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Community richness and stability in agricultural landscapes: The importance of surrounding habitats

Vincent Devictor *, Frederic Jiguet

Centre de Recherches sur la Biologie des Populations d'Oiseaux, UMR 5173 'Conservation des Espèces, Restauration et Suivi des Populations', Muséum National d'Histoire Naturelle, 55 rue Buffon, 75005 Paris, France

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Abstract

In this paper, the role played by habitat diversity in the landscape on species richness and on the stability of farmland bird communities was investigated. Species richness was estimated on 374 samples monitored in farmland by the French breeding bird survey during the 2001–2005 period. A capture–recapture approach was used to estimate species richness accounting for the variation in detection probability among species of the 100 most common species detected in farmland. Landscape structure and composition were measured both in farmland and in adjacent habitats. The independent effect of each variable on community richness and stability was further assessed using hierarchical variance partitioning and taking spatial autocorrelation into account. A strong matrix effect was detected: non-cropped land deeply influenced richness and stability of bird assemblages.

Keywords: Agricultural landscape; Bird; Breeding bird survey; Community dynamics; Detectability; Matrix effect; Spatial analysis; Mixed models

1. Introduction

The negative effects of landscape homogenization and agriculture intensification on biodiversity are recognized (Benton et al., 2003) and have been studied at many spatial scales on plants, invertebrates, and vertebrates (Stoate et al., 2001). Many studies have focused on birds as this taxonomic group provides good indicators of environmental changes since it is easily monitored, and high in the food web. Most of these studies have concluded that farmland species are in trouble (Donald et al., 2001). At the local scale, specific agricultural practices, such as the increased use of pesticide and inorganic fertilizers, were identified as plausible explanations for the decline in farmland bird populations (Chamberlain and Fuller, 2000; Newton, 2004). At the landscape scale, the structure and composition of the landscape matrix have been investigated theoretically and are expected to affect population dynamics (Andrén, 1994). In particular, for a given habitat, the diversity of the surrounding habitats has been shown to deeply influence the community found within the given habitat, although this result differed according to the scale, the habitat and the group considered (Clergeau et al., 2001).

To assess the state of farmland birds, research on communities has principally focused either on farm-scale studies of local patterns or on broader scale relationships between birds and major climatic or land-use variables. Studies at an intermediate spatial scale employing sample plots of a few km^2 are far less common (Heikkinen et al., 2004). Yet, landscape variables of non-cropped surrounding habitats in agricultural landscapes are expected to play a major role in bird assemblage richness (Söderström and Pärt, 2000; Krauss et al., 2004). Indeed, in open and fragmented farmlands, landscapes often consist of two kinds of habitat. The first is the effectively cultivated habitat, where the agricultural practices and the size and structure of the farmland are major components explaining the fate of biodiversity (Selmi and Boulinier, 2003). The other is made up of the surroundings, such as patches of

* Corresponding author. Tel.: +33 1 40 79 57 23; fax: +33 1 40 79 38 35.
E-mail address: devictor@mnhn.fr (V. Devictor).

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wetland, woodland, or human settlements. These non-agricultural patches may strongly affect farmland bird communities by providing breeding sites, food supplies, or by potentially allowing the colonization by individuals and species (Woodhouse et al., 2005; Buckingham et al., 2006).

Little attention has been paid to such matrix effects on organisms living in open habitats in which species may have high mobility and a generalized habitat use (Söderström and Pärt, 2000). Moreover, when communities were studied within complex landscapes, community composition was often only described in terms of observed species richness or abundance for target species, while the dynamic processes were rarely considered for the whole community (Chamberlain and Fuller, 2000; Bennett et al., 2004).

The aim of this study was to identify the relative effects of the landscape's structure and the composition of agricultural and non-agricultural habitats on species richness and community stability at a landscape scale, while accounting for heterogeneity in species detection and spatial autocorrelation. More specifically, a positive effect of either agricultural or adjacent habitat diversity on bird species richness was expected. Concerning community dynamics, species found in more diverse landscapes any given year should, on average, have a higher probability of still being present the following year. Negative effects of intensively farmed uniform landscape, such as reduced habitat hedges and low connectivity among diverse habitats should lead to an increase in community instability. Thus, the prediction of a higher temporal variability in bird communities in more homogeneous farmland landscapes was also tested.

2. Methods

The French breeding bird survey (BBS) is a standardized monitoring program in which volunteer skilled ornithologists identify breeding birds by song or visual contacts each spring. Each observer is allocated a locality, and a four km^2 plot to be surveyed which is randomly selected within a 10-km radius around this locality (i.e. among 80 possible plots). Such random selection ensures that the survey covers a representative selection of habitats (including intensive farmland, ordinary forest, suburbs and cities). Each plot is monitored twice in the spring, once before and once after the eighth of May, with 4–6 weeks between sampling events. In each plot, the observer carries out 10 evenly distributed point counts, within which the observer records every species heard or seen during a 5-min period. The same observer monitors the same plot each year (Julliard and Jiguet, 2002). In this study, all plots monitored during the 2001–2005 period, in which at least five points located in farmland (according to the habitat codes recorded by the observers in the field) were analyzed. The first five farmland point counts of each square were then selected (in order to compute community parameters with a constant sampling effort) and, for each given point, counts of the two annual visits were summed. Species recorded at these point counts were mainly farmland bird specialist species. However, in order to extend the scope of the analysis to other species encountered in farmland, the 100 most common passerine and near-passerine bird species (from Columbiforms to Piciforms) detected by the BBS were considered. Therefore, many of the species considered may benefit from secondary habitats (hedges, bushes, buildings or small wetlands), but are not strictly linked with farmland.

The matrix of presence/absence of encountered species at each of the five point counts was processed each year to estimate species richness by running the COMDYN program (Hines et al., 1999). COMDYN's algorithm allows one to consider heterogeneous detection probability among species, using the capture–recapture model $M(h)$ and the associated jackknife estimator. This model was the most frequently selected model in the framework of species richness estimation for breeding bird survey data (Boulinier et al., 1998b; Jiguet et al., 2005). For each plot, species richness estimates were averaged over 2001–2005. Only plots for which there were more than two annual estimates of species richness were included in the analyses. Second, community stability for each BBS plot was expressed as the temporal variation in species richness (Boulinier et al., 1998a; Lekve et al., 2002; Newmark, 2006). The relative year-to-year variability in species' numbers was estimated using the coefficient of variation (CV) of species richness over 2001–2005 using variance estimates of annual species richness over that period, with an approach proposed by Link and Nichols (1994) that accounts for sampling variance. When available, the sampling variance which is induced by the sampling procedure (e.g. induced by heterogeneity in detection probability) can be subtracted from the raw variance estimate to get an estimate of the true process variance. Therefore, the average sampling variance associated with annual estimates of species richness (provided by COMDYN), was subtracted from the overall total variance (estimated over time using the point estimate of species richness). Community stability was thus the ratio of the square root of the estimated true temporal variance to the mean of the species richness estimate (Boulinier et al., 1998a). This community stability estimate was independent of the number of years considered for each plot (ANOVA, $F_{371,2} = 1.39$, $P = 0.24$) and not correlated to the mean of species richness ($r = 0.069$, $P = 0.18$).

Variables related to landscape features within each surveyed plot were obtained using the geographical information system package ArcView 3.2 (ESRI, 2000) and the Corine land cover database. The latter is a national geo-referenced database including the main habitats for the whole country in contiguous polygons classified according to 44 different land-cover categories (Bossard et al., 2000). BBS squares were overlaid on this independent land cover database and two groups of explanatory variables were built: habitat cover and landscape diversity variables (Table 1).