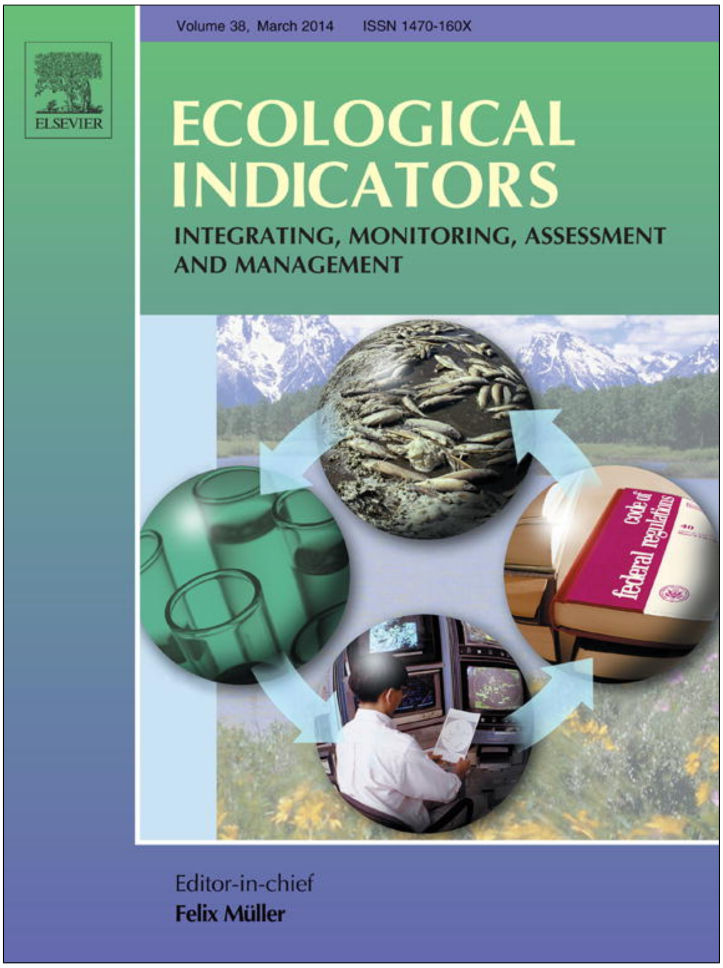
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Birds as useful indicators of high nature value (HNV) farmland in Central Italy

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ABSTRACT

Birds are commonly cited as an example of declining farmland biodiversity in Europe, especially in the economically and agriculturally developed countries of Western Europe. However, even in extensive farmland there are still patches of rich biodiversity, including of birds. These areas are known as high nature value (HNV) farmland. In these circumstances, more effort is needed to understand the importance of the spatial heterogeneity and dynamics of residual natural habitat for farmland birds, including the various links between land use and marginal vegetation structure and bird communities and the occurrence of individual species.

In this study we use species distribution models (SDMs) in order to explore the importance of these patches for birds and examine the relationship between bird species richness and land use, landscape and vegetation type characteristics at a local scale in traditional farmland in Central Italy. Our results show that some forest related passerines and shrubland bird species are well represented in these farmlands. The HNV farmlands in Central Italy can also be studied using bird species as bioindicators. In our particular case, HNV farmlands were well predicted by the joint presence of four species and the absence of two bird species.

Traditional farmland is therefore a valuable habitat and not 'just' a soft matrix for these birds. Moreover, complex models were better supported by the data than simpler models for all passerines. Modern agricultural techniques which simplify the structural complexity of farmland are likely to exclude many passerine species. Thus incentives to maintain small scale heterogeneity in traditionally managed farmland will be critical for maintaining their rich passerine bird communities.

1. Introduction

Agricultural landscapes are artificial mosaics of different land use types, that represent one of the most common habitats for several bird species in Europe (Donald et al., 2006). Although by definition agricultural areas were created by human activity, during recent decades agricultural landscapes have been subject to rapid and large-scale change, caused mainly by the intensification and mechanization of agricultural activities (Chamberlain et al., 2000; Donald et al., 2001, 2006). Agricultural intensification occurs mainly at two different spatial scales: local scale – e.g. increased use of agrochemicals or pesticides (Geiger et al., 2010) and landscape scale – e.g. destruction of semi-natural and marginal habitats (Benton et al., 2003).Recent studies also underlined that the main cause of negative impacts on biodiversity was a decline in the heterogeneity of land use, although in some agricultural landscapes the intensity of farmlands remained relatively stable (Flores Ribeiro et al., in press). The latter affects the marginal and unproductive elements of farmland removing shrubs, hedgerows, isolated trees and uncultivated patches. These marginal elements represent key habitats for many species, for nesting, feeding and protection (Perkins et al., 2002), as well as providing ecological corridors (Bennett, 1991; Reijnen et al., 1997).

Farmland also forms one of the most important habitats for wildlife in Europe because it covers up to 60% of some countries. But during recent decades a dramatic decline of farmland biodiversity has occurred across Western Europe. In an effort to protect farmland biodiversity, several studies were performed to assess the quality of agricultural landscapes, and in defining high nature value (HNV) farmland (Bartel, 2009; Pointereau et al., 2007). Originally, the term HNV was introduced by Baldock et al. (1993) and Beaufoy et al. (1994). More recently Andersen et al. (2003) proposed a conceptual definition for HNV farmland as 'those areas in

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Europe where agriculture is a major (usually the dominant) land use and where agriculture supports or is associated with either a high species and habitat diversity or the presence of species of European conservation concern or both'. This was subsequently followed by a mapping approach at EU level developed by Paracchini et al. (2008). HNV farmland (represented by a binary indicator) is defined as one of the following three types (Andersen et al., 2003): farmland with a high proportion of semi-natural vegetation, farmland dominated by low intensity agriculture or a mosaic of semi-natural and cultivated land and small-scale features, and farmland supporting rare species or a high proportion of European or World populations. The first two types are identified on the basis of land cover data (CORINE database) and agronomic farm-level data (in particular the Farm Accounting Data Network), and the third type of HNV can only be identified by means of monitoring species occurrence.

HNV farmland comprises hotspots of biological diversity in rural areas, corresponding ecologically to more functional heterogeneity and therefore high values of biodiversity and species abundance (Hoffmann and Greef, 2003; Kleijn and Sutherland, 2003; Kleijn et al., 2009; Morelli et al., 2012). Habitat diversity is associated with an increase in niche availability for species (Kisel et al., 2011). Recent studies conducted in France, were investigated the relationship between measures of bird biodiversity and HNV farmlands. Therefore, the authors found differences on farmland bird species abundances and composition of bird communities (measured by the community specialization index, CSI) in relationship to the HNV farmland and not-HNV farmland. The same research had shown how HNV farmland plays a role in supporting the specialist bird species (Doxa et al., 2012).

On the other hand, biodiversity generally decreases with increased intensity of farming (with increased fertilizers and pesticide inputs, increased use of machinery and an overall increase in productivity). Concerns about current Common Agricultural Policies (CAP) highlighted the negative trend in biodiversity, entrusting each European country with responsibility to tackle biodiversity loss (Baldock et al., 1993; Bennett et al., 2006; de la Concha, 2005; Oñate, 2005), encouraging farmers to conserve biodiversity through the maintenance of extensive farming systems and preservation of semi-natural landscape features, and encouraging extensification of farming systems (Kleijn and Sutherland, 2003; Pain and Pienkowski, 1997). However, latest findings showed that agri-environmental measures might be ineffective in some intensive farmland (Kleijn et al., 2011; Ohl et al., 2008; Konvicka et al., 2008), highlighting the need for more research in order to increase their effectiveness in such situations (e.g. Kleijn and Sutherland, 2003).

The need for measures to prevent the loss of HNV farmland and to mitigate the loss of biodiversity is widely acknowledged, and requires urgent attention. The use of bioindicators can help to more fully understand the impact of variation in agricultural landscapes on biodiversity. Furthermore, the use of bioindicators has already demonstrated efficiency in preventing biodiversity loss; as a useful tool to speed decisional policies. Bird species have been used as bioindicators in many studies (e.g. Padoa-Schioppa et al., 2006), because the presence of many species are strongly linked to different characteristics of environments (Benton et al., 2002; Brambilla et al., 2007; Morelli, 2011, 2012a; Perkins et al., 2002; Skorka et al., 2006; Tryjanowski et al., 2011).

In this study were examined the relationships between HNV farmland and occurrence of bird species in Central Italy, by means of species distribution models (SDMs) in order to determine the best set of bird species useful as indicators of HNV farmland. Furthermore were examined the relative importance of each characteristic of farmland in explaining the distribution of these selected bird species.

2. Materials and methods

2.1. Study area

The study was carried out in an agricultural section of the North Eastern of Marches region, in Central Italy (43°46′ N; 12°42′ E) (Fig. 1) covering circa 65,000 ha, ranging from 0 to 350 m a.s.l., among low hills and the Adriatic coasts. The climate in Central Italy is temperate (Tomaselli et al., 1972) and characterized by high spring and summer temperatures and a marked summer drought. This area was selected because it contains a large variety of different farming practices. Within this area 160 sites were selected at random, separated by at least 500 m from each other.

2.2. Species and environmental data

In order to record the farmland bird communities, point-counts were used, recording all the birds detected visually and acoustically within a radius of 100 m from the observer over a 10-min period (Bibby et al., 1997). The study took place from 15 May 2011 to 30 June 2011 during the breeding season. All bird counts were carried out in the morning within 5 h following sunrise, in sunny weather conditions. The sampled sites were visited at least twice during the breeding season. Non breeding species and diurnal or nocturnal raptors were all excluded from subsequent analysis as they require different survey methods. In each sampled site species richness was calculated as the maximum number of birds recorded. The species frequency was calculated as the percentage of occurrence on the total sampled points.

From the 55 bird species recorded, 25% are listed on the national red list as vulnerable species. The remaining species are listed in categories of lesser concern (near threatened, least concern, data deficient or not evaluated) (Peronace et al., 2012). 54% of recorded species are considered to be of European conservation concern (SPEC1, SPEC2, SPEC3) (BirdLife International, 2004).

Habitat descriptions of the 100-m radius area around the sampled point were made in order to quantify land-use composition and structural characteristics of each site, i.e. covering 3-ha each. The percentages of land-use composition and all semi-natural and marginal vegetation typologies within these areas was calculated through GIS analysis (intersect operator between regional land cover map 1:10,000 (AAVV, 2001) and buffer areas generated around the sampled points (using as center the coordinates from point-counts). Furthermore, a landscape description of farmland was carried out using the environmental parameters listed in Table 1, classified at landscape or land-use scales. Land use diversity (lud) at each site was calculated using the Shannon diversity index, $H' = -\Sigma p_i \times \log p_i$, where p_i is the relative proportion of land-use i.

All farmland sites were classified in a binary variable as HNV (1) or non-HNV (0) farmland, following the classification applied by Galdenzi et al. (2012). The classification was derived by overlapping Galdenzi's map of HNV in the Marches region of Central Italy with our farmland sites. Sites were also classified as HNV if they had values of "mv" (marginal vegetation, Table 1) and "lud" above the mean for all 160 sites. An indication of "extensive" farming practice was collected in situ during the surveys or from the presence of grasslands. Unfortunately data on fertilizer and pesticide applications were not available.

2.3. Data analysis

The nature and strength of relationships between HNV farmland and bird species occurrence were examined using Generalized Linear Models (GLM) (McCullagh and Nelder, 1989) with dependent variable (HNV) modeled specifying a binomial distribution.

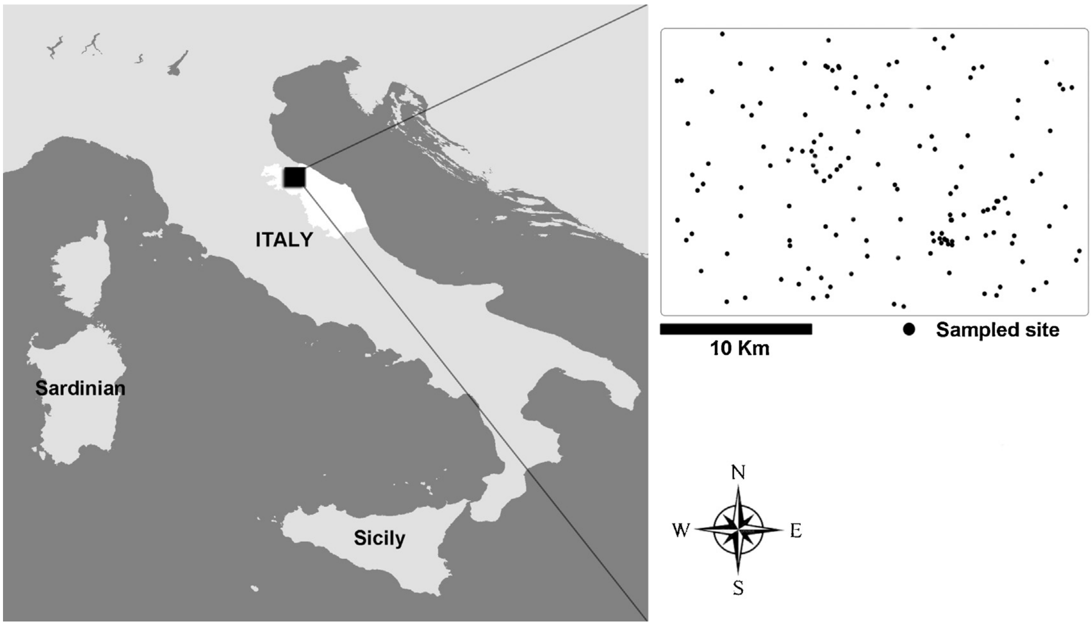

Fig. 1. Study area and sampled sites in the Marches region, Central Italy.

Independent predictive variables were expressed as categorical variables: the presence (1) and absence (0) of each bird species.

In order to avoid the co-linearity of variables, parameters with strongest correlation between them (>0.7) were eliminated. A stepwise backwards procedure was followed in order to select the best predictors using AIC (Akaike, 1974; Anon, 1999). Sites were treated as independent units because the spatial autocorrelation between geographic distance and species presence on sites was low (Mantel test $r = 0.203$, $n = 160$ sites, $p > 0.05$) (Betts et al., 2006).

The goodness of fit (GOF) of a statistical model describes how well it fits to a set of observations, summarizing the discrepancy between the observed values and the values expected under a statistical model. In this work, we used the area under the ROC curve (AUC) in order to measure the goodness of fit of the best SDM's. The receiver operating characteristic (ROC) is a graphical plot which illustrates the performance of a binary classifier system as its discrimination threshold is varied. It is created by plotting the fraction of true positives out of the positives (true positive rate) vs. the fraction of false positives out of the negatives (false positive rate), at various threshold settings. The AUC calculated for each SDM selected the predictive performance is expressed as an index ranging from 0 to 1 (DeLong et al., 1988). An approximate guide for classifying the accuracy of AUC is that proposed by Swets (1988): 0.90–1.00 excellent; 0.80–0.90 good; 0.70–0.80 fair; 0.60–0.70 poor; 0.50–0.60 fail.

From total bird species recorded, for statistical purposes were selected only breeding bird species with frequencies of occurrence equal or greater than 10% over all sampled sites. Furthermore, to avoid multi co-linearity issues and to reduce the number of independent variables avoiding also over fitting problems on models (Stokes et al., 2000), regressors with strongest correlation between them were manually eliminated (>0.7). The full model was performed using 21 bird species as regressors. The bird species selected in the best model were considered as the better predictors or indicators of HNV farmland. Subsequently were performed species distribution models (SDMs) using the occurrence of selected bird species (indicators of HNV) as the response variable, and environmental characteristics of farmland as independent variables. Independent predictive variables were transformed using the arcsin root square in the case of proportions. Species distribution

Table 1
Environmental descriptors of farmland in Central Italy. The spatial scale where metrics were measured was 3-ha around the point count.

Parameter	Abbreviation	Level	Details
Altitude	alt	Landscape	Altitude of the point count (m/a.s.l.)
Slope	slo	Landscape	No slope (less than 3°): 0, slight slope (between 3 and 8°): 1, slope (greater than 8°): 2
Roads	roa	Landscape	Length and type of roads (paved and unpaved)
Powerlines	pow	Landscape	Number of electricity wires
Urban	urb	Land use	%
Forest	for	Land use	%
Shrubs	shr	Land use	%
Uncultivated	unc	Land use	%
Badland	bad	Land use	%
Grassland	gra	Land use	%
Hedgerows	hed	Land use	%
Isolated trees	tre	Land use	%
Vineyards	vin	Land use	%
Olive orchards	oli	Land use	%
Cultivated	cul	Land use	%
Marginal vegetation	mv	Land use	Sum of coverage on shr, unc, hed, tre
Land use diversity	lud	Land use	Shannon diversity index on land uses

models are numerical tools that combine observations of species occurrence or abundance with environmental estimates (Elith and Leathwick, 2009).

Finally, the total contribution of each environmental parameter was calculated by means of the hierarchical partitioning protocol (Chevan and Sutherland, 1991) on the series of SDMs. The relative importance of independent variables was measured using the MuMIn package in R which employs goodness of fit for each possible model to identify the variables that mostly affect the dependent variable (Barton, 2011). The relative importance value output is a numeric vector ranging from 0 to 1, named as the predictor variables, resulting from the sum of 'Akaike weights' over all models including the explanatory variable (Burnham and Anderson, 2002).

Difference in bird species richness in different farmland categories (HNV and non-HNV) was tested using Student's *t*-test. All tests were performed with the R program (R Core Team, 2013).

3. Results

Of the 160 farmland sites, 54 (34%) were classified as HNV. The most common road type in farmland sites was paved (67% of cases), while 24% had unpaved roads, and 9% were mixed (pavement and unpaved). Power lines were widespread on farmland (90% of sites). The most common slope category was "no slope" or "slight slope", with only 10% of sites steeper.

Bird species richness was significantly greater in HNV (mean ± SD of bird richness: 16.8 ± 3.1, range 12–25) than in non-HNV farmland (14.5 ± SD 4.1, range 5–22) ($t = -3.78$, df: 158, $p < 0.001$).

3.1. Bird indicators of HNV farmland

Working through the process of model selection from the full model that included all bird species as independent variables, the best model was obtained with only seven bird species as predictors, six of which were significant for predicting HNV farmland (four positively and two negatively, Table 2). The best model had a goodness of fit value of 0.88, indicating that about 88% of cases were classified correctly by the model, approaching the excellent category.

The model using only the four bird species positively related to HNV had a performance slightly lesser (0.82).

3.2. Relative importance of HNV farmland characteristics on bird distribution

The most important characteristics of farmland for the distribution of bird species selected as indicators of HNV were: hedgerows (present in more of 86% of best models, highly significantly three times ($p < 0.05$) and three times significantly at $p < 0.1$), followed by shrubs, isolated trees, uncultivated patches and land-use diversity (all 43%) and grassland (29%). However, the relative importance of each HNV characteristic was different for each bird species (Table 3). The occurrence of the four bird species positively correlated to HNV farmland was mainly explained by cover of hedgerows and shrubs. On the other hand, the occurrence of the two bird species negatively correlated to HNV farmland was mainly explained by cover of hedgerows and trees (avoided by *Alauda arvensis*) and land use diversity and grasslands (avoided by *Chloris chloris*).

Furthermore, some bird species (e.g. *C. chloris* and *Passer italiae*) were related positively or negatively to several environmental characteristics (four parameters for each), while *Emberiza calandra* was characterized by one main variable to which it was strongly positively linked (shrubs) (Table 3).

4. Discussion

HNV farmlands in Central Italy were relatively widely dispersed (34% of the studied farmland sites). Bird species richness was greater in HNV than compared with standard farmland, indicating that this parameter can be used as a surrogate of biodiversity (Caro and O'Doherty, 1999; Devictor et al., 2010; Weibull et al., 2003). However, it is important to be cautious on ecological interpretations, since the higher species richness recorded in the HNV farms may be due to an increase in the number of habitat-generalist species. Thus, further analysis should take into account the composition of the bird community, in terms of farmland specialists and habitat generalists, in order to best describe the variations in functional diversity. Other studies in Western Europe found that species richness was not higher within HNV farmland, but bird communities were composed by more specialist species than in non-HNV areas (Doxa et al., 2010).

In this study, six bird species (four positively and two negatively) were significantly related to HNV farmland and it is possible to group these species ecologically as follows: species typical of urban green areas, hedgerows and forest (European Greenfinch, *C. chloris* (here result negatively related to HNV) and Blackbird, *Turdus merula* (positively related to HNV in this study) (Cramp and Perrins, 1994), species typical of shrublands and uncultivated areas (Common Whitethroat, *Sylvia communis* and Corn Bunting *E. calandra*) (Cramp and Perrins, 1994; Donald and Evans, 1994), species typical of grassland and lowland arable areas (Sky Lark, *A. arvensis*) (Erdõs et al., 2009) and species more ubiquitous (Italian Sparrow, *P. italiae*) (Brichetti et al., 2008). The last bird species excluded in the backward selection procedures for the model (Red-backed Shrike, *Lanius collurio*) can be considered typical of heterogeneous or mixed farmland (Morelli, 2012a, 2012b; Tryjanowski et al., 2000). Two selected species are considered as vulnerable and of national concern (status red list) while the other species are considered at least concern (Peronace et al., 2012).

The presence of just four bird species on a farmland was enough to classify it as HNV with a performance of 82%, and the contemporary absence of two other bird species increased the accuracy of our predictions to 88%.

The occurrence of each bird species used in the indicator, however, was related to different parameters of farmland. For example, *E. calandra* was strongly associated with a few parameters relating to 'field margins' (shrubs and hedgerows). Thus modifications to this parameter, as making more big field margins on farmlands or preserving few patches of shrubs near to croplands, could be highly beneficial for this species, as also highlighted in other studies (Kosiński and Tryjanowski, 2000). Conversely, several bird species were strongly related to different parameters, such as *C. chloris* or *P. italiae* (four out of six parameters), and such species are less susceptible to changes to any one of them. *A. arvensis*, in contrast, was negatively related to hedgerow presence but positively related to grasslands.

The negative relationship between *C. chloris* and HNV farmlands could be due to the strong preference of the species by forestal patches (present only as marginal habitats in HNV farmlands) or urban tissues (virtually absent or present with very low coverage in HNV farmlands). In the case of *A. arvensis* instead, the negative correlation between this species and HNV farmlands could be explained by the fact that agricultural landscapes monitored in our study were mainly composed by croplands and few grasslands.

The importance of marginal elements, considered as unproductive elements of agricultural landscapes, for farmland bird diversity, is already known (Báldi and Batáry, 2011; Benton et al., 2003; Fuller et al., 2001, 2004; Herzon and O'Hara, 2007; Morelli, 2013). Our results underlined the relative importance of hedgerows (for four of six selected species, the presence of hedgerows significantly

Table 2
Frequency, IUCN status, National conservation status (Peronace et al., 2012), generalist/specialist species classification and results of logistic regression for best model relating HNV farmland with bird species occurrence in Central Italy. The table shows the significant parameters selected after a stepwise procedure using AIC (significant *p*-values in bold) on the multiple-variables analysis. The first four rows are bird species related positively to HNV farmland. The next two are negatively related to HNV farmland. The AIC value of best model was 147.32, lowest if compared with the AIC value for full model (163.94). Goodness of fit of the model: 88%. Red list categories: LC = least concern, NT = near threatened, VU = vulnerable. The classification on generalist and specialist bird species follow the classification from British Trust for Ornithology (BTO) and Royal Society for the Protection of Birds (RSPB), available online (http://www.bto.org/).

Bird species	Name	Frequency (%)	IUCN red list	Italian red list	Generalist/specialist	Estimate	SE	*Z* value	*p*-Values	Relative importance
T. merula	Blackbird	76.3	LC	LC	Generalist	3.791	1.225	3.095	**0.002****	0.995
S. communis	Common whitethroat	24.5	LC	LC	Specialist	1.760	0.638	2.758	**0.006****	0.967
E. calandra	Corn bunting	32.5	LC	LC	Specialist	2.432	0.926	2.625	**0.008***	0.776
P. italiae	Italian sparrow	76.3	–	VU	Generalist	1.289	0.623	2.069	**0.038***	0.568
C. chloris	European greenfinch	37.5	LC	NT	Generalist	−2.537	0.624	−4.066	**0.000*****	0.998
A. arvensis	Sky lark	33.7	LC	VU	Specialist	−1.313	0.651	−2.016	**0.044***	0.750
L. collurio	Red-backed shrike	16.3	LC	VU	Specialist	−1.374	0.758	−1.812	0.070	0.477
Intercept						−5.575	1.547	−3.602	**0.000*****	

positively explained their distribution, for one other species was significantly negatively related), followed by shrubs and by surrogates of landscape heterogeneity (land-use diversity). In fact, the presence of natural and semi-natural features, such as field margins or hedgerows, can increase the number of ecological niches available for several bird species, having a positive effect on bird species richness (Batáry et al., 2010; Green et al., 1994; Hinsley and Bellamy, 2000; Parish et al., 1994, 1995). For several carnivorous birds (insectivorous or predators of micro-mammals) these residual elements on road margins can represent an optimal feeding habitat, because they constitute effective ecological corridors for wildlife (Vermeulen, 1994; Vermeulen and Opdam, 1995). Our study also highlights how other land use categories such as shrubs, uncultivated and abandoned land (all descriptors of HNV farmland) are important to explain the distribution of several bird species (Brambilla et al., 2007; Girardello and Morelli, 2012; Kosiński and Tryjanowski, 2000; Morelli et al., 2012).

Our results underlined how while some studies correlate HNV farmlands mainly with specialist or threatened species, therefore the better set of bird species suitable to predict the HNV farmlands in Central Italy is a set of few relatively common bird species, three specialist species and three generalist species. Percentage that is repeated also if we analyze only the four species positively correlated to HNV farmlands. And this fact can be interpreted as a confirm about the importance that these type of farmlands represent also for more common bird species.

In summary, the use of the joint occurrence of bird species (presence–absence) on GLM approach to perform SDM's is suitable not only to identify important areas for birds or biodiversity hotspots (Brown et al., 1995; Caro and O'Doherty, 1999; Noss, 1990) but also to study and classify agro-ecosystems. The proposed framework seems work well even on relatively medium-sized datasets. Anyway, we suggest also the use of multi-model inference (MMI) approach when working on models with many covariates, considering what was said by Stokes et al. (2000) about the issues related to models with too many regressors and the over fitting risk. The dataset should be at least 5–10 observations for each parameter considered in the full model. Otherwise, the MMI could be a good statistical choice.

Furthermore, the use of the right parameters, in addition to the hierarchical partitioning protocol, constitutes a powerful tool to study and monitor HNV farmland from a conservationist perspective. As suggested by Doxa et al. (2012), to some extent it is possible to reverse biodiversity decline caused by agricultural intensification, if appropriate management actions are taken in the near future on HNV farmland. Because an effectively protecting HNV farmlands may thus require a better integration of horizontal policies and agri-environment schemes (Flores Ribeiro et al., in press), considering also the use of ecological assessment tools. For this reason, the identification and study of a set of few bird species suitable to assessment the HNV farmland, could be used also as a tool to monitoring quickly the HNV status in the time, then, useful as "alarm bell" for example when one of these bird species disappears.

Clearly the set of bird species will be subject to changes following the local bird species and the characteristics of the area where the method will be applied. But the procedure could be also applied on different type of agro ecosystems, taken into account these local differences.

In addition, the knowledge of the characteristics of landscape or environment that explain the occurrence of each bioindicator, can constitute an address for conservation efforts, showing the target to be preserved, elements that may potentially buffer the effects of intensification on biodiversity. Mainly as results at local scale studies, that could provide high quality data with improved

Table 3
Relative importance of each characteristic of HNV farmland on bird occurrence in Central Italy. The significant parameters resulted in the best model for each bird species are identified by means of bold text and the significance codes. In brackets are the sign of the model-averaged parameter estimates for the effects of environmental parameters on each bird species. Abbreviation of HNV characteristics: shrubs, shr; hedgerows, hed; isolated trees, tre; uncultivated patches, unc; grassland, gra; land-use diversity, lud. The importance values showed in the table are the Akaike weights obtained from best model for each bird species.

Species	shr	hed	tre	unc	gra	lud
T. merula	(+) 0.300	(+) **0.998*****	(−) 0.334	(−) 0.397	(−) 0.260	(+) **0.998*****
S. communis	(+) **0.937****	(+) **0.783.**	(+) 0.259	(+) **0.985****	(−) 0.263	(+) 0.357
E. calandra	(+) **0.999*****	(+) **0.665.**	(−) 0.287	(+) 0.363	(+) 0.365	(+) 0.500
P. italiae	(−) 0.365	(−) 0.264	(+) **0.920***	(−) **0.994****	(+) **0.851***	(−) **0.985****
C. chloris	(+) 0.255	(+) **0.605.**	(+) **0.969****	(+) **0.943****	(−) 0.292	(−) **0.999*****
A. arvensis	(+) 0.318	(−) **0.978***	(−) **0.714.**	(−) 0.262	(+) **0.274***	(−) 0.283
L. collurio	(+) **0.820***	(+) **0.586***	(+) 0.271	(+) 0.270	(−) 0.318	(−) 0.433

Significance codes: '.' $p < 0.1$.
* Significance codes: $p < 0.05$.
** Significance codes: $p < 0.01$.
*** Significance codes: $p < 0.001$.

precision which could be useful from the applied point of view (Tryjanowski et al., 2011; Voříšek et al., 2007). An useful device for ecological restoration planning at the local scale (Abensperg-Traun et al., 2004) in the slipstream of European agricultural policy. This is especially important considering that one of the main aims of the Common Agricultural Policy (CAP) is the reduction in the negative trends in biodiversity, entrusting each European country with the specific task of biodiversity conservation within its own territory (Baldock et al., 1993; de la Concha, 2005; Kleijn and Sutherland, 2003; Oñate, 2005).

Furthermore, the set of common birds resulted indicators of HNV farmland in this study, should be included on developing the Italian farmland bird index FBI and other indices of agricultural biodiversity (Billeter et al., 2008; Campedelli et al., 2009; Gregory et al., 2005) at a local or regional scale.

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References

AAVV, 2001. Land Use Map 1:10,000 Marche Region. Regional Cartographic Office, Ancona, Italy.

Abensperg-Traun, M., Wrbka, T., Bieringer, G., Hobbs, R., Deininger, F., Main, B.Y., Milasowszky, N., Sauberer, N., Zulka, K.P., 2004. Ecological restoration in the slipstream of agricultural policy in the old and new world. Agricultural, Ecosystems & Environment 103, 601–611.

Akaike, H., 1974. A new look at the statistical model identification. IEEE Transactions on Automatic Control 19, 716–722.

Andersen, E., Baldock, D., Bennett, H., Beaufoy, G., Bignal, E., Brouwer, F., Elbersen, B., Eiden, G., Godeschalk, F., Jones, G., McCracken, D.I., Nieuwenhuizen, W., van Eupen, M., Hennekens, S., Zervas, G., 2003. Developing a High Nature Value Indicator. Report for the European Environment Agency, Copenhagen, available from http://eea.eionet.europa.eu/Public/irc/envirowindows/hnv/library

Anon, 1999. S-PLUS 2000 Guide to Statistics, vol. 1. MathSoft, Seattle, WA.

Báldi, A., Batáry, P., 2011. Spatial heterogeneity and farmland birds: different perspectives in Western and Eastern Europe. Ibis 153, 875–876.

Baldock, D., Beaufoy, G., Bennett, G., Clark, J., 1993. Nature Conservation and New Directions in the Common Agricultural Policy. Institute for European Environmental Policy, London.

Bartel, A., 2009. High nature value farmland as an European evaluation indicator – definition, function and status quo. In: International Workshop of the Salvere-Project, 15:18.

Barton, K., 2011. MuMIn: Multi-model inference, R package version 1.0.0. http://CRAN.R-project.org/package=MuMIn

Batáry, P., Matthiesen, T., Tscharntke, T., 2010. Landscape-moderated importance of hedges in conserving farmland bird diversity of organic vs. conventional croplands and grasslands. Biological Conservation 143 (9), 2020–2027, http://dx.doi.org/10.1016/j.biocon.2010.05.005.

Beaufoy, G., Baldock, D., Clark, J., 1994. The Nature of Farming. Low-Intensity Farming Systems in Nine European Countries. Institute for European Environmental Policy, London.

Bennett, A.F., Radford, J.Q., Haslem, A., 2006. Properties of land mosaics: implications for nature conservation in agricultural environments. Biological Conservation 133, 250–264.

Bennett, A.F., 1991. Roads roadsides and wildlife conservation: a review. In: Saunders, D.A., Hobbs, R.J. (Eds.), Nature Conservation 2: The Role of Corridors. Surrey Beatty & Sons, Chipping Norton, pp. 99–118.

Benton, T.G., Bryant, D.M., Cole, L., Crick, H.Q.P., 2002. Linking agricultural practice to insect and bird populations: a historical study over three decades. Journal of Applied Ecology 39, 673–687.

Benton, T.G., Vickery, J.A., Wilson, J.D., 2003. Farmland biodiversity: is habitat heterogeneity the key? Trends in Ecology and Evolution 18, 182–188.

Betts, M.G., Diamond, A.W., Forbes, G.J., Villard, M.A., Gunn, J.S., 2006. The importance of spatial autocorrelation, extent and resolution in predicting forest bird occurrence. Ecological Modelling 191, 197–224.

Bibby, C.J., Burgess, N.D., Hill, D.A., 1997. Bird Census Techniques. Academic Press, London.

Billeter, R., Liira, J., Bailey, D., Bugter, R., Arens, P., Augenstein, I., Aviron, S., Baudry, J., Bukacek, R., Burel, F., Cerny, M., De Blust, G., De Cock, R., Diekotter, T., Dietz, H., Dirksen, J., Dormann, C., Durka, W., Frenzel, M., Hamersky, R., Hendrickx, F., Herzog, F., Klotz, S., Koolstra, B., Lausch, A., Le Coeur, D., Maelfait, J.P., Opdam, P., Roubalova, M., Schermann, A., Schermann, N., Schmidt, T., Schweiger, O., Smulders, M.J.M., Speelmans, M., Simova, P., Verboom, J., van Wingerden, W.K.R.E., Zobel, M., Edwards, P.J., 2008. Indicators for biodiversity in agricultural landscapes: a pan-European study. Journal of Applied Ecology 45, 141–151.

BirdLife International, 2004. Birds in Europe: Population Estimates, Trends and Conservation Status. BirdLife International, Cambridge, UK.

Brambilla, M., Rubolini, D., Guidali, F., 2007. Between land abandonment and agricultural intensification: habitat preferences of Red-backed Shrikes *Lanius collurio* in low-intensity farming conditions. Bird Study 54, 160–167.

Brichetti, P., Rubolini, D., Galeotti, P., Fasola, M., 2008. Recent declines in urban Italian Sparrow *Passer (domesticus) italiae* populations in northern Italy. Ibis 150, 177–181.

Brown, A.F., Stillman, R.A., Gibbons, D.W., 1995. Use of breeding bird atlas data to identify important bird areas: a northern England case study. Bird Study 42 (2), 132–143.

Burnham, K.P., Anderson, D.R., 2002. Model Selection and Multimodel Inference: A Practical Information-Theoretic Approach, 2nd ed. Springer-Verlag, New York.

Campedelli, T., Tellini Florenzano, G., Sorace, A., Fornasari, L., Londi, G., Mini, L., 2009. Species selection to develop an Italian farmland bird index. Avocetta 33, 87–91.

Caro, T.M., O'Doherty, G., 1999. On the use of surrogate species in conservation biology. Conservation Biology 13 (4), 805–814.

Chamberlain, D.E., Fuller, R.J., Bunce, R.G.H., Duckworth, J.C., Shrubb, M., 2000. Changes in the abundance of farmland birds in relation to the timing of agricultural intensification in England and Wales. Journal of Applied Ecology 37, 771–788.

Chevan, A., Sutherland, M., 1991. Hierarchical partitioning. American Statistician 45, 90–96.

Cramp, S., Perrins, C., 1994. The Birds of the Western Palearctic, vol. 8. Oxford University Press, Oxford.

de la Concha, I., 2005. The common agricultural policy and the role of rural development programmes in the conservation of steppe birds. In: Bota, G., Morales, M.B., Mañosa, S., Camprodon, J. (Eds.), Ecology and Conservation of Steppe-Land Birds. Lynx Edicions & Centre Tecnològic Forestal de Catalunya, Barcelona, pp. 141–168.

DeLong, E.R., Delong, D.M., Clarke-Pearson, D.L., 1988. Comparing areas under two or more correlated receiver operating characteristic curves: a nonparametric approach. Biometrics 44 (3), 837–845.

Devictor, V., Mouillot, D., Meynard, C., Jiguet, F., Thuiller, W., Mouquet, N., 2010. Spatial mismatch and congruence between taxonomic, phylogenetic and functional diversity: the need for integrative conservation strategies in a changing world. Ecology Letters 13, 1030–1040.

Donald, P.F., Evans, A.D., 1994. Habitat selection by corn buntings *Miliaria calandra* in winter. Bird Study 41, 199–210.

Donald, P.F., Green, R.E., Heath, M.F., 2001. Agricultural intensification and the collapse of Europe's farmland bird populations. Proceedings of the Royal Society of London B 268, 25–29.

Donald, P.F., Sanderson, F.J., Burfield, I.J., van Bommel, F.P.J., 2006. Further evidence of continent-wide impacts of agricultural intensification on European farmland birds 1990–2000. Agriculture, Ecosystems and Environment 116, 189–196.

Doxa, A., Bas, Y., Paracchini, M.L., Pointereau, P., Terres, J.M., Jiguet, F., 2010. Low-intensity agriculture increases farmland bird abundances in France. Journal of Applied Ecology 47 (6), 1348–1356, http://dx.doi.org/10.1111/j.1365-2664.2010.01869.x.

Doxa, A., Paracchini, M.L., Pointereau, P., Devictor, V., Jiguet, F., 2012. Preventing biotic homogenization of farmland bird communities: the role of high nature value farmland. Agriculture, Ecosystems and Environment 148, 83–88.

Elith, J., Leathwick, J.R., 2009. Species distribution models: ecological explanation and prediction across space and time. Annual Review of Ecology, Evolution and Systematics 40, 677–697.

Erdős, S., Báldi, A., Batáry, P., 2009. Nest site selection and breeding ecology of Sky Larks *Alauda arvensis* in Hungarian farmland. Bird Study 56, 259–263.

Flores Ribeiro, P., Lima Santos, J., Nuno Bugalho, M., Santana, J., Reino, L., Beja, P., Moreira, F., 2013. Modelling farming system dynamics in high nature value farmland under policy change. Agriculture, Ecosystems and Environment (in press).

Fuller, R.J., Chamberlain, D.E., Burton, N.H.K., Gough, S.J., 2001. Distributions of birds in lowland agricultural landscapes of England and Wales: how distinctive are bird communities of hedgerows and woodland? Agriculture, Ecosystems and Environment 84, 79–92.

Fuller, R.J., Hinsley, S.A., Swetnam, R.D., 2004. The relevance of non-farmland habitats, uncropped areas and habitat diversity to the conservation of farmland birds. Ibis 146, 22–31.

Galdenzi, D., Pesaresi, S., Casavecchia, S., Zivkovic, L., Biondi, E., 2012. The phytosociological and syndynamical mapping for the identification of high nature value farmland. Plant Sociology 49 (2), 59–69, http://dx.doi.org/10.7338/pls2012492/04.

Geiger, F., Bengtsson, J., Berendse, F., Weisser, W.W., Emmerson, M., Morales, M.B., Ceryngier, P., Liira, J., Tscharntke, T., Winqvist, C., Eggers, S., Bommarco, R., Pärt, T., Bretagnolle, V., Plantegenest, M., Clement, L.W., Dennis, C., Palmer, C., Oñate, J.J., Guerrero, I., Hawro, V., Aavik, T., Thies, C., Flohre, A., Hänke, S., Fischer, C., Goedhart, P.W., Inchausti, P., 2010. Persistent negative effects of pesticides on biodiversity and biological control potential on European farmland. Basic and Applied Ecology 11, 97–105.

Girardello, M., Morelli, F., 2012. Modelling the environmental niche of a declining farmland bird species. Italian Journal of Zoology 79 (3), 434–440.

Green, R.E., Osborne, P.E., Sears, E.J., 1994. The distribution of passerine birds in hedgerows during the breeding season in relation to characteristics of the hedgerow and adjacent farmland. Journal of Applied Ecology 31, 677–692.

Gregory, R.D., van Strien, A., Vorisek, P., Meyling, A.W.G., Noble, D.G., Foppen, R.P.B., Gibbons, D.W., 2005. Developing indicators for European birds. Philosophical Transactions of the Royal Society B – Biological Sciences 360, 269–288.

Herzon, I., O'Hara, R.B., 2007. Effects of landscape complexity on farmland birds in the Baltic States. Agriculture, Ecosystems and Environment 118, 297–306.

Hinsley, S.A., Bellamy, P.E., 2000. The influence of hedge structure, management and landscape context on the value of hedgerows to birds: a review. Journal of Environmental Management 60, 33–49.

Hoffmann, J., Greef, J.M., 2003. Mosaic indicators: theoretical approach for the development of indicators for species diversity in agricultural landscapes. Agriculture, Ecosystems and Environment 98, 387–394.

Kisel, Y., McInnes, L., Toomey, N.H., Orme, C.D.L., 2011. How diversification rates and diversity limits combine to create large-scale species–area relationships. Philosophical Transactions of the Royal Society B – Biological Sciences 366, 2514–2525, http://dx.doi.org/10.1098/rstb.2011.0022.

Kleijn, D., Sutherland, W.J., 2003. How effective are European agri-environment schemes in conserving and promoting biodiversity? Journal of Applied Ecology 40, 947–970.

Kleijn, D., Kohler, F., Báldi, A., Batáry, P., Concepción, E.D., Clough, Y., Díaz, M., Gabriel, D., Holzschuh, A., Knop, E., Kovács, A., Marshall, E.J.P., Tscharntke, T., Verhulst, J., 2009. On the relationship between farmland biodiversity and landuse intensity in Europe. Proceedings of the Royal Society of London Series B, Biological Sciences 276 (903), 909.

Kleijn, D., Rundlöf, M., Scheper, J., Smith, H.G., Tscharntke, T., 2011. Does conservation on farmland contribute to halting the biodiversity decline? Trends in Ecology & Evolution 26 (9), 474–481, http://dx.doi.org/10.1016/j.tree.2011.05.009.

Konvicka, M., Benes, J., Cizek, O., Kopecek, F., Konvicka, O., Vitaz, L., 2008. How too much care kills species: grassland reserves, agri-environmental schemes and extinction of *Colias myrmidone* butterfly from its former stronghold. Journal of Insect Conservation 12, 519–525.

Kosiński, Z., Tryjanowski, P., 2000. Habitat selection of breeding seed-eating passerines on farmland in Western Poland. Ekologia (Bratislava) 19, 307–316.

McCullagh, P., Nelder, J.A., 1989. Generalized Linear Models. Chapman and Hall, London.

Morelli, F., 2011. Importance of road proximity for the nest site selection of the Red-backed shrike *Lanius collurio* in an agricultural environment in Central Italy. Journal of Mediterranean Ecology 11, 21–29 http://www.jmecology.com/

Morelli, F., 2012a. Plasticity of habitat selection by red-backed shrikes *Lanius collurio* breeding in different landscapes. Wilson Journal of Ornithology 124, 52–57.

Morelli, F., 2012b. Correlations between landscape features and crop type and the occurrence of the Ortolan Bunting *Emberiza hortulana* in farmlands of Central Italy. Ornis Fennica 89, 264–272.

Morelli, F., 2013. Relative importance of marginal vegetation (shrubs, hedgerows, isolated trees) surrogate of HNV farmland for bird species distribution in Central Italy. Ecological Engineering 57, 261–266.

Morelli, F., Santolini, R., Sisti, D., 2012. Breeding habitat of Red-backed Shrike *Lanius collurio* on farmland hilly areas of Central Italy: is functional heterogeneity an important key? Ethology, Ecology & Evolution 24, 127–139.

Noss, R.F., 1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation Biology 4, 355–364.

Ohl, C., Drechsler, M., Johst, K., Wätzold, F., 2008. Compensation payments for habitat heterogeneity: existence, efficiency, and fairness considerations. Ecological Economics 67, 162–174.

Oñate, J.J., 2005. A reformed CAP? Opportunities and threats for the conservation of steppe-birds and the agri-environment. In: Bota, G., Morales, M.B., Mañosa, S., Camprodon, J. (Eds.), Ecology and Conservation of Steppe-Land Birds. Lynx Edicions & Centre Tecnològic Forestal de Catalunya, Barcelona, pp. 141–168.

Padoa-Schioppa, E., Baietto, M., Massa, R., Bottoni, L., 2006. Bird communities as bioindicators: the focal species concept in agricultural landscape. Ecological Indicators 6 (1), 83–93.

Pain, D.J., Pienkowski, M.W., 1997. Birds and Farming in Europe: The Common Agricultural Policy and its Implications for Bird Conservation. Academic Press, San Diego, CA.

Paracchini, M.L., Petersen, J.-E., Hoogeveen, Y., Bamps, C., Burfield, I., van Swaay, C., 2008. High Nature Value Farmland in Europe. An Estimate of the Distribution Patterns on the Basis of Land Cover and Biodiversity Data. European Commission Joint Research Centre Institute for Environment and Sustainability. Report EUR23480 EN. Office or Official Publications of the European Communities, Luxembourg, 87pp.

Parish, T., Lakhani, K.H., Sparks, T.H., 1994. Modelling the relationship between bird population variables and hedgerow and other field margin attributes. I. Species richness of winter, summer and breeding birds. Journal of Applied Ecology 31, 764–775.

Parish, T., Lakhani, K.H., Sparks, T.H., 1995. Modelling the relationship between bird population variables and hedgerow and other field margin attributes. II. Abundance of individual species and of groups of similar species. Journal of Applied Ecology 32, 362–371.

Perkins, A.J., Whittingham, M.J., Morris, A.J., Bradbury, R.B., 2002. Use of field margins by foraging yellowhammers *Emberiza citrinella*. Agriculture, Ecosystems and Environment 93, 413–420.

Peronace, V., Cecere, J.G., Gustin, M., Rondinini, C., 2012. Lista Rossa 2011 degli uccelli nidificanti in Italia. Avocetta 36, 11–58.

Pointereau, P., Paracchini, M.L., Terres, J.-M., Jiguet, F., Bas, Y., Biala, K., 2007. Identification of high nature value farmland in France through statistical information and farm practice surveys, Report EUR 22786 EN. Office for Official Publications of the European Communities, Luxembourg, pp. 62.

R Core Team, 2013. R: A Language and Environment for Statistical Computing. R Foundation for Statistical Computing, Vienna, Austria http://www.R-project.org/

Reijnen, R., Foppen, R., Veenbaas, G., 1997. Disturbance by traffic of breeding birds: evaluation of the effect and considerations in planning and managing road corridors. Biodiversity and Conservation 6 (4), 567–581, http://dx.doi.org/10.1023/A:1018385312751.

Skorka, P., Martyka, R., Wójcik, J.D., 2006. Species richness of breeding birds at a landscape scale – which habitat is the most important? Acta Ornithologica 41, 49–54.

Stokes, M.E., Davis, C.S., Koch, G.G., 2000. Categorical data analysis using the SAS System, 2nd ed. SAS Publishing BBU Press and John Wiley Sons Inc, Cary, NC.

Swets, J.A., 1988. Measuring the accuracy of diagnostic systems. Science 240, 1285–1293.

Tomaselli, R., Balduzzi, A., Filipello, S., 1972. Carta Bioclimatica d'Italia Scala 1:2.000.000. Istituto di Botanica – Università di Pavia, Ministero Agricoltura e Foreste, Collana Verde, pp. 33.

Tryjanowski, P., Hartel, T., Báldi, A., Szymański, P., Tobolka, M., Herzon, I., Goławski, A., Konvička, M., Hromada, M., Jerzak, L., Kujawa, K., Lenda, M., Orłowski, M., Panek, M., Skórka, P., Sparks, T.H., Tworek, S., Wuczyński, A., Żmihorski, M., 2011. Conservation of farmland birds faces different challenges in Western and Central-Eastern Europe. Acta Ornithologica 46, 1–12, http://dx.doi.org/10.3161/000164511X589857.

Tryjanowski, P., Kuźniak, S., Diehl, B., 2000. Breeding success of the red-backed shrike (*Lanius collurio*) in relation to nest site. Ornis Fennica 77, 137–141.

Vermeulen, H.J.W., Opdam, P., 1995. Effectiveness of roadside verges as dispersal corridors for small ground-dwelling animals: a simulation study. Landscape and Urban Planning 31, 233–248.

Vermeulen, H.J.W., 1994. Corridor function of a road verge for dispersal of stenotopic heathland ground beetles carabidae. Biological Conservation 69 (3), 339–349.

Voříšek, P., Klvanova, A., Gregory, R., Aunins, A., Chylarecki, P., Crowe, O., de Carli, E., del Moral, J.C., Escandell, V., Foppen, R.P., Fornasari, L., Heldbjerg, H., Hilton, G., Husby, M., Jawińska, D., Jiguet, F., Joys, A., Kuresoo, A., Lindstrom, A., Martins, R., Noble, D.G., Reif, J., Schmid, H., Schwarz, J., Szep, J., Teufelbauer, N., Vaisanen, R., Vansteenwegen, C., Weiserbs, A., 2007. The State of Europe's Common Birds, 2007 – CSO/RSPB, Prague, Czech Republic, 23pp.

Weibull, A.C., Östman, Ö., Granqvist, Å., 2003. Species richness in agroecosystems: the effect of landscape, habitat and farm management. Biodiversity and Conservation 12, 1335–1355.