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Birds and plants: Comparing biodiversity indicators in eight lowland agricultural mosaic landscapes in Hungary

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ABSTRACT

This study compares biodiversity indicators based on plant and bird communities in eight mosaic landscapes in Hungary, dominated by a mixture of agro-ecosystems and grasslands. The eight landscapes were selected to represent the diversity of the mixed agricultural landscapes of South-East Europe, where a mosaic pattern of intensively managed farmlands and high nature value semi natural grasslands is still relatively prevalent. Bird communities were described using several assemblage-level (species number, total abundance, and Shannon diversity of the assemblage, based on 15 pre-selected key farmland bird species), as well as species-level (presence/absence of the 15 bird species) indicators, which were checked against a synthetic landscape quality indicator describing the degradation of the local plant communities with respect to an ideal baseline (vegetation-based natural capital index, NCI). The authors were interested if and how the assemblage- and species-level bird indicators can describe landscape quality in South-East European agricultural mosaic landscapes.

It was found that assemblage-level bird indicators were poorly associated to the landscape quality measured in terms of NCI: only total abundance correlated significantly with NCI. On the other hand, species-level indicators were much more successful in predicting landscape quality. Six (*Alauda arvensis*, *Emberiza calandra*, *Falco tinnunculus*, *Motacilla flava*, *Limosa limosa*, *Vanellus vanellus*) of the 15 farmland bird species studied showed significant positive correlation with NCI, while three species (*Emberiza citrinella*, *Galerida cristata*, *Sylvia communis*) exhibited negative correlations. We also found that it was possible to draw conclusions about the landscape quality in an agricultural landscape based on the bird communities better, than to predict the bird assemblages from vegetation condition.

The negative correlations for species that indicate good quality habitats in Western Europe, underline the context specificity of biodiversity indicators: whereas the conditions preferred by these species can be considered relatively natural in Western Europe, they correspond to relatively degraded habitats in South-East Europe. The nine farmland bird species which showed a significant connection to NCI can be seen as potential candidates for a regional Farmland Bird Index customized for agricultural landscapes in South-East Europe, in the Pannonian biogeographic region, or in Hungary.

1. Introduction

For centuries, traditional farming practices created and maintained species-rich habitats in Europe and other developed regions of the world (Bignal and McCracken, 1996; Vera, 2000). From the 1950′ onwards agricultural intensification has dramatically degraded these habitats, which led to the decline of many, previously common species and the disappearance of less common ones. This process involved several elements of agricultural intensification and land use change, including increased use of agrochemicals and mechanization (Robinson and Sutherland, 2002), an increase in plot sizes (Aebisher et al., 2000), drastic changes in animal husbandry (Chamberlain et al., 2001), and a general loss in semi-natural habitats in agricultural regions (García-Feced et al., 2014). Several processes, like the disappearance of low intensity grasslands (Aebisher et al., 2000), are particularly evident in Western

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Europe and North America (Herkert, 1994; Pain and Pienkowski, 1997), while in South-East Europe this process is less obvious (Verhulst et al., 2004). In Western Europe, many studies have been made concerning the effect of intensive agriculture on birds and other animal groups (Aebisher et al., 2000; Pain and Pienkowski, 1997; Robinson and Sutherland, 2002). The bird species linked to agrarian landscapes has drastically decreased due to the agriculture becoming more intensive and profit-oriented (Pain and Pienkowski, 1997). Farmland birds suffered the highest losses during these unfavourable processes (Pain and Pienkowski, 1997; Robinson and Sutherland, 2002). On the other hand, due to the relatively milder and delayed intensification in agriculture, extensively managed farmland landscapes in South-East Europe are still a hotspot of biodiversity (Báldi et al., 2005; Verhulst et al., 2004), frequently coupled with outstanding cultural values (Filepné et al., 2012). However, these areas are now increasingly being threatened by intensification (Aebisher et al., 2000; Lefranc, 1997; Verhulst et al., 2004).

In order to stop this unfavourable process it is necessary to explore the different ecosystem processes collecting data on the state of these ecosystems at a broad scale. However, the immense complexity of ecological systems, the lack of time and money, the lack of adequate professional experiences and the incomplete technical conditions cause serious difficulties to biodiversity monitoring (Rodrigues and Brooks, 2007). To overcome these difficulties various types of biodiversity indicators have been proposed that describe the status of ecosystems and their biodiversity in an aggregated form (Eglington et al., 2012; Lindenmayer et al., 2000; van Strien et al., 2009). Such indicators are more than simple metrics to measure the diversity of organisms, they should rather be regarded as general indicators monitoring the state of the ecosystems (ten Brink, 2006; Niemeijer and de Groot, 2008).

One of the most straightforward ways of characterizing the state of an ecosystem is to study its species. According to Juhász-Nagy's (1986) "universal indication principle", any species can be good indicator for its environment, indicating that conditions enabling survival are present in that locality. Thus the occurrence and/or the abundance of a group of well-chosen species can render meaningful and reliable information on the ecological conditions of a certain location. Biodiversity metrics quantified over major taxonomic groups are often used as general-purpose biodiversity indicators for the evaluation and monitoring of ecosystem state and trend (Browder et al., 2002; Canterbury et al., 2000; Mace and Baillie, 2007).

One of the major taxonomical groups used most frequently for creating general purpose biodiversity indicators is that of the birds. Scientists often apply bird species and assemblages as proxies for quantifying the state of ecosystems and biodiversity (Bildstein, 2001; Gregory et al., 2005). The causes of popularity of birds are manifold: their taxonomy is stable, their natural history is well known, they are relatively easily monitored, they appear in all types of habitats up to the top-level of the food-web, they are sensitive to environmental changes, and in several countries there are lots of monitoring programmes and databases dealing with them (Burger, 2006; Gregory et al., 2003; Pearson, 1994). Several studies have shown that there is a close relationship between bird diversity and overall biodiversity (Gregory and van Strien, 2010; Kati et al., 2004; Sauberer et al., 2004). Birds are suitable to characterize the ecological status of a landscape unit at a broader scale, although there are some limitations (e.g. migratory species, or species living in several different habitats inevitably convey signals that are difficult to decipher – Gregory et al., 2003, 2005; Gregory and van Strien, 2010). Nevertheless, birds were taken as the basis of ecosystem health indicators in forests (Canterbury et al., 2000), riparian-wetland areas (Croonquist and Brooks, 1991), grasslands (Browder et al., 2002) and marshes (Smith-Cartwright and Chow-Fraser, 2011). The demise of low intensity farmlands and the degradation/loss of wetlands exert particularly high impact on many bird species. This relationship is made explicit in the Farmland Bird Index developed in the UK and Europe, which describes farmland bird population trends associated with agricultural practices (Gregory et al., 2005), and is one of the most recognised multi-species bird indicators at the landscape level.

Plants are also frequently used as the basis for biodiversity indicators in many contexts including agroecosystems (Matzdorf et al., 2008). The most important characteristics of plants which make them good indicators are the following: they are easy to observe and identify, relatively well-known (with many charismatic species), they reflect their direct physical environment, and they are the primary target of many of the pressures (Landsberg and Crowley, 2004). Furthermore, plants constitute the basis of the food web, thus they are in a key role in ecosystems. Plants and vegetation are especially frequently used for assessing and mapping the naturalness (or hemeroby, which is essentially the opposite of naturalness) of specific habitat types (Battisti and Fanelli 2016; Fanelli and Battisti 2015; Fanelli and De Lillis, 2004; Hill et al., 2002). Spatially aggregated forms of plant-based naturalness indicators (i.e. the "average naturalness" of a larger area) is considered to be a reliable and highly policy relevant metric for landscape quality over large areas (e.g. the vegetation-based NCI is widely used for this purpose in Hungary, and it has been proposed as a key sustainability indicator, KSH, 2008) However, to get a good spatial overview of the naturalness of a large area, vast quantities of plant/vegetation data are needed. Fortunately, in most of the Western countries there are several monitoring programmes and databases for plants available (Gonzales-Alonso et al., 2004; Schaminée et al., 2009).

Birds and plants are undoubtedly the two taxonomic groups most frequently used as biodiversity indicators. The importance of birds and plants as key indicator organisms in South-East European agricultural landscapes has also been confirmed (Sauberer et al., 2004). There are several studies where indicators of birds and plants were compared in various geographic and ecological contexts (Flather et al., 1997; Ricketts et al., 1999; Qian and Ricklefs, 2008), showing that bird- and plant-based indicators diverge at the local scale (<10 ha), but are well-correlated at relatively coarse spatial scales (>100 km^2) (Sauberer et al., 2004). Nevertheless, most of these studies are confined to Western Europe and North America, so there is little knowledge on this relationship in relatively diverse agricultural landscapes typical for Eastern Europe. There are many inherent differences in the application of birds and plants as biodiversity indicators. Birds, like many other large-bodied and vagile animals, require a mosaic of habitats to live, feed and breed, and thus can provide already an aggregated overview on the ecological state of the landscape. Sessile plants, on the other hand, convey information only about their immediate habitat, which offers a significantly higher potential for spatial resolution, but also needs a lot more data. Plants also exhibit a much higher taxonomical diversity with a more intensive spatial variation among local and regional flora. Consequently, instead of using single species or pure "community descriptors"(e.g. species number, Shannon diversity) for this purpose, most of the "useful" plant-based biodiversity indicators (e.g. Czúcz et al., 2012; Hill et al., 2002; Parkes et al., 2003; Winter, 2012) are created in a synthetic way, based on the conservation value and the main functional characteristics of the individual species.

This study compares landscape-level biodiversity indicators based on two popular taxonomic groups (plants and birds) in eight mosaic landscapes dominated by a mixture of agro-ecosystems and grasslands in Hungary, Eastern Europe. Whereas both species groups are elements of the same ecosystem, the inherent differences in how the underlying species use and perceive the landscape may result in highly different responses to processes like degradation and regeneration. In order to explore this relationship, we asked the following questions:

- What is the connection between vegetation-based natural capital index and indicators of bird assemblages, such as number of individuals, total abundance and Shannon-diversity in South-East European agricultural mosaic landscapes? Are they correlated? Are they redundant or do they convey independent information?
- Are assemblage-level bird indicators more correlated to local vegetation condition than individual bird species? Which bird species' abundance reflect most the landscape quality measured in NCI?
- The quantification of the average vegetation-based NCI of a large area demands lots of vegetation data. Can bird data provide the same information on landscape quality, just in an easier way, with less effort and/or more precision? How could/should an indicator for Hungarian farmland birds be defined, so that it would reflect an "overall landscape quality" similarly to vegetation-based NCI in rural landscapes?

This last question has particular policy relevance for Hungary, where NCI has become established as a general purpose biodiversity indicator, but as there were no broad scale vegetation mappings in the last 10 years, the vegetation data necessary for NCI are starting to get outdated. Applying bird data as a replacement or a complementary source of information can be particularly important in this context.

2. Material and methods

2.1. Study area

To compare the vegetation-based and the bird-based biodiversity indicators, a set of focus areas from the lowland regions of Hungary were selected first. To ensure a level of coherence and homogeneity of environmental conditions within the focus areas, the list of Hungary's geographical microregions (Dövényi, 2010) was used to pick out potential focus areas. The selection procedure was restricted to microregions, which were dominated (at least 70%) by a mosaic of arable land and semi-natural grasslands. Altogether, eight nonadjacent microregions with diverse environmental conditions (soil, dominant habitat types) and levels of land use intensity (ratio of arable fields, urbanisation) were chosen. A slight exception was allowed to the 70% rule for a highly urbanized (Vác-Pesti-Duna-völgy) and a wetland co-dominated (Nagyberek) geographic microregion, and in the case of two relatively large microregions (Csepeli-sík, Hortobágy) where the focus area was restricted to the most characteristic central part of the microregion. This way eight focus areas were obtained covering a total of$\sim$ 5255 km^2 (their size varied between 141 and 1141 km^2), which are relatively homogeneously distributed over the lowland regions of Hungary (Fig. 1). It was assumed that the resulting set of focus areas would represent the diversity of the mixed agricultural landscapes of Central-Eastern Europe, where a mosaic of intensively managed farmland and high nature value semi natural grasslands is still relatively prevalent (Biró et al., 2013; Kümmerle et al., 2008).

As a next step six study sites were randomly identified within each focus area. Each study site consisted of seven adjacent MÉTA grid cells: a central hexagon and its six neighbours, forming a rosette. Accordingly, sampling design was organized in three different levels: (1) the eight focus areas each of which were represented by (2) six study sites, consisting of (3) seven adjacent hexagons of 35 ha each. A hexagon of this size can be approximated with a circle of $\sim$330 m radius, whereas a study site (a rosette of seven adjacent hexagons) can be approximated with a circle of $\sim$880 m radius. Three designation criteria were defined: a) the central point of the rosette could be accessed relatively easily; b) 80% of all the ground area of the seven MÉTA hexagons constituting the rosette could be accessible; c) there should be at least 70% open area within the rosette. If the designation criteria were not met, another potential central point was looked for among the centres of the neighbouring hexagons, heading east first and then moving along a spiral in clockwise direction until a suitable one was found. Both the vegetation-based and the bird-based biodiversity indicators were assessed at the level of hexagons.

2.2. Vegetation data

The vegetation-based natural capital index (NCI) (Czúcz et al., 2008, 2012) was used as a biodiversity indicator describing the ecological state of the hexagons based on the composition and structure of local plant communities, which is essentially a national application of UNEP's NCI framework (ten Brink, 2006; UNEP, 2002). Vegetation-based NCI is a synthetic metric for vegetation naturalness, based on naturalness estimations of local plant communities aggregated over a large area. This index was calculated based on the MÉTA database, a national vegetation map and database covering entire area of Hungary (Molnár et al., 2007). The database was created between 2003 and 2008 based on extensive fieldwork and satellite imagery. Altogether 86 habitat types were differentiated during the surveys. The spatial units of the MÉTA database are the above-mentioned 35 ha hexagonal grid cells. Habitat types were listed within each hexagon, along with several attributes including the estimated area of each habitat in% of the hexagon and its naturalness measured on a five grade ordinal scale. Naturalness was assessed using a separate key for each major habitat type, comparing the actual vegetation condition to an ideal reference state based on simple criteria on vegetation composition (e.g. the presence/abundance of key species) and structure (e.g. homogeneity, canopy closure – see details in Bölöni et al., 2007; Molnár et al., 2007). In the case of natural habitat types (e.g. zonal vegetation types) the reference was the pristine state, whereas for semi-natural habitat types (e.g. hay meadows) an equilibrium condition with traditional land use was considered as the ideal reference. The compositional and structural criteria (e.g. the names of and thresholds for the key species) were constructed in a 3-year open consultation process, compiling the centennial knowledge of Hungarian botanists into a detailed field protocol (Bölöni et al., 2011). The identification of habitat types and naturalness were done in the field by the mappers themselves, recording only their synthetic judgements into the database. The whole procedure was highly standardized and supported with a series of field trainings and thorough ex-post control checks (Molnár et al., 2007).

Thus the vegetation condition of each patch within a hexagon is rated on a 1–5 scale against the reference state pertaining to its habitat type. The NCI of a hexagon is directly formed from these vegetation condition data as the area weighted mean naturalness of its patches, using the simple "equal steps" approach of Butchart et al. (2004). The calculation of the NCI values is described in detail by Czúcz et al. (2012). Vegetation-based NCI is currently the most established naturalness indicator in Hungary with many applications in national biodiversity policy.

2.3. Bird data

To characterize the landscape quality from the perspective of birds we used several indicators derived from bird count data. The ornithological surveys were carried out with point count method (Báldi et al., 1997) at the level of hexagons, between late April and mid-June in 2011 (Csepeli-sík, Hortobágy, Nagyberek) and 2012 (Beregi-sík, Borsodi-Mezőség, Gerje-Perje-sík, Sárvíz-völgye, Vác-

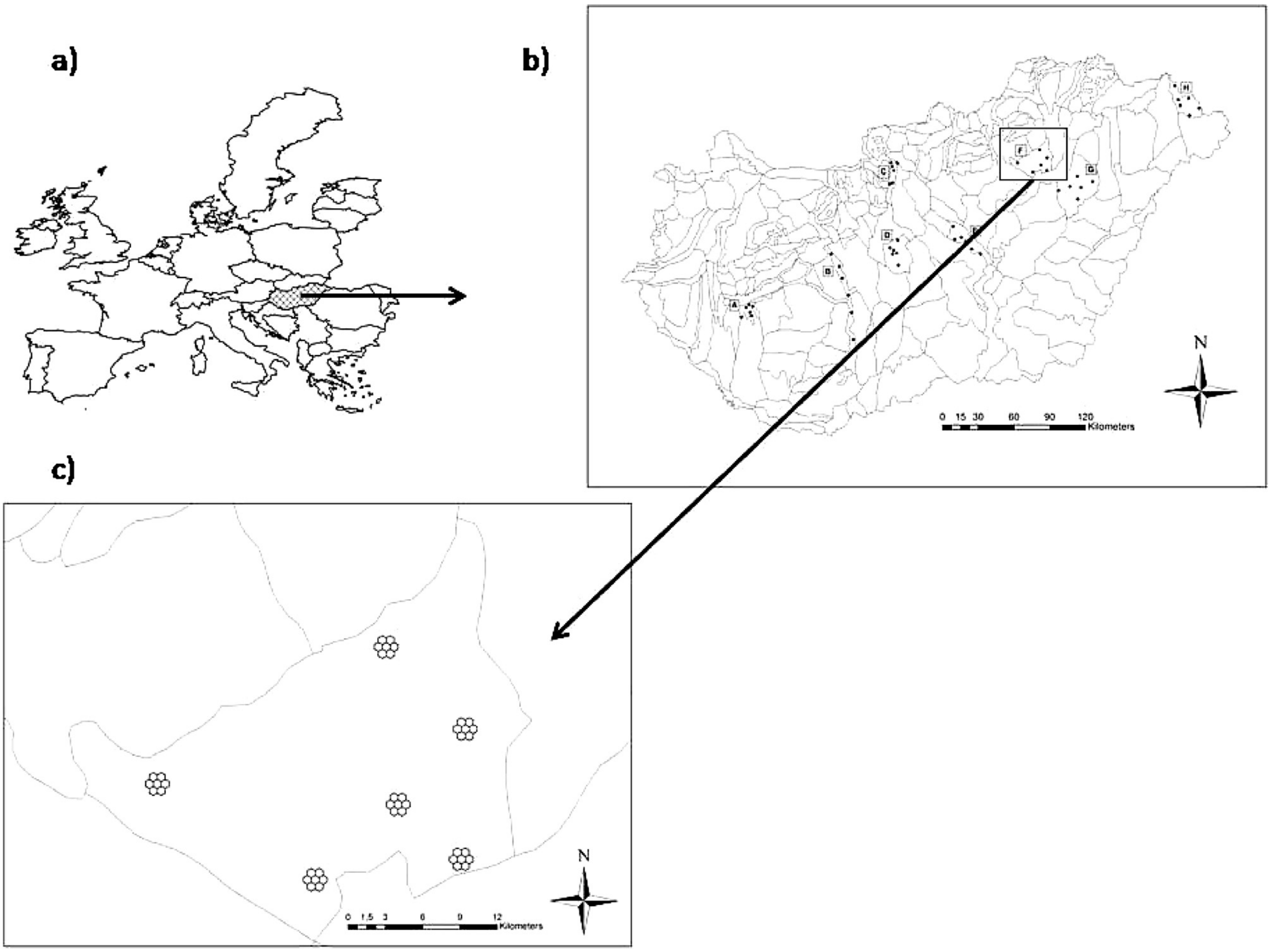

Fig. 1. (a) Location of Hungary in Europe (b) Location of the eight geographical microregions including rosettes (A – Nagyberek, B – Sárvíz-völgy, C – Vác-Pesti-Duna-völgy, D – Csepeli-sík, E – Gerje-Perje-sík, F – Borsodi-Mezőség, G – Hortobágy, H – Beregi-sík) (c) Location the six rosettes and 42 MÉTA hexagons in the Borsodi-Mezőség geographical microregion.

Pesti-Duna-völgy). The activity (e.g. singing, display and mating) of most bird species is the highest during this time of the year. To minimize travel cost and survey time hexagons within the same study site were surveyed during a single morning between 5 am and 10 am. On the other hand, sampling days for the different study sites within the same focus area were chosen so that they would be uniformly distributed across the whole survey period, thus ensuring a more comprehensive assessment of bird community. Further criteria for selection of survey days were to avoid rain and wind speeds above 20 km/h. The surveyors tried to avoid disturbing the birds as much as possible.

The point count method was adapted to the current study design so that the centre of each MÉTA hexagon was chosen as the survey point, where all bird species observed (seen and heard) within 100 m during a 10 min survey period were recorded. The recording included both breeding and feeding birds, but excluded flying ones just crossing over the 100 m circle. Furthermore, we added records of birds leaving the site on the surveyor's arrival in the case of few middle-sized or large birds (e.g. northern lapwing *Vanellus vanellus* or white stork *Ciconia ciconia*) which tend to take flight in the presence of humans.

Even though during the surveys all bird species were recorded, the analysis was confined to farmland birds, defined according to the Pan-European Common Bird Monitoring Scheme (PECBMS) (EBCC, http://www.birds.cz/pecbm/indik_lists.php?list_species=1&result_set=Publish2014&indik=E_C_CEE_Fa). Two of the 23 Central and East European farmland bird species, grey partridge (*Perdix perdix*) and european serin (*Serinus serinus*) were not observed in the study sites. We excluded further 3 species from the analysis: meadow pipit (*Anthus pratensis*) because it does not breed in Hungary, as well as lesser grey shrike (*Lanius minor*) and red-backed shrike (*L. collurio*), most of the breeding population of which returns only in mid/late May – thus too late to be reliably captured during the survey period. Furthermore, the flocking species, namely rook (*Corvus frugilegus*), common starling (*Sturnus vulgaris*) and barn swallow (*Hirundo rustica*) were also eliminated from the records, as we considered that to reliably capture the relatively rare occurrences of the large flocks of these birds much higher survey efforts and different sampling approaches would be necessary.

Accordingly, a total of 1700 records of 15 farmland bird species were included in the following analysis, all of which are common in Hungary: white stork (*Ciconia ciconia*), common kestrel (*Falco tinnunculus*), northern lapwing (*Vanellus vanellus*), black-tailed godwit (*Limosa limosa*), european turtle dove (*Streptopelia turtur*), eurasian tree sparrow (*Passer montanus*), common skylark (*Alauda arvensis*), crested lark (*Galerida cristata*), yellow wagtail (*Motacilla flava*), common whitethroat (*Sylvia communis*), whinchat (*Saxicola rubetra*), common stonechat (*S. torquata*), common linnet (*Carduelis cannabina*), yellowhammer (*Emberiza citrinella*) and corn bunting (*Miliaria calandra*).

Based on the bird count data three assemblage-level indicators for each hexagon were defined to describe the quality of their habitats from the perspective of the 15 farmland bird species studied: (1) the number of farmland bird species in the sample (species number, SN), (2) the total number of farmland bird individuals (total abundance, TA), and (3) the Shannon diversity of farmland bird species/individuals (SD). Furthermore, in addition to the assemblage-based indicators, each of the 15 selected farmland bird species was considered as a biodiversity indicator on its own.

2.4. Statistical analysis

To check if the assemblage-level bird indicators (SN, TA, SD) depend on the NCI of the hexagon, first an overall general linear model of variance was developed. As these three bird diversity metrics were highly significantly correlated ($p < 0.01$; $N = 336$ for each pair), a single multivariate model was applied to these response variables. Accordingly, a MANCOVA nested design with SN, TA and SD as dependent variables, focus area (FA) and rosette (R) as independent blocks (R is nested in FA), and vegetation-based natural capital index (NCI) of the hexagons as the single covariate predictor of interest was used. To normalize the distribution of TA, it was transformed using a Box-Cox transformation with $\lambda = 0.7$ (Box and Cox, 1964).

In order to prove that all the necessary assumptions of the nested MANCOVA model are fulfilled (Tabachnick and Fidell, 2013), the following were tested:

(1) the normality of the residuals by Shapiro-Wilk's test ($p > 0.05$);
(2) whether the covariate (NCI) improves the model, indeed, i.e. the significance of the linear relationship between NCI and the dependent variables ($F(1;196) > 8$; $p < 0.01$ was calculated for all the three variables);
(3) the homogeneity of the regression slopes by checking that there is no significant fixed factor*covariate (FA*R*NCI) interaction effect ($F_{SN}(46;241) = 1.119$, $p = 0.291$; $F_{SD}(46;241) = 1.221$, $p = 0.172$; $F_{TA}(46;241) = 0.927$, $p = 0.609$).
(4) the homogeneity of variances. Though it was seen that this assumption was slightly violated, the method was considered to be robust enough provided the sample sizes do not differ significantly – as in this case. According to Scheffe (1959) the probability of type I error does not exceed 0.06 at a significance level of 0.05, if the ratio of the largest and smallest variances is less than 6. In the present case this ratio was under 2 for both NS and SD and it was ~5.2 for TA.

The overall multivariate test calculated the explained variances and their respective significance levels (Pillai's trace) (Pillai, 1955). Once a significant multivariate effect was detected, we also performed a follow-up one-way analysis to evaluate the effect of covariate on each dependent variable, separately. The effect size measure (denoted by partial η^2) was calculated, which estimates the variance explained by a given independent factor remaining after excluding the variance explained by the other independent factors. The higher the partial η^2 values are, the stronger the effect sizes are (Everitt and Dunn, 1991).

As a next step, the relationship between NCI and the presence of individual bird species was investigated: whether or not it can be stated that NCI influences and/or determines the presence of a species (or the other way round)? To this end NCI values were discretized into five categories (0: $NCI = 0$; 1: $0 < NCI \leq 0.2$; 2: $0.2 < NCI \leq 0.4$; 3: $0.4 < NCI \leq 0.6$; 4: $0.6 < NCI$). Then, a cross-tabulation based on these values was conducted and the presence/absence of the bird species and calculated Somers' symmetric and asymmetric d values for each species determined. From the signs and significance levels of the symmetric d statistic, the presence and the direction of a significant relationship between the presence of the species and the landscape quality can be detected. Furthermore, the values and the significance of asymmetric d value scan indicate whether knowing the presence of a bird a reliable prediction on NCI can be made or vice versa. The cross-tabulation-based rank statistics applied is a very careful and conservative approach which was chosen as we do not know anything about the distribution of species abundances (nor NCI values). It was expected that the relationships found with this conservative approach are real and robust, resulting from the underlying relationships between landscape-level plant and bird communities, or common factors shaping both of them.

3. Results

The multivariate tests were very slightly significant for NCI (Pillai's trace = 0.025; $F(3;285) = 2.392$; $p = 0.069$) with a very low effect size (partial $\eta^2 = 0.025$). Checking the assemblage-level bird indices one by one a slightly significant NCI effect could be found on the total number of individuals (total abundance, TA), while in the case of species number (SN), and Shannon diversity (SD) no significant NCI effect was detected (Table 1).

Examining the relationship between NCI and the presence/absence of the individual bird species, nine species were found to show significant association, and further three species that showed slightly significant association with NCI (Table 2). Asymmetric Somer's d values indicated in each case a bird species = >NCI direction of indication. From the nine significant cases there were three species (crested lark *Galerida cristata*, common whitethroat *Sylvia communis*, yellowhammer *Emberiza citrinella*) with negative association rates, which means that the presence of these species suggest low NCI values, i.e. these birds tend to be absent from the more natural landscapes in our sample. The remaining six significant species indicate a relatively natural vegetation: common kestrel (*Falco tinnunculus*), northern lapwing (*Vanellus vanellus*), black-tailed godwit (*Limosa limosa*), common skylark (*Alauda arvensis*), yellow wagtail (*Motacilla flava*) and corn bunting (*Miliaria calandra*). There were also six farmland bird species, which did not show any significant association to NCI.

4. Discussion

Assemblage-level plant-based and bird-based biodiversity indicators seem to yield a non-contradicting, but only moderately coherent evaluation of the ecological state of South-East European agricultural mosaic landscapes. It was found that the total abundance (TA) of bird assemblages was the only assemblage-level bird indicator that was related to NCI, yet with a very weak significance and low effect size. This is in accordance to the general observation that the number of bird individuals is higher in a landscape consisting of more natural vegetation (e.g. Mills et al., 1991). This statement is confirmed by other studies in agricultural landscapes, old-fields and grasslands (Browder et al., 2002; Pärt and Söderström, 1999; Vessby et al., 2002; Verhulst et al., 2004), and even in forested areas (Canterbury et al., 2000). The lack of correlation between NCI and the species number (SN) or the Shannon diversity (SD) of the bird assemblage seems to be in accord with previous studies, too. Bradford et al. (1998), for example, investigated several assemblage-level bird indicators including species richness, Shannon diversity and total abundance, which were all found to be unreliable for predicting the biological integrity of the studied rangeland ecosystems. Other studies in Sweden confirmed that the species richness of farmland birds cannot be used as an indicator for total biodiversity in semi-natural grasslands, and there was no correlation between vegetation and farmland birds (Pärt and Söderström, 1999; Vessby et al., 2002). Battisti and Fanelli (2015) found that generalist species are more abundant at intermediate levels of disturbance than in highly degraded places (e.g. urban areas). Our study seems to strengthen this statement: almost all

Table 1
One-way ANOVA results for each dependent variable and the covariate NCI (+significant at the $p < 0.1$ level; * at the $p < 0.05$ level; ** at the $p < 0.01$ level; *** at the $p < 0.001$ level; ns not significant).

Dependent variables	Coefficient of NCI	F(1;287)	Partial η^2	p-value
SN	0.584	1.400	0.005	0.238
TA	0.140	3.026	0.010	0.083+
SD	0.977	2.008	0.007	0.158

Table 2
The value and significance of Somers' symmetric and asymmetric d calculated for discretized NCI values and the presence of each species. Species with significant positive association to NCI are shown in bold, species with significant negative association are shown in bold italics (+significant at the $p < 0.1$ level; * at the $p < 0.05$ level; ** at the $p < 0.01$ level; *** at the $p < 0.001$ level; ns not significant).

Species	Symmetric d	Asymmetric d (NCI | species)	Asymmetric d (species | NCI)
Motacilla flava	0.206***	0.262	0.170
Miliaria calandra	0.133**	0.214	0.096
Galerida cristata	−0.129***	−0.524	−0.074
Vanellus vanellus	0.105*	0.211	0.070
Limosa limosa	0.097**	0.546	0.053
Emberiza citrinella	−0.096**	−0.409	−0.055
Falco tinnunculus	0.095*	0.251	0.058
Alauda arvensis	0.092*	0.146	0.067
Saxicola torquata	−0.077+	−0.147	−0.052
Sylvia communis	−0.072*	−0.194	−0.044
Passer montanus	−0.063 n.s.	−0.164	−0.039
Streptopelia turtur	−0.046+	−0.259	−0.025
Saxicola rubetra	0.043 n.s.	0.127	0.026
Carduelis cannabina	−0.029+	−0.395	−0.015
Ciconia ciconia	0.012 n.s.	0.106	0.007

of the species in our study can be considered generalists and they were more common in natural and semi-natural landscapes than in more degraded areas, such as vast intensive croplands or urban environments. The relationship for species number can be masked by the fact that many of the farmland species from western Europe seem to favour degraded or man-made vegetation in South-East Europe (Glennon and Porter, 2005; see also the discussion in the following paragraphs). In the case of SD, the lack of a significant relationship can also be attributed to the fact that Shannon diversity is fairly insensitive to rare species (Peet, 1974).

As opposed to assemblage-level indicators, the presence of individual bird species seemed to show a greater level of association with the landscape quality. From the 15 farmland bird species studied, six showed significant positive correlation with NCI, while three species exhibited negative correlations. The six positively correlated species are known to be more abundant in natural grasslands and extensive agricultural areas than intensively used arable fields (Báldi et al., 2005; Hoffmann et al., 2013; Tucker and Evans, 1997; Verhulst et al., 2004). Common kestrel (*Falco tinnunculus*) usually breeds on grasslands and arable land with scattered trees, but its main feeding areas are rodent-rich grasslands (del Hoyo et al., 1994). Common skylark (*Alauda arvensis*) and corn bunting (*Miliaria calandra*) prefer dry natural grasslands with usually short swards and fallow lands (Hoffmann et al., 2013; Tucker and Evans, 1997), while northern lapwing (*Vanellus vanellus*), black-tailed godwit (*Limosa limosa*) and yellow wagtail (*Motacilla flava*) favour natural wet grasslands (Tucker and Evans, 1997). Even though some of these species, especially corn bunting and northern lapwing can breed in arable fields too (Poulsen et al., 1998), these species are considered to indicate good ecological state in an agricultural landscape, and this relationship was also supported by our analysis.

It could be established that crested lark (*Galerida cristata*), common whitethroat (*Sylvia communis*) and yellowhammer (*Emberiza citrinella*) indicate degraded agricultural mosaic landscapes, which underline the three above-mentioned species' habitat preferences. In contrast with Western Europe, these species are less connected to natural habitats in Hungary and other South-East European countries. Crested lark populations tend to live near farm buildings, alfalfa fields, along roads and in human settlements, whereas common whitethroat and yellowhammer prefer shrubs, hedges, tree lines and forest edges, and are not particularly sensitive about ecosystem conditions (BirdLife International, 2014; Tucker and Evans, 1997). None of these habitats are specifically limited to natural or semi-natural vegetation – these habitats are, in fact, most abundant in degraded landscapes near settlements or other kinds of human infrastructure.

Three farmland bird species, European turtle dove (*Streptopelia turtur*), common stonechat (*Saxicola torquata*) and common linnet (*Carduelis cannabina*), which are considered to be reliable indicators of the ecological state of agricultural landscapes in Western Europe (BirdLife International, 2014; Tucker and Evans, 1997) are not or slightly negatively correlated to NCI in Hungary. In the case of three other species, white stork (*Ciconia ciconia*), Eurasian tree sparrow (*Passer montanus*) and whinchat (*Saxicola rubetra*) we did not find any association to NCI. As a possible explanation, these species prefer a medium disturbance in the landscape, and whereas Western Europe lies clearly on the degraded side from the perspective of them, the sample from Hungary included several highly natural landscapes, such as Hortobágy (Wilkinson, 1999). Another potential explanation, which is particularly plausible for white stork is that simply not enough observation records were available for this relatively large bodied species.

Biodiversity indicators relying directly on primary biotic data (species presences and abundances) can never have a global or continental scope, they should be directly linked to the ecosystems they are intended to characterize, and should be created and validated through a series of detailed field-calibrations. This study can be seen as a preliminary study which could support the development of a regional farmland bird index (FBI) customized for South-East Europe, the Pannonian biogeographic region, or Hungary. However the idea of calibrating bird-based indicators to other independent metrics of "landscape quality" can be of interest in a much broader geographical scope.

The establishment of a Hungarian FBI needs further dedicated studies, which take into account user needs (policy, general public) and data availability (e.g. bird monitoring programmes of the Hungarian Ornithological and Nature Conservation Society) in addition to scientific aspects. These studies should include thorough calibration and ground-testing based on detailed bird and NCI data from the same temporal period. should also include rare species in addition to common species, because rare species are sometimes more sensitive to environmental changes (Pearman and Weber, 2007; Renwick et al., 2012). The set of farmland bird species suggested by the present study as prospective indicator species will also have to be supported by these further independent studies. Nevertheless, it is suggested, that the nine farmland bird species showing significant correlation to NCI should be included into all regular and long-term monitoring programmes in the future.

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