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Effects of land abandonment on bird communities of smallholder farming landscapes in post-war Croatia: implications for conservation policies

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Abstract: Land abandonment is a widespread phenomenon in agricultural systems, especially in former communist countries of Eastern and South-eastern Europe. Moreover, Croatia was affected by acts of war which enhanced the depopulation of marginal areas impelling further land abandonment. Agricultural landscapes in Croatia are highly parcelled with various proportions of forest habitats due to traditional smallholder farming systems. Secondary successions as a consequence of land abandonment affect farmland birds that are among the most endangered bird species in Europe. We examined bird communities along a habitat gradient in heterogeneous agricultural landscapes. We used the share of woody vegetation cover as a proxy measure for land abandonment that we classified in four classes. Our results showed no significant Shannon Wiener Index differences of bird communities along the land abandonment gradient. However, there were differences in abundances when we examined bird guilds such as farmland, forest and "other" birds separately. However, the conservation value of each of the four land abandonment classes did not show significant differences. We extracted single bird species such as the Yellowhammer (*Emberiza citrinella*), Red-backed Shrike (*Lanius collurio*), Song Thrush (*Turdus philomelos*) and European Robin (*Erithacus rubecula*) as potential indicator species for the four examined land abandonment levels. With these four species we successfully modelled the distribution of the recorded bird assemblages at the plot level along the four vegetation succession stages. We emphasized the need to develop new and integrative land use management concepts for areas affected by land abandonment in order to formulate sound conservation policy.

Abbreviations: AMSL–Above Mean Sea Level; CLC–Corine Land Cover; DEM–Digital Elevation Model; MRPP–Multiple Response Permutation Procedure.

Introduction

Agricultural landscapes encompass nearly half of the European (EU-27) land area (Stoate et al. 2009) harbouring farmland birds, whose populations have dramatically decreased in the recent past (Donald et al. 2006). The decline of bird populations in agricultural landscapes is largely driven by two adverse processes: the intensification of agricultural practices and vegetation succession after land abandonment. Both processes lead to vegetation homogenization (Robinson and Sutherland 2002, Lasanta-Martineza et al. 2005) causing reductions of habitat heterogeneity (Höchtl 2005) that is considered to be a key feature for both bird species richness and abundance (Benton et al. 2003, Kati et al. 2010).

Major drivers of landscape changes and land abandonment are due to socio-economic factors, such as the depopulation of remote and marginal areas due to unfavourable living conditions and economically unviable management of agricultural land (Preiss et al. 1997, Rey Benayas et al. 2007). In former communist countries of Eastern and South-Eastern Europe this phenomenon was triggered by the sharp change of the political and economic system in the beginning of the 1990s (Baumann et al. 2011). However, these European countries support internationally important populations of many species including farmland birds (Hagemeijer and Blair 1997, BirdLife International 2004) that are jeopardized by land abandonment (Nagy 2002). Yet the effects of land abandonment on bird populations were predominantly studied in Western, Central and Northern Europe (Pavel 2004, Verhulst et al. 2004, Báldi et al. 2005, Donald et al. 2006, Reif et al. 2008) while scarce scientific information on this topic is available from Eastern and South-eastern Europe (Báldi and Batary 2011, Nikolov 2010). This bias can lead to misleading generalizations if policy recommendations from Western Europe are adopted in Eastern Europe without taking into account differences of biogeographical conditions, socioeconomic backgrounds, population statuses and farming practices (Kleijn and Báldi 2005, Whittingham et al. 2007).

Croatia as a succession country of former communist Yugoslavia encompasses a rather small land surface of 56,594 km², but with 230 breeding bird species shows a high level of avian diversity which underlines its conservation importance at the European level (Hagemeijer and Blair 1997, Radović et al. 2003). Depopulation of rural areas is constant since World War II (Stipetić 2005) with one sharp population decline between 1991 and 1995 when one third of the Croatian territory was affected by acts of war. In contrast to some other communist countries, Yugoslavia partially abandoned the practice of obliged collective farming in 1953. As a result, smallholder farming systems have been kept as the dominant agricultural management type (Stipetić 2005). The average Croatian management unit of arable land encompassed 2.8 ha divided averagely into seven parcels (Župančić 1995). Furthermore, only 56% of potentially arable land in Croatian is managed, which accounts for 21% (1.2 million ha) of Croatia's territory. This leaves nearly 1 million ha of unmanaged agriculture and pasture land (Tomić et al. 2008) prone to natural succession as noted by Jelaska et al. (2005) and Ljubičić et al. (2008). It is expected that land abandonment will further increase,

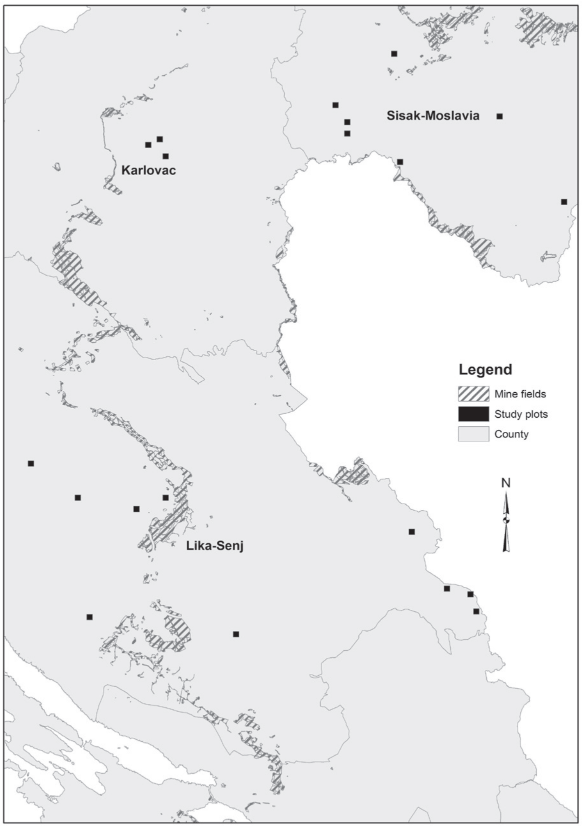

Figure 1. The location of randomly selected plots in Central and mid-highland Croatia; hatched areas are active mine fields (Data obtained from the Croatian Mine Centre), rectangles refer to study plots. Coordinates are given in the ETRS projection system (EPSG code: 3035).

because many rural areas are inhabited by ageing population (Nejašmić 2012).

The traditional agricultural management of small parcels in Croatia has formed spatially heterogeneous landscapes with different shares of pastures, arable lands and forests. Due to different speed of succession rates of abandoned arable land and pastures (Gellrich and Zimmermann 2007) these mosaic landscapes remain heterogeneous in the beginning of secondary successions. Studies about land abandonment and bird communities have usually been carried out at the point level along a habitat gradient (Santos 2000) or at different habitat types (Verhulst et al. 2004) without taking into account the spatial configuration of habitats at the landscape level. Furthermore, it is known that heterogeneous landscapes consist of suitable habitats fragmented by unsuitable non-habitat matrices (Castellón and Sievieng 2006) considering different bird guilds, while generalist species may gain advantage in unstable or disturbed habitats (Juillard et al. 2006).

The present paper deals with bird communities' responses to land abandonment, initiating a landscape level approach that captures habitat heterogeneity, as well as a bird guild approach in order to capture the functional aspect of beta diversity of bird community turnover along a land abandonment gradient. We set in particular the following research objectives: (a) to investigate the bird diversity pattern and bird community composition and structure at point and landscape level along a land abandonment gradient, (b) to investigate the bird guild differentiation in terms of farmland, forest and "other" bird species along a land abandonment gradient, (c) to extract indicator species that can predict the bird species composition of different land abandonment classes, and (d) to interpret our findings under an applied conservation policy context.

Material and methods

Study area

The study area falls within the former War of Independence frontline (1991-1995), where intensive depopulation occurred and active minefields have persisted until today. The area is characterized by mosaic agricultural landscapes with natural occurring hilly and mountain mixed forests, which are spread in the Continental and Alpine bio-geographical region of Croatia. It is sparsely populated and it encompasses three counties that have suffered from population decline since the 1950-70-ies and, more recently, during the war 1991-1995: Sisak – Moslavia County (30% population decline), Karlovac County (36% population decline) and Lika-Senj County (59% population decline). Study plots were situated in hilly landscapes, ca. 120-200 m AMSL in the Continental region and c.a. 450-700 m AMSL in the Alpine region. The average annual temperature is between 9.4°C (Alpine) and 11.2°C (Continental) with hot summers and cold winters (Croatian Bureau of Statistics 2013). The average annual precipitations are between 1000-1500 mm (Filipčić et al. 2012).

Plot selection

At the first step of the plot selection procedure, we identified potential research plots of 1 km × 1 km that were covered with more than 50% of arable land in the past, i.e after the World War II (1945). Since there has been no aerial photography available from the different time periods in the past based on which we could have tracked the land use changes, we used the Corine Land Cover (CLC) databases instead. We used data from 1980 as a baseline, presuming that there have not been significant changes in land use practice in the period from the late 1960s till 1980. We used information from the database 1980 and 2006 as well as the databases of detected changes in land cover classes for the periods of 1980-2006. We identified plots where the abandonment of arable land has been most pronounced. Only grid cells in which agricultural land has been reduced by at least 30% were extracted in the grid cell pool as potential study plots.

Agricultural habitats of interest and habitat changes were analysed at the resolution of 250 m × 250 m and later downscaled to the target resolution of 1 km × 1 km for the final selection. As it is difficult to measure land abandonment *per se*, we used the share of woody plant coverage per study plot as a proxy measure for land abandonment. Using information about the land cover from the past we were able to extract those grid cells where agricultural classes (CLC 211 – non-irrigated arable land; 212 –permanently irrigated land; 221 – vineyards; 222 – fruit trees and berry plantations; 223 – olive groves; 231 – pastures; 242 – complex cultivation; 243 – land principally occupied by agriculture, with significant areas of natural vegetation) have changed into forest or shrub classes (CLC 324 – transitional woodland scrub; 311 – broadleaf forest; 312 – coniferous forest; 313 – mixed forest). In our final sample set we aimed to have 20 study plots that comprise a gradient of woody plant coverage that were classified into four land abandonment classes depending on the share of woody plant coverage: land abandonment class 1 – <25%; land abandonment class 2 – 25-50%; land abandonment class 3 – 50-75%; and land abandonment class 4 – >75%. However, due to the small holder farming system in the study area, we cannot rule out the possibility that some woody vegetation patches in the study plots may have derived from pre-existing forest patches. Study plots that overlapped with existing minefields (data obtained from Croatian Mine Centre) were excluded due to safety reasons.

The maximum average altitude on the selected study plots was decided to be lower than 1000 m AMSL in order to minimize expected avian community differences due to lowland and mountain bird species. Cells with more than 15% area coverage with features such as watercourses, roads and settlements were excluded from the potential grid cell pool since they could have had prevailing influence on the bird community structure due to disturbance and edge effects. From the grid cell pools for each of the four predefined land abandonment classes we ran random selection algorithms in order to extract five cells per class, i.e., 20 research plots in total (Fig. 1).

The whole procedure was performed with R software (R Core Team 2012) using different packages such as *stringr* (Wickham 2012), *rgdal* (Bivand et al. 2013), *maptools* (Bivand and Lewin-Koh 2013), *reshape* (Wickham 2007), *xlsx* (Dragulescu 2013), *stats* (R Core Team 2012), *raster* (Hijmans 2013), *RSAGA* (Brenning 2008), *car* (Fox and Weisberg 2011) and with software for spatial data handling - the System for Automated Geoscientific Analyses (SAGA, Böhner et al. 2006).

Bird count

In each of the 20 selected 1 km ×1 km study plots we collected both qualitative and quantitative data on bird communities from a regularly placed point grid consisting of nine points distributed in distance of 300 m in order to avoid double counts of birds from different points. On each point, birds were counted for five minutes by sight and hearing with a two minute resting phase prior to the bird count. Counting time (2+5 min) was chosen in order to be able to accomplish nine point counts of one study plot during the early morning hours (5-10 h AM). Birds were counted in three radii: 1) < 50 m; 2) 50 – 100 m and 3) > 100 m. Bird counts were performed twice, the first in late spring 2011 (May – June) and the second in early spring (April – May) of 2012 covering early and late migrant breeding species.

Data analysis

Only the maximum count for each bird species during the two visits per plot was used in subsequent analyses. Birds recorded only as flyover during the point counts were included in the occurrence list (Appendix), but excluded from further analyses. In addition, several species with large home ranges or easily heard from a large distance were excluded from the analysis. Those were Common Buzzard (*Buteo buteo*), Common Cuckoo (*Cuculus canorus*), Tawny Owl (*Strix aluco*), Honey Buzzard (*Pernis apivorus*) and Mallard (*Anas platyrhynchos*).

In order to gain a better insight into the bird community structure along the land abandonment gradient, we analyzed data both on the point and plot level. At the point level we used information on birds detected in a 100 m radius around the research points. Nine point counts of one study plot formed the community at the plot level. For the analyses at the landscape level we aggregated data from five plot communities of one land abandonment class. We performed the analysis of incidence-based estimates in 'specpool' using frequencies of species from the sample sites in order to estimate potential species numbers for the study area. Species richness was extrapolated with the bootstrap procedure (*vegan* package for R version 2.0, Oksanen et al. 2011).

Birds were classified into guilds as farmland, forest or "other" bird using the classification system of the Pan-European Common Bird Monitoring Scheme (PECBMS 2014) of the European Bird Census Council (EBCC 2014) based on the recorded predominant regional habitat use of the bird species in Europe (EBCC 2013).

Digital elevation model (DEM) was obtained from NASA (2012) and other environmental variables used in the analyses such as slope, aspect and topographic wetness index, were derived from DEM and prepared with SAGA software for the point and for the plot level (grid cell). The variable 'distance to nearest forest' was measured by processed recent high resolution orthophoto imagery from the Croatian State Geodetic Administration. The latter was used only in the analyses at point level. For the point level analysis, we prepared all variables at 30 m resolution and extracted information for each bird count point. Similarly, all described variables (beside distance to forest) were prepared at 1 km resolution to fit the study plots. Mean values of the research plot were extracted on its centroids.

Point level analysis. Considering point level data (180 points of 100 m radius), we analyzed the relationship between bird assemblages at point level and environmental variables (elevation, potential wetness index, slope, aspect, distance to forest) using the Mantel test. In a second step, those environmental variables were tested for significance with the Canonical Correspondence Analysis (CCA).

Landscape level analysis. Bird assemblages of five study plots per each of the four land abandonment classes were pooled together forming four landscape bird communities, which were further tested. The Shannon-Wiener index (H) of bird diversity for each landscape community was calculated as well as its species composition regarding farmland, forest and other birds. Moreover, we tested the mean number of bird specimens of the bird community at the landscape level with Multiple Response Permutation Procedure (MRPP). The procedure is in its core similar to the analysis of variance and compares dissimilarities within and among groups. In our analysis we used Euclidean metric as basis for dissimilarities among communities. Beta diversity, the measure of species turnover in communities along a habitat gradient, was analyzed using vegan package. All analyses were performed in R environment, using diverse packages for data manipulation, integration, analysis and presentation (R Core Team 2012).

Indicator species for land abandonment. In order to find the smallest set of species whose counts provide enough information about the vegetation cover on the landscape scale, we used the following procedure. First, we excluded rare species, whose counts across all sites and land abandonment classes did not exceed 10 counts. Then, we performed a univariate test of means across the four land abandonment classes for each bird species of our study sample. This procedure was performed with the generalized lineal models (GLM) function (SAS GLIMMIX procedure) using Poisson distribution since it best suited our data (SAS/STAT software, version 9.1 of the SAS system for Windows, © 2002-2003 SAS Institute Inc.)). Obtained p values were used for the selection of species subsets that delineated the study plots on account of the woody plant coverage congruent with our predefined four land abandonment classes. Further, p values were used for the identification of potential landscape indicator species for each of the land abandonment classes.

We tried to fit a multinomial model with each species using *nnet* package (Venables and Ripley 2002) according to the specific p values in ascending order. Before fitting, we split our data from randomly selected stratified samples in two parts. We used one third of the data for model building and two thirds for model evaluation. Since we wanted to test if the subsets of bird species could be used for the classification of bird communities in accordance to their abundance in the land abandonment classes, we prepared, beside the comprehensive model, models with two single species counts as well as models with three and four species counts with the lowest p values obtained from the univariate test. We tested the performance of each prepared model with the confusion matrix error of classification tables. This procedure was repeated for ten independent stratified samples.

The species that revealed at least one significant difference among the land abandonment classes, with univariate comparison of mean counts per land abandonment class, were further tested for contrasts, i.e., for differences in means among pairs of land abandonment classes. With this procedure we wanted to detect the species whose counts differed across all four land abandonment classes. If successful, the species could be regarded as potential indicator species for a certain land abandonment class in the region. Analysis for the detection of indicator species for each land abandonment class was performed in R using the *nnet* package.

Conservation evaluation of land abandonment classes. We prepared indices of conservation values for bird communities on the landscape level. We assigned to each sampled bird specimen one simple and one pondered value based on its conservation status at the European level (Species of European Conservation Concern - SPEC). Simple values were assigned linearly (SPEC category: Non SPEC - 1, SPEC 4 - 2, SPEC 3 - 3, SPEC 2 - 4, SPEC 1 - 5), while pondered values were assigned as suggested by Pons et al. (2003) in geometrical progression (SPEC category: Non SPEC - 1, SPEC 4 - 2, SPEC 3 - 4, SPEC 2 - 8, SPEC 1 -16). In order to see how the SWI, prepared with simple and pondered data, are changing in relation to the land abandonment classes, we tested their means across the four classes with analysis of variance, not assuming equal variance. In the same manner, we tested the four landscape bird communities in order to assess to which extent the total number of specimens is affected by vegetation cover. First, we tested the homogeneity of variance of the conservation values among the four communities using the Levene's test that showed significant results. Therefore, we applied analysis of variance tables for the linear model type III test adjusted to heteroscedasticity using the Anova function from the car package. Every main effect that turned out to be significant, but with no interactions between two main effects, was further tested to extract the communities with significant differences. A similar procedure was performed for testing the SW indices and the conservation values of landscapes across the vegetation cover classes.

Results

Bird communities

We recorded 70 bird species (4262 individuals, including flyovers) at the 20 plots studied (360 point counts); (Appendix). We recorded 19 forest bird species, 16 farmland bird species and 35 "other" bird species, with a proportion of 9% being of high European conservation interest (SPEC 1 & 2). Our sampling was adequate, having sampled more than 85% of predicted species richness as the bootstrap procedure predicted 81.9 species.

The point level. The Mantel test revealed a significant correlation of bird communities with environmental variables at the point level (r = 0.187; P = 0.001; npermut = 999). The CCA showed that the bird communities at the point level were explained by elevation and the potential wetness of the terrain, whilst other variables such as slope, aspect and distance to forest were not significant (Table 1).

The landscape level. We found no significant differences of bird diversity in terms of Shannon-Wiener index (H), ($F_{3;8,52}$ = 1.69; p = 0.241) among the land abandonment classes, with class 4 showing the lowest and class 2 the highest H index respectively (Fig. 2a).

We also found no significant difference of bird abundances across the four landscape classes (MRPP; npermut = 1000; P = 0.759). Beta diversity analysis revealed no gradient differences among the 4 land abandonment classes in terms of species, showing low values (z<0.3) below the determined threshold (Oksanen 2012) (Fig. 2b).

Bird guilds. The diversity patterns of different bird guilds differed across land abandonment classes (Fig. 3a,b). "Other" and forest birds were evenly distributed among the four classes with the highest H indices in class 2. Farmland birds decreased in abundance from class 1 to 4, whilst their H index was the highest in class 2 and with a remarkably low H index in class 4. Farmland birds maintained a higher level of species diversity up to abandonment class 3 despite decreasing abundances.

Table 1. Tested (CCA) environmental variables in relation to bird communities at the point level.

	Chisq	df	F	P (>F)
elevation	0.09	1	2.61	***0.01**
slope	0.04	1	1.17	0.10
aspect	0.03	1	1.02	0.09
potential wetness	0.06	1	1.88	***0.01**
distance to nearest forest	0.03	1	0.91	0.35

H indices of farmland, forest, and "other" birds showed significant differences among each other across the four classes ($F_{2,475}$ = 490.59; P< 0.001). Pairwise testing of effects is presented in Table 2. However, the effect of land abandonment classes on the *H* index did not turn out to be important ($F_{2,475}$ = 2.02; P =0.110) as well as the interaction between bird guilds and land abandonment class ($F_{2,475}$ = 2.09; P = 0.053). The total number of counts of the three bird guilds differed significantly among the four land abandonment classes ($F_{3,351}$ = 12.54; P < 0.001). We performed pairwise post-hoc testing (Table 2). There were significant differences in total recorded specimens between "other" and farmland as well as "other" and forest birds. There were no significant differences in total recorded specimens between forest and farmland birds. There were significant differences in total recorded bird specimens among the land abandonment classes (Table 3). Class 2 showed significantly different total recorded specimens compared to all other classes. A significant difference was also recorded between class 1 and class 4.

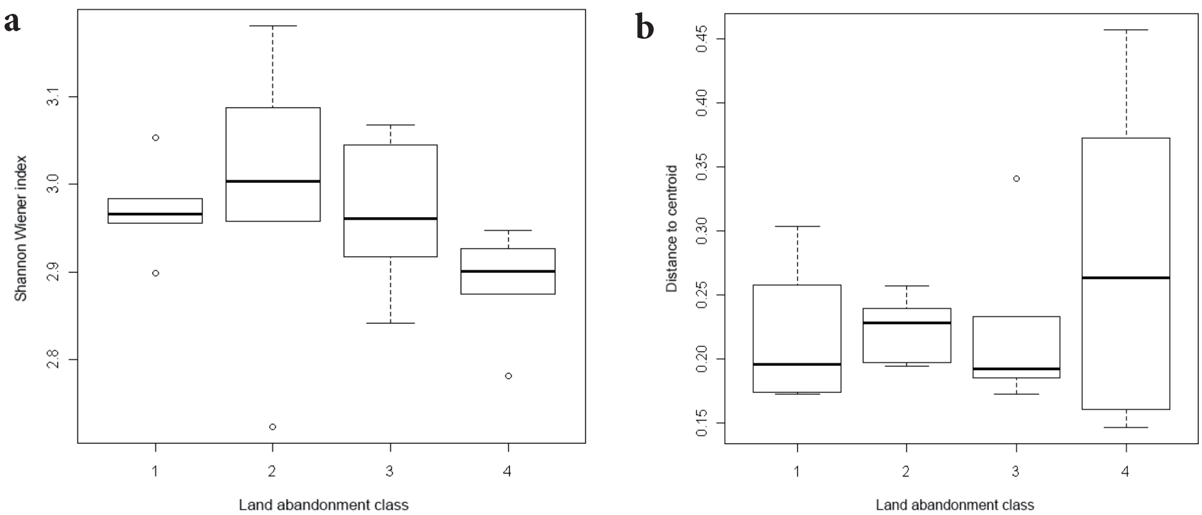

Figure 2. **(a)** Bird community diversity in terms of Shannon-Wiener index and **(b)** beta-diversity of bird communities in terms of recorded species accross the 4 land abandonment classes. 1: <25% woody vegetation cover; 2: 25-50% woody vegetation cover; 3: 50-75% woody vegetation cover; 4: >75% woody vegetation cover.

Table 2. Results of post-hoc testing of differences for Shannon-Wiener indices and total recorded specimens per guild (farmland, forest, other) (main effect: bird guild).

	Farmland birds			Forest birds		
	F	df	P	F	df	P
Shannon Wiener Index						
Forest birds	372 088	2.475	**< 0.001**			
Other birds	4 398 989	2.475	**< 0.001**	3 713 358	2.475	**< 0.001**
Recorded specimens						
Forest birds	0.66	3.351	0.516			
Other birds	409 785	3.351	**< 0.001**	3 713 358	3.351	**< 0.001**

Table 3. Results of post-hoc testing of differences for the number of specimens of bird guilds (farmland, forest, other) and conservation values of bird communities (main effect: land abandonment class).

	CLASS 1		CLASS 2		CLASS 3	
	F	P	F	P	F	P
Specimens of guilds (df = 3.351)						
CLASS 2	49 119	**0.008**				
CLASS 3	0.09	0.914	35 776	**0.029**		
CLASS 4	28 975	**0.029**	0.26	0.768	19 124	0.149
Conservation value (df = 3.351)						
CLASS 2	56 369	**0.004**				
CLASS 3	0.26	0.772	34 966	**0.031**		
CLASS 4	16 595	0.192	11 860	0.307	0.61	0.544

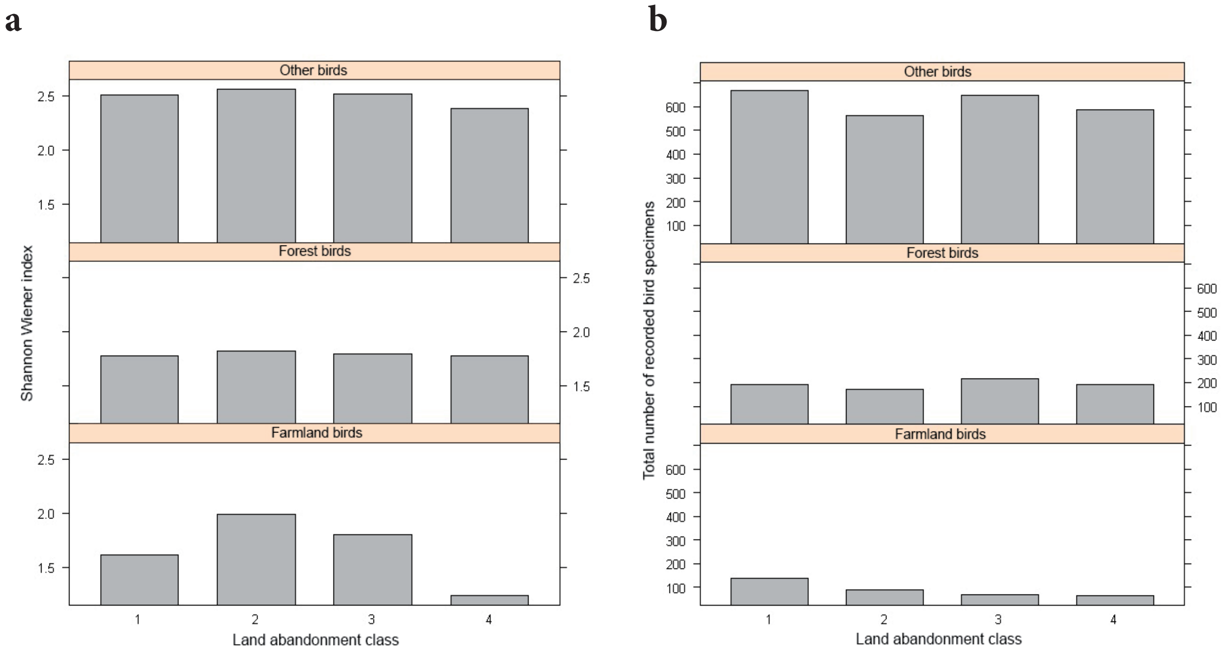

Figure 3. **(a)** Mean Shannon-Wiener index (*H*) of farmland , forest and other bird species and **(b)** total number of recorded bird specimens per bird guild across the land abandonment classes. 1: <25% woody vegetation cover; 2: 25-50% woody vegetation cover; 3: 50-75% woody vegetation cover; 4: >75% woody vegetation cover.

Table 4. Results of pairwise difference testing in means of counts with generalized linear models (SAS GLIMMIX procedure (distribution = Poisson) and testing contrasts between land abandonment classes (only species with significant main effect are presented). The degree of freedom value for all rows is df = 1.176. Abbreviations: Embcit: *Emberiza citrinella*; Erirub: *Erithacus rubecula*; Gargla: *Garrulus glandarius;* Lancol: *Lanius collurio*; Lusmeg: *Luscinina megarhynchos*; Oriori: *Oriolus oriolus*; Parmaj: *Parus major*; Strtur: *Streptopelia turtur*; Stuvul: *Sturnus vulgaris*; Turmer: *Turdus merula*; Turphi: *Turdus philomelos*; Turvis: *Turdus viscivorus*; for English names see Appendix.

	Main effects		Contrasts						
Species	P	F	1vs2	1vs3	1vs4	2vs3	2vs4	3vs4	Indicator
Embcit	**0.001**	8.09	**0.001**	**<0.001**	**0.004**	0.595	0.494	2.234	class 1
Erirub	**<0.001**	10.29	0.170	0.504	**<0.001**	0.044	**<0.001**	**0.002**	class 4
Gargla	**0.027**	3.06	0.123	**0.007**	**0.010**	0.138	0.185	0.866	
Lancol	**0.004**	4.67	**0.021**	0.259	1.000	**0.003**	**0.021**	0.259	class 2
Lusmeg	**0.027**	3.14	0.080	**0.014**	0.999	0.877	0.999	0.999	
Oriori	**0.006**	6.12	0.053	0.692	0.117	**0.004**	0.976	**0.009**	
Parmaj	**0.015**	3.60	**0.002**	0.163	0.554	0.070	0.010	0.417	
Strtur	**0.017**	3.48	**0.033**	0.515	0.2143	0.101	**0.003**	0.067	
Stuvul	**0.012**	4.39	0.070	**0.042**	**0.008**	0.7820	0.070	0.099	
Turmer	**0.020**	3.37	0.233	0.587	0.056	0.514	**0.002**	**0.015**	
Turphi	**<0.001**	7.03	**0.003**	**0.003**	0.706	1.000	**0.001**	**0.001**	class 3?
Turvis	**0.014**	3.64	0.058	0.111	0.149	0.732	**0.005**	**0.009**	

Table 5. Test results of the multinomial model performance on classifying research plots into 4 land abandonment classes according to different number of bird count subsets for ten independent stratified samples.

Subset	Full model	First 2	First 3	First 4
1	0.33	0.58	0.50	0.25
2	0.58	0.42	0.50	0
3	0.50	0.25	0	0
4	0.33	0.42	0	0
5	0.58	0.17	0	0
6	0.50	0.58	0.50	0
7	0.50	0.42	0.50	0
8	0.66	0.42	0.17	0
9	0.25	0.17	0.17	0
10	0.42	0.25	0.17	0
Mean	0.47	0.37	0.25	0.025

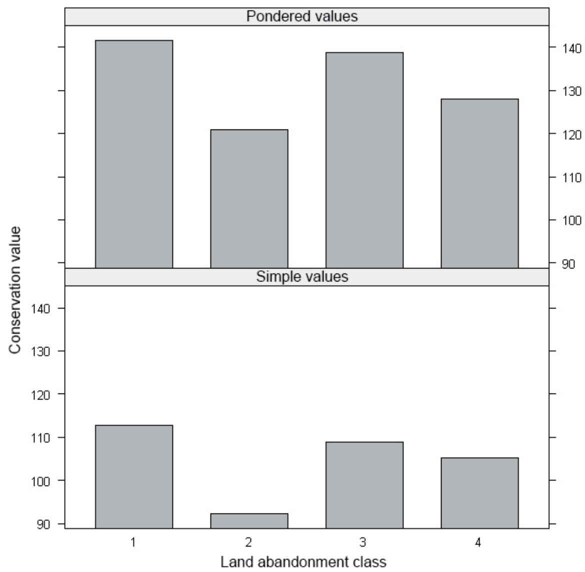

Figure 4. Conservation values of bird communities of the landscapes along the land abandonment classes; pondered values above and simple below. 1: <25% woody vegetation cover; 2: 25-50% woody vegetation cover; 3: 50-75% woody vegetation cover; 4: >75% woody vegetation cover.

Classification and potential landscape indicator species

The species whose differences of counts across the land abandonment classes were the most significant are presented in Table 4 (column 1). The lowest *p* values (column 2) were detected for the Yellowhammer (*Emberiza citrinella*), Red-backed Shrike (*Lanius collurio*), Song Thrush (*Turdus philomelos*) and the European Robin (*Erithacus rubecula*). The counts of these four species were used for the multinomial model fit aiming to classify all bird communities at the plot level into one of the four abandonment classes. The results in Table 5 revealed that the full multinomial model did not outperform simpler models. Even the model using only the counts of the first two species with the most significantly different counts across the four classes performed well. However, the best performance was detected for the model based on the counts of the first four species, but even the model based on the first three species counts performed satisfyingly.

Counts of the Yellowhammer from the plots in land abandonment class 1 differed significantly from the counts of the other three land abandonment classes (Table 4). Therefore this species can be taken as a potential indicator species for the land abandonment class 1. Analogously, the Red-backed

Shrike and the European Robin are potential indicator species for land abandonment class 2 and 4, respectively. Only the Song Thrush did not show clear affiliation to land abandonment class 3 because the counts from categories 2 and 3 did not differ significantly (Table 4).

The procedure of assigning appropriate land abandonment classes to the bird communities based only on the counts of small species subsets (multinomial model performance) was performed for ten stratified samples (Table 5). Models with four species, whose counts differed the most across the 4 classes, performed almost perfectly.

Conservation value

The conservation value of the landscapes showed significant effects across the four land abandonment classes ($F_{3,351}$= 4.33; P=0.005) and revealed significant differences whether we calculated the conservation value as simple sum of recorded specimens or applied ponders to each specimen according to its SPEC category ($F_{3,351}$=7.26; P< 0.001) (Fig. 4). In order to test if the conservation values of bird communities of the land abandonment classes differ, we performed post-hoc tests for significant differences among them (Table 3). The most pronounced differences are found between the communities of classes 1 vs. 2, and classes 2 vs. 3. Hence, the bird community of land abandonment class 2 revealed the lowest conservation value in this study.

Discussion

Bird communities

In our study, no distinct bird community was recorded at one of the four abandonment levels (Fig. 2b). We explain the similarity of bird communities across the gradient of four succession classes by the habitat heterogeneity present in smallholder farming landscapes affected by land abandonment. The scale on which land abandonment takes place is crucial for either promoting or decreasing habitat diversity. If large areas are abandoned, habitat homogenization is likely to occur with negative effects for bird conservation (Nagy 2002). In our study, the three bird guilds (farmland, forest, other) were present in all four land abandonment classes, which underlines the habitat heterogeneity of the examined landscapes. Land abandonment class 2 (25-50% of woody vegetation) showed the highest *H* indices for the three bird guilds, although with the lowest abundances for forest and other birds. The match of high *H* indices of the three bird guilds implicates that there is an edge effect in land abandonment class 2. Reino et al. (2009) found a positive edge effect of forest plantations on five common and widespread farmland birds, but negative effects on steppe birds in Portugal. Therefore, we emphasize the need to distinguish farmland birds according to their habitat scale requirements. Steppe birds such as the Calandra lark (*Melanocorypha calandra*), Short-toed lark (*Calandrella brachydactyla*) (Reino 2009) and Great Bustard (*Otis tarda*) (Báldi and Batary 2011) rely on uniform broad scale agricultural landscapes that are negatively affected by habitat heterogeneity due to fragmentation effects. In contrast, several authors stress the importance of habitat diversity for bird species richness in agricultural landscapes (Moreira et al. 2001, Tworek 2002; Laiolo et al. 2004). Moreover, habitat heterogeneity is crucial for some common farmland species with declining populations such as the Yellowhammer (Bradbury et al 2000), the Common Whitethroat (*Sylvia communis*) (Kati and Sekercioglu 2006; Tsiakiris et al. 2009) and the Red-backed Shrike (Brambilla et al. 2007; Tsiakiris et al. 2009). Structural elements of vegetation like hedges and shrubs can increase the number of these farmland birds on pastures (Nikolov et al. 2011). Landscape mosaics with both cultivated land and woodland can increase the bird richness of those habitats (Farina 1997, Preiss et al. 1997, Moreira et al. 2001) or favour bird species that rely on multiple habitats (Delgado and Moreira 2000). In Croatia, we have observed that land abandonment has negative effects on farmland birds in alluvial grasslands due to the fact that it triggers the encroachment of the invasive false indigo bush (*Amorpha fruticosa*) (Radović et al. 2013).

In this study, farmland birds are the poorest community regarding bird richness, with only 16 recorded species. However, farmland birds are present in all four land abandonment classes and show a high *H* index even in land abandonment class 3 (50-75% woody vegetation), maintaining species richness despite lower abundances. Furthermore, at the point level, differences in the bird community structure were not primarily driven by the distance from the forests, but by the wetness index and elevation (Table 1). We explain this with the fact that there are forest patches in all examined study plots, while micro relief and elevation features were shaping patchy wetland habitats with more distinct bird communities. Moreover, wetness potential could have had prevailing influence on former land use. Lower terrains, which are moist and more exposed to flooding, were used for pastures or as meadows, while higher terrains, were used for crops.

Forest birds were rather evenly distributed along the four land abandonment classes with higher abundances than farmland birds in all examined classes. We had expected a higher number of forest birds in land abandonment classes 3 and 4, i.e., in landscapes with 50-100 % of woody plant cover. However, we have observed that the woody plant cover in our study plots consists of younger forest stands developed as a consequence of land abandonment in the past 20-50 years. Forests in early and mid succession stages harbour bird communities that maintain both lower abundances and species richness compared to old growth forests (Díaz et al. 2005). "Other" birds were dominant both in diversity and abundances in all four land abandonment classes with a total of 35 recorded species. Non-specialized species tend to aggregate in unstable or perturbated habitats. They take advantage of degraded habitats due to lack of competition with specialist species that are affected by degradation (Juillard et al. 2006).

Landscape indicator species

The identified indicator species for each of the four land abandonment classes are suitable for the assessment of secondary successions stages in the continental region of Croatia. The four species Yellowhammer, Red-backed Shrike, Song Thrush and European Robin showed the most significant affiliation to a particular type of land abandonment class (Table 4). The woody vegetation cover of the land abandonment classes matches adequately with the habitat requirements of those species (Cramp 1998). Kati et al. (2004) found significant relationships between birds and woody plants in Greece, however, their species-richness patterns were only congruent in non-forest habitats. In contrast, herbaceous plants could not indicate the species richness of farmland birds in Sweden (Pärt and Söderström 1999, Vessby et al. 2002). We are aware of the local limitation of indicator species describing species-habitat relationships. Nevertheless, indicator species can help decision-makers to formulate policy recommendations that could be measured via indicators (Gregory et al. 2005). We demonstrated an approach with which local research and conservation groups could identify local indicator species of abandoned landscapes suitable for monitoring. The identified indicator species of the study area are common and conspicuous, which makes them easy to monitor even by less trained field workers. However, the indicator strength should be further tested on larger data sets from other parts of continental Europe.

Conservation value

Our results showed that the bird conservation values did not differ significantly among the land abandonment classes, with the exception of the land abandonment class 2 that showed the greatest difference between simple and pondered values, meaning that species present in low abundance had a high conservation status. The conservation value of land abandonment class 3 is nearly the same as in land abandonment class 1. Plots with higher proportion of woody plant cover may have, on the one hand, become suitable for forest specialists, but on the other hand they still harbour farmland birds (Fig 3a; 4). These results imply that clear conservation goals with target species have to be superimposed in conservation strategies. Evaluating landscapes solely on the basis of their conservation value by disregarding the (wanted) species composition of bird communities could prompt the development of misleading habitat management measures.

We expect a further increase of abandoned landscapes in Croatia due to the ongoing human population decline in marginal areas and the economically unviable management of small farms. The effects of land abandonment on biodiversity are controversially discussed. Studies usually highlight negative effects of advanced stages of habitat succession on farmland birds (Nagy 2002, Brambilla et al. 2007), whereas there are positive effects of rewilded abandoned landscapes for large carnivores, forest birds and other biota due to increased area and connectivity of their habitats (Navarro and Pereira 2012). In addition, land use, land use change and forestry (LULUCF) are considered to contribute to carbon sequestration by increasing carbon sinks through growing forests (IPCC, 2000). We think that vast areas affected by land abandonment cannot be solved solely with the system of agrarian subsidies, though significant proportions of high nature value farming landscapes should be maintained through appropriate agro-environmental schemes (AES), in order to preserve suitable habitats for farmland birds.

Based on our used point-count methodology, we were not able to encompass bird guilds like raptors or birds with large home ranges. Most raptor species rely on open habitats as hunting areas. These species are of higher conservation concern than Passerines and could therefore, if taken into account, alter the results of this study. However, birds with large home ranges have to be examined on a much broader scale and it is difficult to encompass both Passerines and raptors within the same study using one methodological approach.

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Appendix

List of all bird species recorded during the research. The file may be downloaded from www.akademiai.com.