 doi: 10.1111/j.1365-2664.2010.01869.x

Low-intensity agriculture increases farmland bird abundances in France

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Summary

1. Farmland biodiversity continues to decline mainly because of agricultural intensification and land abandonment. Agri-environment schemes can be designed to halt this loss by favouring extensification of agricultural practices and through sympathetic management of field boundaries and fallow land. In Europe, High Nature Value (HNV) farmland is defined as low-intensity farmland supporting or associated with a high rate of biodiversity, in terms of species richness or habitat diversity and therefore plays a crucial role in the maintenance of European biodiversity. However, no large-scale analysis has explored the role of these areas in achieving conservation goals.

2. We analysed information from widely used indicators in order to describe the impact of low-intensity agriculture on farmland biodiversity in France. We used the HNV farmland indicator, based on agricultural statistics such as the Farm Structure Survey and the grassland survey, and common bird indicators, i.e. the Farmland Bird Indicator (FBI), the Community Specialization Index (CSI) and species richness indexes, based on the French Breeding Bird Survey.

3. Temporal trends in the farmland bird indicator showed that populations of farmland birds were more likely to increase inside HNV areas compared to non-HNV areas. Although species richness is not higher within HNV farmland, bird communities are composed by more specialist species than in non-HNV areas. In addition, these specialist bird species are significantly more abundant in HNV areas.

4. *Synthesis and applications*. Further farmland biodiversity decline is potentially reversible through an appropriate management of HNV areas. Existing and future agri-environment schemes should focus on preserving and extending HNV farmland, by favouring the maintenance of low-intensity agriculture and landscape complexity. Priority should be given to preserving diversity at the community level, with the help of adequate indicators, such as the ones presented here. The role of HNV farmland or similar concepts in combining agriculture and biodiversity goals should be further analysed and further used as large-scale conservation tools.

Key-words: biodiversity, Breeding Bird Survey, Community Specialization Index, Farmland Bird Indicator, High Nature Value farmland, specialist farmland species

Introduction

There have been significant declines in farmland biodiversity in recent decades, documented in many farmland taxa (mammals: Flowerdew & Kirkwood 1997; arthropods & plants: Sotherton & Self 2000; birds: Donald, Green & Heath 2001). This, together with a growing recognition that conservation should focus on large-scale sources of disturbance that influence population trends, has led to the development of indicators able to adequately describe, quantify and predict biodiversity loss. Birds have been widely used as indicators of biodiversity status and trends because of the availability of good quality data, and the decline of many farmland bird populations has been well documented in Europe (Donald,

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Green & Heath 2001; EEA 2005; Gregory *et al.* 2005; Donald *et al.* 2006). Farmland birds are sensitive to changes in agricultural practices and are affected by both food availability and structural diversity in farmed areas (EEA 2005; Gregory *et al.* 2005; Devictor & Jiguet 2007). The greatest declines – over 40% between 1980 and 2000 – are reported for habitat specialists that depend on key aspects of the agro-ecosystems (Gregory, Noble & Custance 2004b; Gregory *et al.* 2005). In France, farmland birds have declined by an average of 20% over the last 20 years (1989–2008; see Jiguet 2008).

Biodiversity indicators such as the Farmland Bird Indicator (FBI) are widely used in Europe (Gregory *et al.* 2005) and have been formally adopted as structural indicators by the European Union (EU 2005; Commission of the European Communities 2006). Other indicators such as the Community Specialization Index (CSI), which measures the average degree of habitat specialization at the community level, have also been shown to be valuable (Julliard *et al.* 2006). Devictor *et al.* (2008) showed that low values of the CSI are expected in disturbed and fragmented habitats, such as intensively farmed areas, indicating the dominance of habitat generalists within the local community. As communities formed by specialist species are highly sensitive to disturbance, the gradient of this index reflects the impact that land use changes have on structural components of biodiversity. Other indicators that are directly based on agricultural practices can also be linked to effects on biodiversity. The High Nature Value (HNV) farmland indicator is currently included in the EU Common Monitoring and Evaluation Framework for the Rural Development policy (Commission of the European Communities 2006). This indicator aims to identify areas where farming is associated with a high biodiversity value, i.e. HNV farmland. Typically, HNV farming systems are low intensity, low input systems frequently with high structural diversity (European Communities 2009). 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 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', followed by a mapping approach at the level of the EU further developed by Paracchini *et al.* (2008). Even though such an indicator is a useful tool for a large-scale assessment, there are a number of limitations concerning its use as a biodiversity indicator (Andersen *et al.* 2003). The most important is that the large-scale units to which source data refer (i.e. CORINE land cover map of Europe has a 25 ha minimum area unit) potentially underestimate the specific features of local land use and biodiversity elements (Paracchini *et al.* 2008). It has therefore been suggested that for national/regional assessments more detailed sources of information on farm practices and landscape features should be considered (European Communities 2009) and cross-validation with other biodiversity indicators is needed (Bailey *et al.* 2007; European Communities 2009).

In this study, we cross-validate the HNV indicator and the Common Bird Indicators at a national scale in France. As changes in farmland bird populations can be used as an indicator of the general state of farmland biodiversity, we expect higher values of some biodiversity metrics within HNV farmland. To test this prediction, we used monitoring data from the national common Breeding Bird Survey (BBS) in France (Julliard & Jiguet 2002). Data have been collected through national annual breeding surveys conducted by skilled volunteers between 2001 and 2008. This extensive database permitted analysis at different levels, i.e. per species and local communities over space (the national scale) and time (2001–2008). At the species level, we estimated the abundance of the most common farmland bird species over farmed areas with various HNV scores. At the community level, we estimated the species richness and the level of community specialization (following Julliard *et al.* 2006) over the gradient of HNV farmland scores. Finally, we calculated the EU FBI (see Gregory *et al.* 2005) for farmland sites surveyed for birds, and compared the temporal trends of this indicator inside and outside areas of HNV farmland. To our knowledge, the present analysis is the first to combine information from different indicators at the national scale.

Materials and methods

THE HIGH NATURE VALUE INDICATOR

In the IRENA (Indicator Reporting on the integration of ENvironmental concerns into Agriculture policy) approach (EEA 2005), the HNV indicator is estimated using, among other databases, the Farm Accountancy Data Network (FADN; regulation no. 79/65/EEC). However, for the purpose of this analysis and in order to overcome the limitation of the FADN approach concerning the large-scale units, we used national Farm Structure Survey (FSS) data because it provides more detailed information about the agricultural practices, e.g. the herd size, the number of farms using common land and those having landscape elements characteristic of HNV farmland (i.e. hedgerows, forest edges, traditional orchards, wetlands). Data are available at a detailed spatial scale, such as the municipality (local administrative unit – LAU2).

In 2000 in France, 663 807 agricultural holdings were surveyed from the French Agricultural Statistical Service (Recensement Agricole 2000), providing the basis for identification of HNV farmland at the national level. The methodological framework was designed to identify municipalities whose utilized agriculture area (UAA) is mostly HNV. The method used for the estimation of the HNV indicator relies on the calculation and combination of three components: crop diversity, extensification of the farming practices and presence of landscape elements considered as beneficial to biodiversity. The values of the three components were combined to compute a final score identifying areas of HNV farmland in France following Pointereau *et al.* (2007). We incorporated three methodological improvements to the way the final HNV score was computed. (i) We considered an equal weighting between the three components (for more details see Appendix S1, Supporting information). (ii) We included wet meadows in the potential HNV areas, as they may be an important feature of the French HNV farmland. Wet meadows are important habitats for many species; they are found in low-lying farmland but less often at higher altitudes on poorly drained soil. (iii) Fallow land was also included in the indicator.

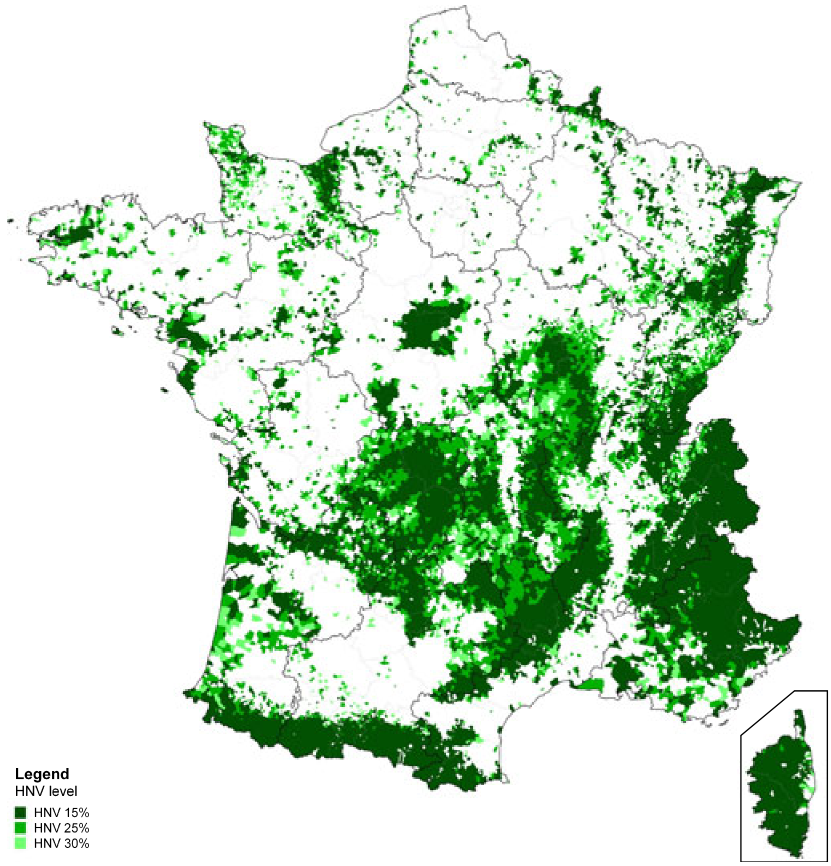

Fig. 1. Location of the high nature value (HNV) farmland in France. Farmland areas classified as HNV are presented according to three different thresholds, in relation to the scoring system described in the main text: 15%, 25% and 30% of the utilized agriculture area considered as HNV. White areas do not qualify for HNV status for any of the three thresholds. Data sources: FSS, NFI, local surveys.

The aim of the HNV indicator was to provide a continuum of scores reflecting the nature value of the UAA in each municipality. Certain analyses though required a clear distinction between HNV and non-HNV farmland. The accepted minimum threshold to qualify an area as HNV farmland was fixed to the 25th percentile of the best municipality (LAU2) scores, i.e. corresponding to 25% of the UAA. The value was set during the IRENA operation for the HNV indicator (EEA 2005). It was considered here as a first (general) estimate but we also tested other threshold values. We conducted a sensitivity analysis of the HNV threshold using the EU FBI. This analysis allowed us to identify which threshold would better reflect ecological differences (different levels of biodiversity) between the areas classified as HNV and non-HNV farmland areas. According to the sensitivity analysis, the best threshold maximizing the differences in FBI between HNV and non-HNV areas was identified to be 30% of the UAA. The areas that were characterized as HNV farmland according to a 15%, 25% and 30% threshold are presented in Fig. 1. For further details on these thresholds and the sensitivity analysis see Appendix S2.

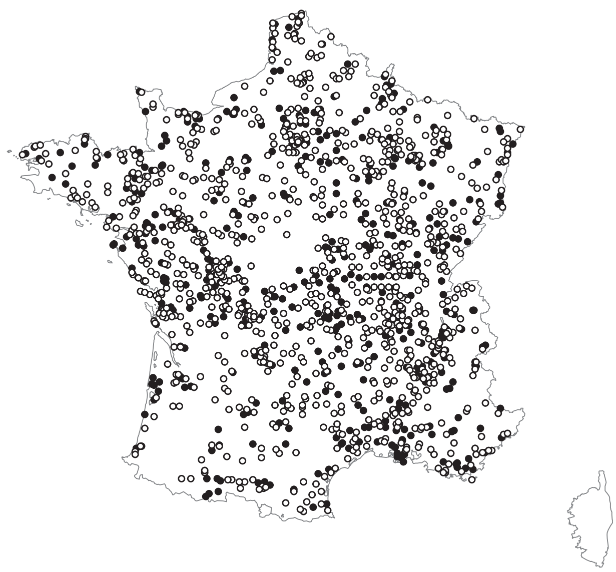

Fig. 2. The spatial distribution of the French Breeding Bird Survey plots. Each dot represents a 2×2 km square monitored for breeding bird populations: black dots for plots located inside high nature value (HNV) farmland and white dots for those located in non-HNV farmland.

THE BIODIVERSITY INDICATORS

Species selection and data analysis

We used data from the French BBS. In this standardized monitoring programme, censuses of breeding birds are carried out on randomly selected sites each spring by skilled volunteer ornithologists (Julliard & Jiguet 2002). The random selection of sites ensures the survey of various types of habitat (including intensive farmland and cities). A total of 1747 sites (plots) were surveyed at least once between 2001 and 2008 (see Fig. 2). Each plot was monitored twice in the spring, before and after 8 May, with 4–6 weeks between the two surveying events. In each plot, the observer carried out 10 evenly distributed point counts, where every individual bird heard or seen is recorded during a 5 min survey. Plots retained for further calculation (n = 1082) had at least five points located within farmland, according to the habitat codes noted by the observers in the field (Julliard *et al.* 2006). Of these plots, 285 were monitored during 1 year, 131 during 2 years, 117 during 3 years and 549 during four or more years. For each monitored square we calculated the local species relative abundance (Godet, Devictor & Jiguet 2007) as follows. First, we estimated the maximum number of individuals detected on each point count during either the first or the second sampling session, for each species and each year. The maximum of the two yearly counts was then retained as a measure of a species relative abundance at each point, to be summed between all points of a square to obtain the yearly local relative abundance per square. We further performed a spatial interpolation of the data to obtain relative abundance values for each square in the country (e.g. 136 000 squares), using kriging models based on spatial autocorrelation and an exponential function. By summing (i) the interpolated relative abundances for all squares whose centre falls in HNV farmland and (ii) for all squares across the country, dividing (i) by (ii) provides an estimate of the proportion of the national population size included in HNV farmland. A total of 144 species was considered for the analysis.

Bird abundance: species-specific responses to HNV scores

To test whether the response of species abundances to the HNV scores was related to species-specific habitat specialization, we performed an analysis based on 103 habitat generalist and farmland specialist species. We selected those species that are most commonly encountered in this type of habitat. We first ran Generalized Linear Models (GLM) using the abundance of each species as the dependent factor and the following independent predictors: the HNV score as a continuous parameter, the site and year as factor parameters, accounting further for spatial autocorrelation modelled by the equation $x + y + x \times y + x^2 + y^2$, where x and y are the geographical coordinates of the centre of a surveyed square. The estimated regression slope of species abundance against the HNV score was considered as the species response to HNV. These responses are estimated with variable precision according to the species presence in farmland areas. We then tested the response of each species in relation to the Species Specialization Index, using GLM, weighting estimates by the reverse of the squared standard error (SE) of each response. To test for more complex nonlinear patterns we used weighted generalized additive models (GAM) with a spline function and 2 d.f. (Siriwardena *et al.* 1998; Guisan, Edwards & Hastie 2002; Devictor *et al.* 2008).

Bird community indices

We estimated three local community indices. First, the local species richness was evaluated for each site, as a general index. Species richness was evaluated using a capture–recapture framework (Burnham & Overton 1979; Hines *et al.* 1999) applied to squares with at least five point counts reported by observers as lying in farmland habitats. We used the Mh model and the associated jack-knife estimator (Jiguet, Renault & Petiau 2005), accounting for heterogeneity in detectability among species with the 5–10 farmland points per square taken as replicates of local community sampling (Boulinier *et al.* 1998; see Devictor & Jiguet 2007 for a similar application). Next, the analyses were restricted to species of conservation concern. For this purpose, the Habitat Specialization Index (Jiguet *et al.* 2007) was used because it discriminates species with high ecological requirements. Species that were twice as abundant in farmland than in any other habitat type ($n = 37$ species) were retained as the more specialized bird species, and the species richness of this specialist community was estimated with the capture–recapture framework. Finally, an index independent of species richness was used: the Community Specialization Index (CSI), as defined by Julliard *et al.* (2006). This index measures the mean degree of habitat specialization among the individuals forming a local community, discriminating ordinary communities formed by generalist species, which are more resilient to perturbations, from specialized communities formed by specialist species, which are especially sensitive to global change. Each of the three community indices was analysed against scores of the HNV indicator initially through linear mixed-effects (LME) models, testing for global positive or negative relationships, using the year as a factor parameter, the HNV score as a continuous parameter and the site as a random parameter. Additionally, for each of the community indices we used GAMs (with spline function and 2 d.f.) in order to explore potentially more complex responses.

European Union Farmland Bird Indicator

Finally, we calculated the EU FBI for surveyed squares located in HNV and in non-HNV farmland areas. For the purposes of the present study we used data from 2001 to 2008, although the overall values of the indicator are available from 1989 onwards (see Jiguet 2008). The first step in this calculation relates to species selection. The species retained here are those retained for the French FBI, with a species selection procedure similar to the one used at the European level (Gregory *et al.* 2005). Only farmland specialist species were therefore initially considered ($n = 20$ species), identified from their specialization index as reported in Jiguet *et al.* (2007). We verified that all 20 species were present in at least five HNV and/or five non-HNV squares (see Appendix S3 for species contributing to FBI). The second step was the estimation of yearly species abundance indices, using log-linear models of abundance, first adjusted to a site effect, then accounting for year as a factor, providing the yearly indices of abundance (after exponential transformation). In a third and final step, yearly species indices were combined for each year and all 20 species using their geometric mean, providing the value of the indicator in a given year (Gregory *et al.* 2005). We calculated this indicator for sites located within HNV and within non-HNV farmland areas, and further compared the temporal trend of these two indicators in a LME model using species yearly indices as the dependent variable, whereas the independent predictors were the species (as a random variable) and year (as a continuous variable), plus the interaction between year and HNV status (as HNV or non-HNV). We looked for the effect of the interaction, which could indicate if temporal linear trends in yearly indices differ globally between HNV and non-HNV farmlands when first adjusted to among-species variations.

Results

SPECIES-SPECIFIC RESPONSES TO HNV SCORES

We estimated the response of species abundance to the HNV score for each of the 103 most common species in farmlands (farmland specialists and habitat generalists): 60 species showed a positive response, of which 6 were statistically significant, i.e. local abundance increased with increasing HNV score (Appendix S4). Of the remaining 43 species that responded negatively, only 1 had a significant negative response to HNV scores. The lack of significant results may be explained by the fact that the HNV indicator takes into account landscape features that are favourable for biodiversity at the community level (as shown by the present study) but does not focus on specific species. Therefore, variance in species-specific responses is high among sites and few species respond significantly to HNV. Plotting the slope of these responses against the Species Specialization Index (SSI) revealed a nearly significant linear effect (slope = 0·071 ± 0·038, P = 0·06; Fig. 3), which might suggest that the more farmland-specialized species are those showing a higher increasing abundance with increasing HNV score. Jiguet *et al.* (2010) reported that characters of their climatic niche (e.g. the species-specific thermal plasticity) affect population trends of breeding birds in Europe. Accounting for the species European thermal maximum (as defined in Jiguet *et al.* 2010; i.e. the average spring/summer temperature of the 5% hottest grid cells where a species breeds in Europe, using data taken from the latest European breeding bird atlas, Hagemeijer & Blair 1997) in the model did not change the results for the SSI, although its effect became just significant (slope = 0·075 ± 0·038, P = 0·050), whereas we found no effect of the thermal maximum (P = 0·13).

We also tested whether the abundance of species with an unfavourable conservation status responded positively to the HNV score. About 30% of all 144 most common bird species (i.e. n = 44) have an unfavourable conservation status (SPEC) as defined by BirdLife International (2004). The analysis of the local relative abundance showed that populations of these species were more numerous in HNV farmland. Moreover, while HNV farmlands cover only 25% of the national farmed territory, 73% of these species had more than 25% of their national populations included in HNV areas. The estimation of the proportion of national population included in HNV farmland (HNV ratio) per species is presented in Appendix S3. We also observed that 15% of species used for this analysis (i.e. n = 22) are wetland-related species. Regarding their national abundances, wetland species were mostly present in HNV areas (Appendix S3), though this was expected as the method included wet meadows and grasslands within the landscape elements contributing to the global HNV scores.

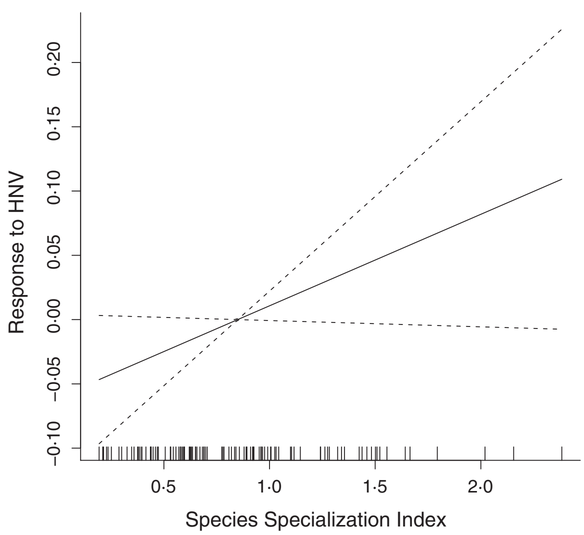

Fig. 3. Response of species abundance to the High Nature Value (HNV) score against the Species Specialization Index (SSI); 95% confidence intervals are shown with dotted lines.

BIRD COMMUNITY INDICES

Species richness

We estimated the response of total species richness and specialized species richness to the HNV score (Fig. 4a,b). We observed no significant linear relationship between the HNV score and total species richness (based on all 144 species; t_{874} = −0·47, P = 0·6; Fig. 4a). Similarly, no significant linear relationship was found between the specialist species richness and the HNV score (37 species; t_{865} = 0·5, P = 0·6; Fig. 4b), with an increase for high HNV scores though associated with a large confidence interval.

Community Specialization Index

We revealed a quadratic relationship between CSI and HNV scores (t_{909} = −3·01, P < 0·005; t_{909} = 3·51, P < 0·001).

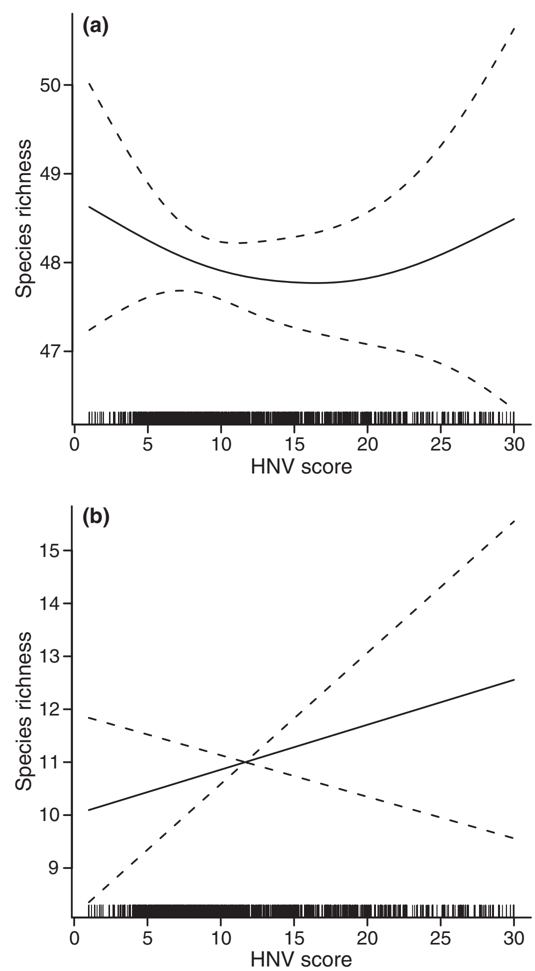

Fig. 4. Response of local bird species richness to the High Nature Value (HNV) score for: (a) all common species (N = 144 species) and (b) farmland specialists only (N = 38 species); 95% confidence intervals are shown with dotted lines.

The increasing level of CSI for high HNV scores is explained by the presence of numerous sensitive species in HNV areas (e.g. *Anthus campestris*, *Lanius collurio*, *Saxicola rubetra*). The lowest levels of community specialization were obtained for intermediate HNV scores (between 10 and 15), while slightly higher values were observed for low (< 10) HNV scores (Fig. 5). This slight increase of the CSI for low HNV scores is explained by an over-representation of three open-area farmland specialists (*Alauda arvensis*, *Motacilla flava* and *Emberiza calandra*) in open field intensive farmland with no trees.

EUROPEAN UNION FARMLAND BIRD INDICATOR

We used monitoring data on 20 species from 2001 to 2008 to build the EU FBI, and the 25% threshold to segregate HNV from non-HNV areas (Fig. 6). During this time period, the indicator increased by 6·5% in HNV farmland. In non-HNV farmland the indicator was quite stable (1·1%) and similar to the national level (1·8%). In a linear mixed model testing for an eventual difference in temporal trends of species indices between HNV and non-HNV farmlands, the interaction between year and HNV status was almost significant (t_{298} = 1·83, P = 0·07). Figure 6 shows a special contribution to the global trends in the early 2000s, reflecting the decline in farmland birds in France during the 1990s (probably more so in non-HNV farmlands) followed by stabilization globally.

Considering a 30% threshold for distinguishing between HNV and non-HNV areas, we obtained a positive trend of the indicator in HNV sites, which was higher than the one obtained with the 25% threshold (+8·5% comparing to +6·5% respectively). In addition, the trend in non-HNV sites was slightly lower than that obtained previously (−0·15%). This shows that increasing the threshold of the HNV indicator from 25% to 30% the difference between HNV and non-HNV areas increased. Indeed, the interaction between year and HNV status was significant for this threshold (t_{298} = 2·21, P = 0·03), indicating that the species contributing to the indicator have higher population growth rates in HNV than in non-HNV farmlands. We thus, conclude that a small increase of 5% in the UAA classified as HNV can, at least for the bird indicator we used, reflect more clearly biodiversity differences between HNV and non-HNV areas.

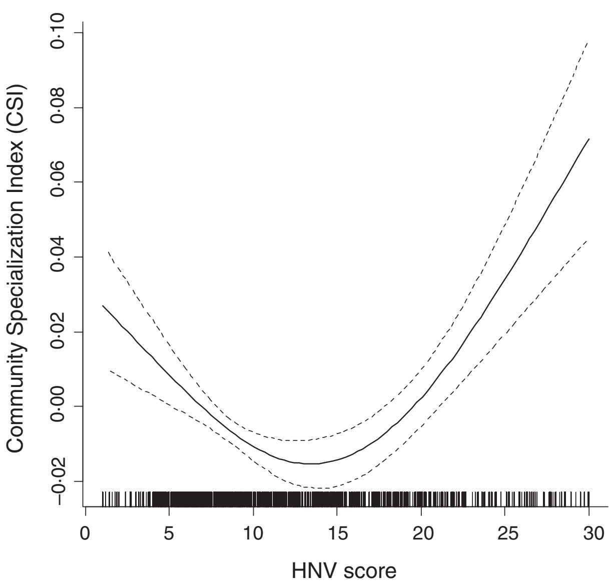

Fig. 5. Quadratic response of the bird Community Specialization Index (CSI) to the high nature value (HNV) score; 95% confidence intervals are shown with dotted lines.

Discussion

In this study, we provide evidence that HNV farmland in France comprises a network of farmland areas where low-intensity management favours a high level of biological diversity. By using several indices of bird communities, i.e. species richness, specialist species richness and CSI, we conclude that HNV farmland does not support more species in total but does support more specialized bird communities than non-HNV farmland. Moreover, habitat specialist birds are more abundant in HNV farmlands. In an effort to enhance farming efficiency, fields have been enlarged resulting in homogeneous farmed landscapes that drastically diminish the number of wild species able to survive in these simplified agro-ecosystems (Tscharntke *et al.* 2005). Replacements of specialist species by generalist ones are widely documented (Fischer & Stocklin 1997; Warren *et al.* 2001; Goulson & Darvill 2004; Julliard, Jiguet & Couvet 2004; Munday 2004). Moreover, simplification of agro-ecosystems affects important ecosystem services via the loss of biodiversity, such as pest control, pollination and decomposition processes (Altieri 1999; Schlapfer, Schmid & Seidl 1999; Tilman *et al.* 2002; Wilby & Thomas 2002). Fragmentation of the remaining natural habitat drives further extinction of fragmented, small and isolated populations (Tilman *et al.* 2002; Benton, Vickery & Wilson 2003).

Maintaining HNV farmland can also act as an effective conservation measure for threatened species. Analysis of local species abundances revealed that over 70% of the species of

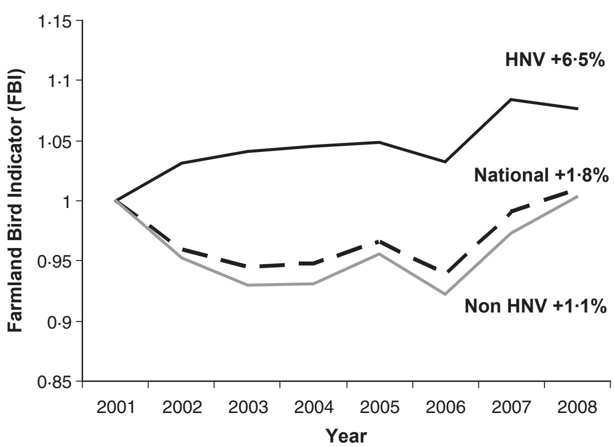

Fig. 6. The Farmland Bird Indicator for high nature value (HNV, black solid line) and non-HNV farmland (black dashed line) using data from sites monitored by the French Breeding Bird Survey scheme. The national indicator for farmland birds in France refers to all surveyed sites together (grey solid line).

European conservation concern had more than 25% of their national farmland populations within HNV areas. Furthermore, wet meadows seem to be an important part of HNV farmland as 15% of the species were wetland-related species, most having a large part of their population (>25%) within HNV farmland. Although there might appear to be some circularity in these results, we did not use the distribution and abundance of threatened species as an *a priori* criterion for assigning the HNV status. The latter was determined from statistics on agriculture and landscape elements, which reinforce our belief that HNV farmland in France has a positive role for the conservation of farmland bird species.

Finally, we found that the temporal trend in the EU FBI was different for HNV and non-HNV farmland in France, even over the relatively short time period of the study (8 years). We obtained slightly different results according to the threshold considered. Fixing a threshold that reflects ecological differences between HNV and non-HNV farmland areas is an interesting but challenging aspect. According to the IRENA project, an appropriate threshold is 25% of the national agriculture area considered as HNV. However, until now no cross-validating analysis using biodiversity components has been provided to justify that threshold. Our sensitivity analysis using the FBI showed that increasing the threshold to 30% provided a better separation of the farmland areas regarding trends in farmland bird abundances. In the unfavourable context of global farmland bird declines and agriculture intensification throughout Europe (Donald, Green & Heath 2001; Gregory *et al*. 2005; Donald *et al*. 2006), HNV farmland is an efficient way to provide favourable conditions for farmland bird conservation in France. Moreover, the efficiency of the EU FBI to track changes over time and space justifies its use as a major tool for management and policy decisions at the European scale.

Several questions remain concerning the driving forces of these trends inside and outside HNV farmland during the last decade. For instance, the effects of the relatively recent implementation of agro-environmental schemes (AES) in France (2001) should be further studied and evaluated. Such studies concerning the effectiveness of AES as part of the EU Common Agricultural Policy (CAP) measures have been made in other European countries, but their conclusions are often controversial (Bradbury *et al*. 2004; Kleijn *et al*. 2006; Whittingham 2007; Blomqvist, Tamis & de Snoo 2009). In addition, assessments of other taxa should be encouraged, with the aim of generalizing from the bird results along a broader ecological spectrum. This additional knowledge might also contribute to defining HNV thresholds, which would more efficiently reflect the biodiversity differences between HNV and non-HNV farmland. Similar studies at the European level should also provide the necessary feedback to support the debate on the revision of the CAP for the programming period 2013–2020 concerning biodiversity conservation issues.

Future conservation measures should focus on preserving HNV farmland over large geographical regions. In France, this goal might be achieved by increasing at least one of the three components that contribute to the HNV farmland scores, i.e. crop diversity, extensive farming practices and landscape elements. About 63% of HNV farms are based on grazing systems and 29% correspond to mixed systems, i.e. livestock and arable (Pointereau *et al*. 2007). Policy measures favouring the maintenance of extensive pastures and grazing systems can have a positive effect on HNV farmland areas. Emphasis should also be placed on landscape elements, like hedges, ditches and isolated forest patches, as their role in habitat connectivity has been largely demonstrated for several taxa (Davies & Pullin 2007; Haenke *et al*. 2009). Existing agri-environment schemes of relevance to HNV farmland include the conservation of permanent grasslands (the grassland premium, ongoing in France since 1993) and the less favoured areas (LFA) scheme, as 90% of HNV farms in France are located in LFA. Additional measures have been applied to maintain extensive systems in HNV farmland (Pointereau *et al*. 2007). Other agri-environment schemes focus on specific threatened species including those listed on the EU Birds Directive. New management options may arise from the reorientation of the existing agri-environment schemes or the application of complementary ones focusing on the community level. Existing or future measures aimed at maintaining HNV farmland and associated farming systems should shift from a species-specific to an ecosystem approach.

Appropriate management of agricultural habitats is crucial for halting biodiversity loss. Although agricultural intensification and land abandonment are important causes of the biodiversity loss, low-intensity land-use systems may also be important elements for large-scale conservation programmes (Tscharntke *et al*. 2005). Our study gives evidence that HNV farmland actually provides favourable conditions for farmland birds and hence probably for other taxa. The recent increase in the EU FBI in French HNV farmland indicates that declines are potentially reversible and that appropriate management of HNV areas might be crucial in halting biodiversity loss. However, if HNV farmland is to be sustainable, economic and social aspects should also be considered. The fact that HNV farms are mostly located in LFA and that farm income in HNV farms is lower than in non-HNV farms (Pointereau *et al*. 2007) suggest that while the risk of intensification may be limited, mostly because of environmental constraints, land abandonment needs to be prevented. Further abandonment of agricultural lands, including some of the ecologically most valuable areas, is an ongoing threat to existing HNV farmland. We advocate a biodiversity friendly farming approach in an economically viable system of agricultural production (Green *et al*. 2005). Similar studies may help in providing guidelines for adaptive management scenarios and policies to ensure the resilience and sustainability of HNV farmland in Europe.

Acknowledgements

We especially wish to thank the hundreds of volunteers who count breeding birds yearly within the French Breeding Bird Survey scheme. We also thank

Frédéric Coulon for his help on HNV indicators and two anonymous referees whose comments and advice greatly improved the paper. This study was funded by the Joint Research Centre of the European Commission, Institute for Environment and Sustainability.

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Received 17 February 2010; accepted 5 August 2010
Handling Editor: Davy McCracken

Supporting Information

Additional Supporting Information may be found in the online version of this article.

Appendix S1. Methodological improvements from previous high nature value (HNV) scoring system (Pointereau *et al.* 2007): weighting of the different components of the HNV indicator.

Appendix S2. Sensitivity analysis of the threshold of the high nature value (HNV) indicator.

Appendix S3. All breeding bird species considered in the analyses. Evaluation of the potential effect of high nature value (HNV) on bird species conservation by evaluating the proportion of national population included in HNV (HNV ratio) for each species. Species in bold with an asterisk are those contributing to the European Union farmland bird indicator.

Appendix S4. Species-specific responses to high nature value (HNV) score. Species that had a significant positive or negative response are indicated by an asterisk. Among farmland-related species in France, the Rook (*Corvus frugilegus*) and the European Bee-eater (*Merops apiaster*) had a significantly positive response to increasing HNV scores. Blackbird (*Turdus merula*), Tree sparrow (*Passer montanus*), Jackdaw (*Corvus monedula*) and Fieldfare (*Turdus pilaris*) also responded positively. Starling (*Sturnus vulgaris*) responded negatively to HNV, which is because of the species distribution in France, in low altitude open-field farmlands that are not considered as HNV.

Appendix S5. The number of squares monitored per year in high nature value (HNV) and in non-HNV farmland.

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