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Nesting strategy predicts farmland bird response to agricultural intensity

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ABSTRACT

Large-scale studies investigating impacts of agricultural practices on biodiversity showed that farmland bird population sizes are negatively related to national agricultural intensification indices in Europe. Here, it was tested whether the nesting strategy of farmland species predicted their abundance variations along a gradient of agricultural production intensity. Ground-nesters, which are strongly declining all over Europe, were expected to be impacted more directly by production intensity than hedge-nesters which would be instead impacted by hedge loss. To test this prediction, previously unavailable fine-scale agricultural data were used over an entire country representing highly diverse farmlands. We modelled the local abundance of 43 farmland bird species, using data from the French breeding bird survey, along an index of agricultural production intensity based on standardized crop yields and herbivore stocking rates, controlling the analysis for local climate and farmed habitat type.

68% of ground-nesters had lower relative abundance in more productive farmlands, whereas only 17% of hedge-nesters did. Nesting strategy explained an important part of bird species responses to spatial variation in agricultural production intensity. Our results suggest that although hedge loss and production intensification were parts of the strong agricultural intensification in Europe, these two phenomena are impacting different bird species.

1. Introduction

Agricultural intensification largely impacts biodiversity (Krebs et al., 1999) and threatens diverse ecosystem services (Bjorklund et al., 1999). More particularly, the implementation of Common Agricultural Policy in numerous eastern European countries could amplify wider farmland bird declines over the continent (Habeck, 2004). Such declines have been linked to both spatial and temporal variations in agricultural production intensity (Chamberlain et al., 2000; Donald et al., 2001, 2006; Wretenberg et al., 2007). However, similar patterns of agricultural intensification in various European countries do not necessarily result in similar farmland bird trends (Fox, 2004). In addition, similar trends can result from different patterns in agricultural changes (Wretenberg et al., 2006). Farmland bird declines have been associated with (i) direct effects of production intensification, such as depletion of food supply (Morris et al., 2005), farming operations (Burton et al., 1999) or cattle trampling (Pavel, 2004), or (ii) more indirect effects such as loss of natural microhabitats within farmlands (Gillings and Fuller, 1998) or landscape homogenisation (Benton et al., 2003), these components being often correlated and hence difficult to disentangle.

This study takes advantage of the French context where a strong heterogeneity in land consolidation implementation resulted in a low correlation between hedge density and local production intensity (Baudry and Burel, 1984; Vitikainen, 2004). This allows to investigate the impact of agricultural practices intensification independently from the impact of the decrease in landscape features.

Nesting on the ground has been proposed as a promoting factor of farmland species sensitivity to intensification but poorly explains recent trends (Siriwardena et al., 1998). Besides, the loss of hedgerows in western European landscapes is presumably responsible for the decline of many species nesting in these elements (Gillings and Fuller, 1998). It was hypothesized that ground-nesters would respond more negatively to local production intensity than hedge-nesters, and that hedge-nesters abundance should be positively linked to the presence of bush/tree elements. The robustness of the nesting strategy effect was tested against other potentially correlated traits.

2. Breeding Bird Survey data

Data on breeding birds was obtained by a national Breeding Bird Survey scheme launched in France in spring 2001 (Jiguet et al., 2007). In this scheme, volunteer ornithologists counted all visible and singing individual birds at permanent points. Surveyed sites are two-by-two km squares randomly selected for each observer

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within a 10 km radius around a locality specified by the volunteer. Observers carried out 10 point counts of 5 min each per square, twice per spring, i.e. once before and once after the 8th May, with 4–6 weeks between sessions, with points separated by at least 300 m. Counts were repeated yearly by the same observer at the same points, on about the same date, and at the same time of day. The 7307 points which were localized adjacent to farmland were selected from this dataset.

For each species and each point, the yearly count with the maximum number of individuals detected among the two sessions was retained. Only individuals detected within a 100 m radius around the observer were considered so that the birds were actually seen in their habitat. Yearly counts were averaged for squares that were monitored over several years between 2001 and 2006.

Observers were also asked to classify land use/habitat within 100 m of each point into 11 types, i.e. maize, other cereals, rape, root crop, sunflower, other temporary crop, permanent crop, dry grassland, grazed heathland, wet meadow and classical pasture. The frequencies of 11 farmland habitat types per point were then calculated by averaging yearly frequencies, thus taking into account inter-annual crop rotations. Non-farmland habitat frequency was not used in the statistical modelling because it was a simple linear combination of the 11 farmland habitat types frequencies (1 − sum of them). Thus, species responses to non-farmland habitats was accounted for by the mean of the 11 farmland frequencies. Observers also recorded the presence of bush/shrubs and trees. The 50 species that were detected on at least 50 different points and were more abundant adjacent to farmland than in other habitats were then retained. Among these, *Phasianus colchicus*, *Perdix perdix* and *Alectoris rufa* were excluded as their local abundances strongly depended on releases for hunting purposes, as well as *Ardea cinerea*, *Merops apiaster*, *Hirundo rustica* and *Acrocephalus scirpaceus* because of their specific nesting strategies. The 43 remaining species were classified as either ground- ($n = 19$), or hedge-nesters ($n = 24$) as described in Cramp and Perrins (1994).

3. Agricultural data

An overall estimate of local agricultural production intensity was developed using data from the French Farm Structure Survey Census conducted in 2000 (SCEES, 2001). These data contain the farmed area of the 36,027 French municipalities, detailed through 37 crop and five pasture types, and the number of herbivorous livestock per municipality, detailed through 21 types. Data from the French Annual Agricultural Statistics were also gathered: crop yields of 161 crop types for the 94 French departments (SCEES, 2005b). For each crop, yields were averaged over the 2000–2004 period.

To summarize local production intensity using yields for the different crops and livestock density for pastures, these metrics had to be standardized to obtain an overall index. This standardization was performed in three steps.

First of all, livestock density was calculated for each municipality containing pastures, using a livestock unit table that provided equivalences between different types of herbivores (SCEES, 2005a) and dividing this herbivores quantity by the total area of local pasture systems.

Secondly, we looked for reference values for all crop yields and livestock density which could all represent an equivalent level of production intensity. For this purpose, European agricultural data from the FAOSTAT database was used (FAO, 2006) and a European mean yield for each crop was calculated, adjusted to the effect of country. This calculation allowed us to obtain reference values representing an equivalent level of production intensity for each crops and for pastures. To synthesize these measures in one production intensity index by municipality (Fig. 1), the production intensities of all cropping and pasture systems was standardized, averaged and weighted by the corresponding covered areas:

$$PI_m = \frac{1}{ALA_m}\sum_i\left(\frac{Y_{im} - R_i}{R_i} \times A_{im}\right)$$

where ALA_m is the agricultural area of the municipality m, Y_{im} is the local yield of the ith cropping system, R_i is the reference yield and A_{im} is the cropping system area.

Lastly, the municipalities delimitation was overlaid to the BBS grid to obtain PI of each surveyed BBS square:

$$PI_s = \frac{\sum_m PI_m \times ALA_{sm}}{\sum_m ALA_{sm}}$$

where PI_s is the production intensity in the square s and ALA_{sm} the agricultural area intersected by the square s and the municipality m.

4. Statistical analysis

The impact of production intensity (PI) on farmland birds was analysed in two steps (as in Jiguet et al., 2006). First, each species responses to PI and to woody elements were estimated thanks to French BBS data. Then, the effect of nesting strategy on the 43 species estimated responses was assessed.

For that purpose, local abundance of each 43 species was modelled by a multiple regression with production intensity (PI) as independent variable associated with variables controlling for potential habitat and climate effects. Climatic requirements were controlled by using quadratic functions of four basic climatic variables from the WorldClim database: BIO5, BIO6, BIO13 and BIO14 at a 2.5 arc-minutes precision (Hijmans et al., 2006).

Each of the 43 models was formulated as follows:

$$\text{Abundance} \sim F_1 + F_2 + \cdots + F_{11} + C_1^2 + C_1 + C_2^2 + C_2 + C_3^2 + C_3 + C_4^2 + C_4 + \text{TP} + \text{SP} + PI$$

where F_s are the 11 farmland habitat frequencies, C_s are the four climatic variables, TP is tree presence/absence, SP is shrub presence/absence and PI the production intensity index.

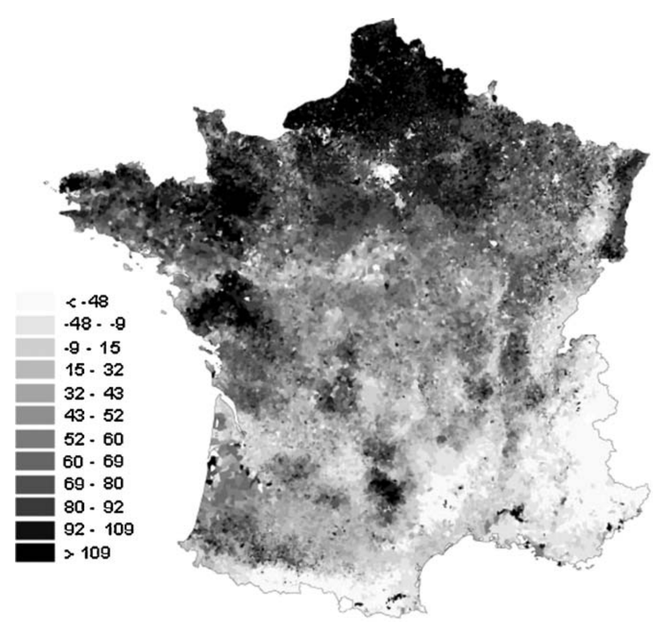

Fig. 1. Graphic output of the agricultural production intensity index (PI) as used in this study (see Section 3). The darker the colour, the more intensive the local agricultural production.