards is probably magnified by pesticide usage as was shown for breeding birds (e.g., Bishop et al. 1998; Gill et al. 2000; Wiącek and Polak 2008). In contrast, abandoned orchards had the highest avian species richness as well as significant associations with several species. Old abandoned orchards have probably a more complicated vertical and spatial structure than the other orchard types as well as a high cover of unmown herbs that constitute an excellent food source for birds. The cover of buildings, which strongly correlated with land cover diversity, often traditional homesteads, also probably contributed to the number of bird species in abandoned and extensive orchards since several synanthropic species such as Magpie, House Sparrow, and Collared Dove were observed in orchards.

Effects of orchard size and structural complexity

Our results indicate that several orchard features have a crucial impact on bird species. Orchard area positively affected species richness and this result is consistent with basic assumptions of species–area relationship (Rosenzweig 1995) as well as results of empirical studies on bird communities living in wooded habitat islands (e.g., Hinsley et al. 1996; Ney-Niffle and Mangel 2000). However, the density of birds showed an inverse relationship with orchard size. This may be related to distribution of resources within orchards (Helzer and Jelinski 1999). Many of the birds recorded in orchards are so-called ecotonal species, which utilize resources in arable fields, grassland patches, mid-field woods, and orchards (Tryjanowski et al. 2009).

Tree density positively affected bird species richness in all orchard types. On the other hand, tree density positively affected bird densities only in abandoned and traditionally managed orchards but negatively in intensive ones. Trees in abandoned orchards are often old, left uncut, and posses dead branches. All of these features may increase bird densities because of rich food resources and also due to many holes that may provide roosting sites. Thus, tree quality (from a bird's perspective) may be high in abandoned orchards and this may explain why densities of birds in abandoned orchards increased with tree density but not in intensively managed orchards where tree density is already extremely high. However, each tree within an orchard is a potential food resource or shelter for birds and adds to the structural complexity of an orchard, and this may explain the positive effect of this variable on species richness, independent of orchard management type. Tree density also significantly affected species composition in orchards as evidenced by redundancy analysis. Some passerine species (for example House Sparrow) may favor densely growing trees because they provide shelter from adverse weather conditions and possibly from birds of prey.

Tree species diversity positively affected bird species richness in all orchards. One of several niche theories argues that species composition is driven by environmental heterogeneity (Bolliger et al. 2002; Tokeshi and Schmid 2002). Thus, a higher number of tree species in an orchard may represent more microhabitats for different species. Birds searching for food depart significantly from random in their use of tree species, even when these trees are generally similar in life form (Holmes and Robinson 1981; Unno 2002). Thus, maintaining diverse tree species may significantly contribute to bird species richness in orchards. For example, planting one new tree in an orchard would result in one new bird species there (number of bird species = 0.978 × number of tree species + 1.921, r^2 = 0.260). This is also confirmed by redundancy analysis, which showed that this variable seemed to be much more important for shaping bird species composition than fruit density, which is usually attributable to orchards and birds.

Food-resource abundance

Food resources for birds in orchards during winter constitute mainly fruits (both on trees and on the ground), insects hibernating in trees, and seeds of herbs. Fruit density influenced positively the density of birds but not species richness. Fruits, which in our orchards were almost exclusively apples, constitute the main food for Fieldfares, Blackbirds, and Mistle Thrush, have been shown to be one of the prime factors affecting frugivorous bird abundance during winter and migration (Kwit et al. 2004; Skórka et al. 2006; Foster 2007). Fieldfares and Mistle Thrushes often set winter territories when fruits are abundant and chase all other species that try to eat fruit within their territories or even when enter them (Snow and Snow 1984; Skórka et al. 2006). Such winter territories usually encompass several trees with the largest number of fruits. However, in our study, density of Fieldfares was positively related to number of other bird species [log10(number of species) = 1.966 × log10 (density of fieldfares) + 0.825, r^2 = 0.402]. Thus, it is possible that environmental variables played a more important role in shaping species richness that interspecific interactions between birds.

Regardless of the orchard type, avian species richness and density was positively related to the cover of unmown herb layer. The importance of a herb layer rich in seeds for wintering birds is regarded as the factor limiting the occurrence of birds in farmland (e.g., Perkins et al. 2000; Siriwardena and Stevens 2004; Buckingham et al. 2011). Herbs provide food resources for seed-eating birds but they may also benefit arthropods and, in turn, densities of some insectivorous birds. In an open agricultural landscape, seed sources may be hardly available, especially during long periods with thick snow cover. Orchards, on the other hand, act like a shield protecting from wind, and tree canopies may prevent formation of thick snow making weeds and seeds more accessible for birds (author's unpublished observations).

Diversity of surrounding landscape

Land cover diversity in the landscape positively affected the number of bird species and their density, and these results are in agreement with the hypothesis that spatial heterogeneity may increase species richness and biodiversity in general (e.g., Ricklefs and Lovette 1999; Atauri and De Lucio 2001). Land cover diversity index positively correlated with grassland, forest, orchard and building covers and, therefore, it described their joint effect on birds. Agricultural landscapes that are more diverse are inhabited by more species (Tworek 2004; Herzon and O'Hara 2007; Chiron et al. 2010; Geiger et al. 2010). Such landscapes are also more permeable for moving birds, thus, higher land-cover diversity may enhance orchard utilization by birds by reducing effects of orchard isolation. Orchard isolation was found to be the prime factor limiting bird species richness during the breeding season (Bailey et al. 2010). Wiącek and Polak (2008) also found that a higher number of avian species breed in orchards located in landscapes diversified by grasslands, woodlands, and orchards.

Management recommendations and final remarks

Our study suggests that orchards may be important habitats offering food resources and refuge for several wintering birds. Old abandoned as well as extensively managed orchards are especially valuable habitats and should be protected since their existence is threatened due to agriculture intensification (Cooper et al. 2007). Abandoned and traditionally managed orchards should be included into existing agri-environment schemes to increase ecosystem services in farmland. Moreover, factors that shaped bird community structure in orchards can serve as the basis for recommendations for orchard managers and conservationists. Firstly, we propose to leave part of the herb layer unmown and not harvest several trees in intensive orchards. Birds attracted by these food sources can serve as pest control during the breeding season (Mols and Visser 2002) as well as in winter. Secondly, the management of landscapes around the orchards, e.g., keeping and creation of grassland and forest patches, may benefit conservation of farmland birds and enhance positive role of orchards in agricultural landscapes. The positive effects of land-cover diversity suggest that abandoned orchards together with diverse surroundings should constitute a unit of special conservation interest.

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