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Impacts of agricultural intensification on bird communities: New insights from a multi-level and multi-facet approach of biodiversity

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ABSTRACT

Following the multiplicity of studies dealing with the effects of agricultural intensification on bird diversity, one of the lessons drawn is that these effects depend on both the taxonomic group, the component of diversity, the aspect of intensification, and the spatial scale. This often leads to disparate results among studies suggesting that the investigation of agriculture-biodiversity relationships suffers from scale-dependence, information redundancy, non-linearity problems, and thus, unpredictability.

Here, we propose a multi-scale and multi-facet approach to clarify the impacts of agricultural intensification on biodiversity and possible mitigating actions. Our study is based on bird and agricultural practice surveys of 199 agricultural fields in three agricultural regions of France. Using landscape characteristics and agricultural practice variables, we disentangled four main gradients of agricultural intensification on our study sites: landscape opening (farmland expansion), landscape homogenization (decrease in crop and land cover diversity), chemical intensification (fertilizer, insecticide, and fungicide), and tillage vs. herbicide.

We tested whether and how these gradients interacted with each other at field, farm and regional levels in shaping taxonomic diversity (alpha, gamma and beta diversity) and ecological responses of bird communities (relative proportion of specialist vs. generalist species, trophic categories).

Landscape homogenisation and opening affected the taxonomic and ecological responses of birds at field and farm levels, but not at the regional level, highlighting the scale-dependence of agriculture–biodiversity relationships. At field and farm levels, landscape opening had a positive effect on beta diversity, and community specialization by enabling the existence of farmland specialists, while heterogeneous landscapes promoted generalists.

Chemical intensification had negative impacts, especially at the farm level and on almost all facets of diversity. However, some bird species seemed to tolerate higher levels of both chemical and tillage intensification.

Some important interaction effects between landscape and agricultural practices, which are often disregarded, were also revealed, such that landscape homogenization in interaction with tillage reduction was correlated with higher specialization.

The field level appeared mostly relevant for explaining community variations by habitat and resource availability. Meanwhile at the coarsest scale, i.e., the Small Agricultural Region, only some possible dispersal limitations were likely to occur. Finally, our results highlight the farm level (intermediate scale) as a relevant unit for management and agricultural policies, since the community responded to both landscape and agricultural practices intensification at this level. In particular, we emphasize the necessity to conserve both heterogeneous and homogeneous agricultural landscapes under extensive

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practices; the former promotes taxonomic diversity, when the latter favors specialized farmland biodiversity.

1. Introduction

Agricultural intensification has multiple detrimental impacts on biodiversity caused by the degradation of suitable habitats (Altieri, 1999) and a reduced availability of resources (Benton et al., 2003), especially for farmland birds (Donald et al., 2001).

The effects of agriculture intensification through landscape modifications on biodiversity have been widely studied those last decades (Tscharntke et al., 2005). As a result, several conceptual compromises of land management have been proposed (e.g., wildlife friendly farming vs. land sparing; (Fischer et al., 2008; Green et al., 2005) in order to conciliate crop production and biodiversity conservation. Most of these compromises give rise to important scale issues among others (Gonthier et al., 2014; Phalan et al., 2011; Quinn et al., 2012) because, to find optimal spatial scales of managing, one needs to understand at which scales biodiversity responds to environmental conditions.

The intensification of agriculture through intensive field practices and habitat simplification has been shown to influence bird biodiversity at the field, farm, landscape and/or regional levels (Gabriel et al., 2010). For instance, higher pesticide and fertiliser inputs and loss of semi-natural habitats reduce bird richness at the field and regional levels because of the extirpation of farmland specialists (Filippi-Codaccioni et al., 2010; Karp et al., 2012; Tscharntke et al., 2008). Agricultural intensification can also affect functional diversity but not necessarily in the same direction as taxonomic diversity, depending on the spatial scale considered (Devictor et al., 2010; Filippi-Codaccioni et al., 2010; Meynard et al., 2011). Overall, ignoring the multi-facets of biodiversity and the scale dependency in individual responses to agricultural intensification may lead to a simplistic view of biodiversity dynamics in farmlands and jeopardises the specific conservation efforts that should be implemented (Clough et al., 2007; Gabriel et al., 2010; Hendrickx et al., 2007). Moreover, although the potential interaction effects on biodiversity between landscape modifications and agricultural practices intensification have been suggested, they are still poorly quantified across scales that may be relevant in terms of land management (e.g., field, farm, agricultural region).

Partitioning diversity into local (namely alpha), inter-local (namely beta) and regional (namely gamma) diversities (Whittaker, 1972) offers a view of multi-scale agriculture–biodiversity relationships (e.g., Flohre et al., 2011; Gabriel et al., 2006). However, this partition (additive or multiplicative) has been weakened by many methodological limitations, notably the non-independence between real turnover and change in species richness (De Bello et al., 2010; Jost, 2007; Karp et al., 2012; see also Appendix A), and the inability to disentangle species-specific differences among sites (Jurasinski et al., 2008).

To remedy these limitations, firstly, we used a measure of beta diversity which was calculated independently to alpha, i.e., as a measure of inter-sites dissimilarities which will allow drawing hypothesis on species-specific contributions to the general patterns of beta diversity. Secondly, according to Baselga (2010), we proposed to partition beta diversity into two independent components: nestedness and spatial turnover. Nestedness refers to community size (i.e., species richness) and occurs when all species belonging to smaller communities also belong to richer communities (see Wright and Reeves, 1992). A beta diversity which is only determined by nestedness thus results from differences in community size, reflecting a non-random process of species loss (or gain) as a consequence of any differences in habitat suitability, occupancy level (Gaston and Blackburn, 2008), and selective colonization or extinction (Cook and Quinn, 1995). True spatial turnover occurs regardless of the difference in community size and results from the replacement of some species by others, due to environmental filtering or spatial and historical constraints. Defining beta diversity as nestedness and spatial turnover allows disentangling and testing alternative hypotheses on the processes structuring diversity, regardless the inventory diversity (Jurasinski et al., 2008).

Complementing the information derived from taxonomic diversity indices, several integrative indices have also been proposed to quantify the relative abundance of species with specific traits that can shape diversity patterns.

Indeed, for instance, the preference for the farmland habitat strongly contributes to the species positive response to landscape homogenization (Clavero and Brotons, 2010; Guerrero et al., 2011). Thus the Species and the Community habitat Specialisation Indices (SSI and CSI, respectively) were shown to decrease with habitat disturbance and fragmentation in farmland (Devictor et al., 2008; Filippi-Codaccioni et al., 2010). Specialization of farmland communities is also favoured by low-intensity practices (Doxa et al., 2010). Similarly, a Community Trophic Index (CTI), adapted from the Marine Trophic Index (Pauly and Watson, 2005), has been proposed as a surrogate of the potential trophic complexity within bird communities (Jiguet et al., 2012). This index has not yet been tested in agricultural landscapes, though these have been shown to favour granivorous and ground insectivorous species, leading to less diversified diet composition in farmland than in forested areas (Hanspach et al., 2011).

Agriculture intensification is characterized by high levels of chemical inputs (pesticides and fertilizers), tillage operations and landscape homogenisation (or simplification) (e.g., Flohre et al., 2011; Wilson et al., 1999). Landscape homogenisation is usually described based on two features: land use intensification (Flynn et al., 2009) and agriculture expansion (Medan et al., 2011). At the local scale, land use intensification relates to the intensity of agricultural practices (Flynn et al., 2009), while at the landscape scale, it is strongly related to agriculture expansion (Tscharntke et al., 2005). Indeed, a landscape is intensively managed when entirely agricultural and less intensively managed when composed of half-agriculture half-natural, or semi-natural land covers. Thus, in this study, we integrated these different aspects of agricultural intensification; landscape alterations, as represented by land use intensification and agriculture expansion, and practices intensification.

We aimed to disentangle the changes in bird taxonomic diversity and in specialization and trophic complexity due to landscape characteristics and agricultural practices at different spatial scales. For this purpose, we investigated the responses of alpha, beta and gamma diversities, and ecological indices (CSI, CTI) of the community to landscape characteristics and agricultural practices, using a bird survey conducted on 199 fields in three French agricultural regions in 2010 and 2011. Then, we analysed the species-specific contributions to the observed changes in beta diversity in order to relate the changes in community composition and spatial distribution of species to particular ecological traits. This provided an interesting opportunity to complement the community approach with a focus on species for a better understanding of the biodiversity responses to environmental