Agriculture, Ecosystems and Environment 253 (2018) 55–61

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Research paper

Contrasting bird communities along production gradients of crops and livestock in French farmlands

Camille Dross[a,*], Karine Princé[c,d], Frédéric Jiguet[c], Muriel Tichit[a]

[a] UMR SADAPT, INRA, AgroParisTech, Université Paris-Saclay, 75005, Paris, France
[c] Centre d'Ecologie et des Sciences de la Conservation (CESCO UMR7204), Sorbonne Universités, MNHN, CNRS, UPMC, CP51, 55 rue Buffon, 75005, Paris, France
[d] Department of Forest and Wildlife Ecology, University of Wisconsin-Madison, Madison, WI 53706, USA

ARTICLE INFO

Keywords:
Agricultural production
Farmland birds
Specialization
Trophic structure

ABSTRACT

Impacts on birds of intensive management practices and of landscape simplification have been widely studied, but there is a lack of knowledge about impacts on birds of landscapes associated with intensive livestock production. The objective of this work was to investigate changes in several bird community descriptors along different production gradients. Production of arable crops and from grazing livestock was computed over French agroecosystems and expressed in terms of edible energy. Using data from the French Breeding Bird Survey along with data from national agricultural statistics, we modeled the relationship between production and five bird community descriptors, namely, community trophic index, community specialization index, and three group-specific species richness indices. Bird communities were shaped by two production gradients. Along a gradient of increasing crop production, we observed a shift from locally species-diverse communities dominated by generalist or grassland specialist species towards species-poor communities dominated by granivorous species specialized in arable habitats (all p-values ≤ 0.002). Second, we observed a shift towards homogenized communities dominated by generalists along a gradient of increasing livestock production (p-values ≤ 0.001). Our research highlights the need to consider crop and livestock separately when investigating their impacts on biodiversity. It also hints towards the need for differentiated strategies to protect farmland birds in crop regions and in livestock regions.

1. Introduction

Man appropriates a substantial share of the planet's ice-free land surface (Ramankutty et al., 2008) and of the terrestrial net primary production (Haberl et al., 2007; Krausmann et al., 2013), in particular through agriculture. In Western Europe, agricultural intensification through both intensive management practices and landscape simplification has made it possible to increase food production considerably in the second half of the twentieth century, but it has had detrimental effects on Europe's biodiversity (Donald et al., 2001, 2006; Le Féon et al., 2010; Storkey et al., 2012).

Impacts on birds of intensive management practices have been well studied. Results show contrasted responses for different bird groups, with "loser" and "winner" species (Phalan et al., 2011; Teillard et al., 2015). Habitat specialists are generally the most vulnerable to human-induced disturbances (Devictor et al., 2008), as can be shown using the habitat species specialization index (hereafter SSI) proposed by Julliard et al. (2004). This index discriminates between species with much higher abundances in one particular habitat than anywhere else, which have a high SSI and can be called habitat specialists, and species with equal abundances in most habitats, which have a low SSI and are referred to as habitat generalists. Farmland habitat specialist species, which are specialists of farmland habitat, are probably the most vulnerable to intensive management practices because they spend most of their time in farmland and rely mainly on resources and habitat found there. Doxa et al. (2012) have observed a decline of farmland specialist abundances only in highly intensified agriculture areas and not in High Nature Value Farmland. In arable regions, the most specialized species are the most vulnerable to pesticide applications (Filippi-Codaccioni et al., 2010a), and the mean specialization of the bird community is negatively correlated with herbicide doses (Chiron et al., 2014). Chiron et al. (2014) have also observed a positive relationship between herbicide doses and bird species richness. This result could be due to generalist species, which are generally bad competitors in agricultural landscapes, colonizing habitats that have been deserted by specialist species following an herbicide treatment.

Impacts of landscape intensification of crop production (Tscharntke et al., 2005) or of extensive grassland-based livestock production have

* Corresponding author at: UMR 1048 SADAPT, 16 rue Claude Bernard, 75005 Paris, France.
E-mail addresses: camille.dross.2008@polytechnique.org (C. Dross), karine.prince@gmail.com (K. Princé), fjiguet@mnhn.fr (F. Jiguet), muriel.tichit@agroparistech.fr (M. Tichit).

http://dx.doi.org/10.1016/j.agee.2017.10.025
Received 19 November 2016; Received in revised form 21 October 2017; Accepted 28 October 2017
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been widely studied. Landscape simplification, that is to say, the increase of the extent of cropland and the size of fields, is generally considered to have a positive impact on farmland specialists, and a negative impact on all other species (Chiron et al., 2014; Filippi-Codaccioni et al., 2010a; Jeliazkov et al., 2016). Recently, Teillard et al. (2014) have split the farmland specialist species into three groups according to their within-farmland specialization, making it possible to show that specialist species benefit from a higher extent of their habitat within farmland. Thus, arable specialists thrive in regions specialized in crops, whereas grassland specialists are favored in regions where grasslands are present. Conversely, habitat generalist species and indeed a majority of species depend on a heterogeneous mosaic of land uses, and there are far fewer species in simplified landscapes. Little is known about the impacts on birds of landscapes associated with intensive livestock production, although a recent study by Dross et al. (2017) has failed to detect covariations between bird biodiversity and livestock production.

The objective of this work was to investigate changes in several bird community characteristics along gradients of increasing crop or livestock production. First, we estimated crop production, meat and milk production across French farmlands. Then, we computed the mean specialization index of the community, the mean trophic index and three group-specific species richness (SR) indices to capture the shifts in composition associated with production. Finally, we used generalized additive mixed models to assess the relationship between production and each bird community descriptor. In particular, we tested the following mutually exclusive hypotheses:

H1. Specialist species as winner species, possibly because the extent of their habitat increases as more land is dedicated to production.

We expected a shift from generalists to arable specialists along a crop production gradient, as well as a shift from generalists to grassland specialists along a livestock production gradient. We expected both shifts to be accompanied by an increase in the community specialization index.

H2. Specialist species as loser species, possibly because they are more vulnerable to intensive management practices than generalist species.

Along both production gradients, we expected an increase in generalist species richness, and a decrease in the community specialization index and any specialist species richness.

2. Material and methods

2.1. Agricultural data

We focused on agricultural ecosystems in France, and more particularly on land dedicated to arable crops or grazing livestock, i.e., cattle, sheep, and goats. Hereafter, the area of this land is referred as the agricultural area. These production systems produce three main types of products which are crop products, meat, and milk. We computed two production metrics: arable crop production (hereafter crop production) and production from grazing livestock (hereafter livestock production), both being expressed in terms of edible energy. Since our focus was on the agricultural area and on bird communities within this agricultural area, we divided these metrics by the agricultural area.

We computed production for 244 Small Agricultural Regions (SARs), which had a mean area of 1 418 km^2. French SARs are consistent with administrative boundaries and have homogeneous soil-climatic conditions and agricultural production systems. They have been used with success to model bird community responses to landscape composition (Teillard et al., 2014). Data on the volume of milk production, and on the mass of meat or crop production, were derived from 2010 annual statistics. Since this data set was available only at the Nomenclature of Territorial Units for Statistics (NUTS) 3 level, which have a mean area of circa 5 800 km^2, it was necessary to estimate these data at the SAR level. Assuming crop yield and animal productivity to be uniform within each NUTS 3 level made it possible to do this using SAR-level data on crop surfaces and livestock numbers obtained from the 2010 Agricultural Census. The estimations thus obtained were then converted into edible energy using conversion coefficients (FAO, 2003; ANSES, 2013). Information regarding the estimation process and validation can be found in Dross et al. (2017). The maps of computed production are available in Appendix A in Supplementary materials.

2.2. Bird data

We focused on common birds, which are widespread and commonly surveyed (Jiguet et al., 2012). They are also considered an accurate gauge for measuring environmental health (Gregory and van Strien, 2010) and are generally sensitive to change (Jiguet et al., 2007). Also, because they are rather high in the food chain, they may reflect changes occurring in other taxa (Wilson et al., 1999). We focused on 74 common bird species, listed in Table C-1 in Supplementary materials. Some species were classified as habitat generalist or farmland specialist species following Jiguet et al. (2012). Farmland specialist species could be further classified into arable specialist or grassland specialist species following Teillard et al. (2014).

All bird data were taken from the French Breeding Bird Survey (FBBS). The FBBS is a nationwide, standardized monitoring program conducted by skilled volunteer ornithologists who count breeding birds in randomly selected sites each spring (Jiguet et al., 2012). Each FBBS site consists of a 2 × 2 km square, in which 10 point counts are evenly distributed and placed no less than 200 m apart. All point counts are unbounded, and observers record every individual bird either heard or seen, along with the distance of contact (< 25 m, 25–100 m, > 100 m), during a 5-min survey conducted twice every spring (before and after May the 8th, at least 4 weeks apart).

We computed five bird community descriptors: two trait-based metrics and three metrics based on particular species groups. The latter metrics were the number of generalist species (generalist SR), the number of grassland specialist species, and the number of arable specialist species. The two trait-based metrics were the Community Trophic Index (CTI) (Princé et al., 2013; Teillard et al., 2015) and the Community Specialization Index (CSI) (Devictor et al., 2008). The CTI discriminates between communities with more granivorous species, which are at a low trophic level, and communities with more insectivorous and carnivorous species, which are at a high trophic level. It is computed as the mean of the species trophic indices (STI) of the species present weighted by the proportion of each species in the community. Species trophic indices are determined on the basis of the species' diet, specifically, the proportions of plants, invertebrates, and vertebrates that the species consumes (based on Perrins and Cramp, 1998). The CSI differentiates between communities dominated by habitat specialists, which are at a high specialization level, and highly disturbed communities, which are dominated by generalists and are at a low specialization level (Devictor et al., 2008). It is computed as the mean of the species specialization indices (SSI) of the species in the community. Species' STI and SSI are given in Supplementary Tables B.1 to B.4.

We computed all five bird community descriptors for 516 sites of the FBBS that had a least half their area in agricultural land (Fig. 1a and b). These FBBS sites were identified by computing the share of area usable for grazing or under arable or fodder crop cultivation for each FBBS site in databases provided by Sausse et al. (2015). As agricultural activities are relatively slow changing, and since our aim was not to study potential temporal trends or inter-annual variability of the measured metrics, we used bird data collected from 2010 to 2013 and averaged retained metrics for each site across all sampled years in this period.

For each year and each site, we computed abundances for each species in 3 steps:

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