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Pesticide doses, landscape structure and their relative effects on farmland birds

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ABSTRACT

Agricultural changes related to the intensification of farming practices and the simplification of landscape elements often occur simultaneously. Their respective effects on biodiversity are thus difficult to disentangle and are poorly understood. This study assessed the relative contribution of each component of agricultural intensification on taxonomic and functional bird communities.

The bird communities studied were composed of 70 species, both farmland and non-farmland birds, found in 66 fields covering three main cereal departments of France. Herbicide dose was related to measurable negative effects on the Community Specialization Index (CSI). Overall, the proportion of habitat specialists, particularly of herbivorous species, decreased, and the proportion of generalists increased as pesticide doses increased. Pesticides also had a positive effect on total abundance and richness, whereas no influence of insecticide or fungicide doses could be detected. Landscape simplification was associated with a loss of bird species diversity and an increase in the CSI.

Our findings suggest that the intensification of agriculture in this area, as reflected by increasing pesticide doses, modified communities by homogenizing species assemblages, whereas landscape element simplification led to the selection of only a few typical farmland birds enabled to persist in a simplified arable landscape. These results highlight the importance of combining taxonomic with functional diversity indices to fully understand changes in communities that occur in response to agricultural intensification.

1. Introduction

In farmland landscapes across the world, continuous declines of animal and plant populations, as well as the simplification of communities associated with the loss of certain ecosystem services, are important conservation issues (Swift et al., 2004; Green et al., 2005). At the field level, agricultural intensification, reflected by increasing chemical inputs and field areas and decreasing crop diversity, leads to increased yield, whereas at the farm level, the spread of cropped areas results in a loss and fragmentation of natural and semi-natural habitats (Doxa et al., 2012). One of the most debated aspects of intensification is the use of pesticides, due to their potential direct and indirect consequences at the individual, population and community levels (Guerrero et al., 2011; Mitra et al., 2011). Numerous studies have addressed this issue using different methodologies. Toxic effects of chemicals can arise rapidly after treatment (Mitra et al., 2011), whereas indirect effects of pesticides on populations usually occur after one or several years of treatment. Some ecological studies have tried to assess the total effects of pesticides (i.e., both direct and indirect effects) by comparing biodiversity between differently managed agro-ecosystems represented by low and high input levels (e.g., organic versus conventional; Hole et al., 2005; Bruggisser et al., 2010) or by analyzing biodiversity along a gradient of pesticide inputs. However, these studies have not addressed the short- and long term effects of pesticides separately or the environmental risks induced by pesticide doses applied explicitly. For wheat crops, the intensity of pesticide treatment varies between farmers (Burger et al., 2012). Farmers can follow a systematic treatment plan by using the maximum recommended doses to prevent pest development. Others adapt their treatments based on their observations, which results in the use of a lower pesticide dose, adjusted to the prevailing pest

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level (Jørgensen et al., 2008). The potential toxicity of products can also vary, with relatively highly toxic products causing more severe effects on bird populations than less toxic products (Bouvier et al., 2010). Treatment schemes for a given pesticide group can also be farm-specific. For instance, the variation in insecticide use is higher compared with that of herbicide and fungicide treatments (Freier et al., 2008). Finally, farmers can treat only a portion of the field and leave the other part untreated. To better reflect the consequences of pesticide use practices on biodiversity, the present study assessed the effects of pesticide doses while accounting for all active substances used, the recommended application rate and the percentage of the treated area.

Many studies have focused either on one or a few species (e.g., Potts, 1986; Morris et al., 2005), while others studied the fate of the community using measures of taxonomic diversity and abundance (Verhulst et al., 2004; Geiger et al., 2010) but rarely structural and functional features of biological communities (Guerrero et al., 2011). At the species level, Filippi-Codaccioni et al. (2010) proposed the use of the specialist–generalist concept and the continuous measure of habitat specialization (Julliard et al., 2006). Farmland specialists are predicted to be more affected by intensive practices than generalists, as they are more susceptible to toxic effects and habitat degradation than generalists, which can breed and shift to other resources. This study used a measure of species and community habitat specialization as a predictor of bird responses to the overall effects of pesticides. To assess the responses of birds to pesticide treatments, we investigated the effects of insecticides, herbicides and fungicides according to species diet preferences. Pesticides can reduce food resources directly (e.g., fewer non-cultivated fruits and seeds in herbicide-treated fields) or indirectly through cascading effects on the trophic chain (e.g., fewer insects in herbicide-treated fields due to the reduction of insect-attracting plants), hence reducing bird abundance. Finally, apart from the role of field practices and pesticides, the simplification of landscapes, with increased areas of arable land and the loss of remnant or semi-natural vegetation, can have notable effects on bird populations (Pain and Pienkowski, 1997; Devictor and Jiguet, 2007; Haslem and Bennett, 2008; Kleijn et al., 2009). Our analyses thus accounted for landscape and field characteristics to assess the relative effects of pesticide input on bird community richness, abundance, and composition. Increasing doses of herbicide and non-herbicide treatments were predicted to reduce abundance, richness, habitat specialization level and the diet of bird species and communities during both the year of treatment and afterwards. The responses of the most abundant bird species to distinct pesticide groups, i.e., insecticides, fungicides and herbicides, were then evaluated. We predicted that species with more specialized diets would be less abundant in fields treated with high doses of pesticides targeting its food resources. We conclude by discussing the possible role of landscape heterogeneity in mitigating the effects of farming intensification and pesticides on bird species and communities.

2. Materials and methods

This study covered 66 cereal fields located in three French departments (27 fields in Yonne, 12 in Charente-Maritime and 27 in Seine-et-Marne) (Fig. 1). Although the crops represent a significant proportion of the studied departments (>25% of the area), they also include different habitats, such as heterogeneous arable landscapes like pastures and small fields interspaced by bushes and woody areas, and other more natural lands. The fields sampled were thus located in both heterogeneous (complex) and intensive (simple) landscapes (cf. Section 2.3). For homogeneity purposes, we selected fields that were cropped with winter wheat or spring and winter barley for two consecutive years but differed in the amount of pesticides applied and other field practices (Table 1).

2.1. Bird counts and indices

Two point counts per field were located along the field margin at least 250 m apart to avoid double counting of birds. Point counts were surveyed twice in the springs of 2008, 2009 (in Seine-et-Marne) and 2010 (in Yonne and Charente-Maritime), once before and once after the 8th of May, with 4–6 weeks between the two counting events, following the standardized French sampling method (French Breeding Bird Survey (FBBS); Jiguet et al., 2011). This sampling method allows the most common sedentary and migratory breeding birds to be detected. Bird counts were carried out in the morning, from dawn to midday, under favorable weather conditions (i.e., windy, cloudy, or rainy weather was avoided) by three experienced bird observers who covered one department each. Every bird species heard or seen around the observer during a 5-min period was recorded (except birds flying over). Birders counted the birds present inside and outside the fields (on field edges and adjacent habitats), as we were interested in both farmland specialists and other species breeding in adjacent habitats. As the detectability of birds is influenced by the distance to the observer, only those birds recorded in a radius of 100 m around the observer were retained. Among all birds observed, four species were excluded from the analysis: gray partridge *Perdix perdix*,

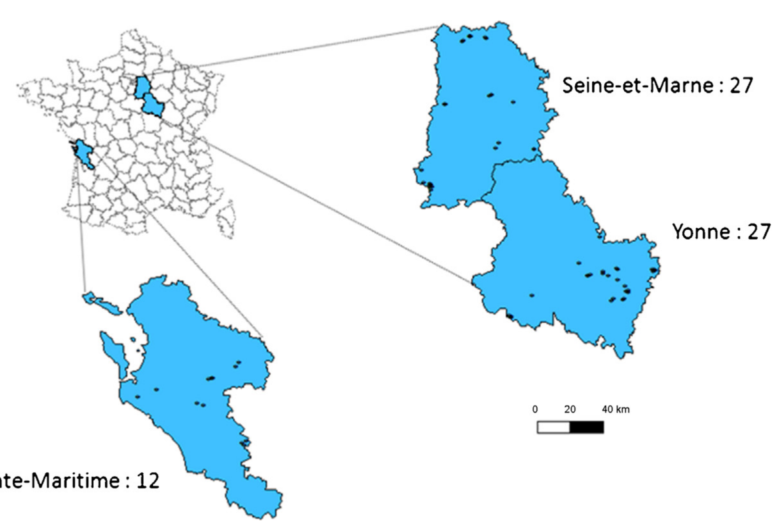

Fig. 1. Location of the 66 fields sampled within the three departments studied (Charente-Maritime, Yonne and Seine-et-Marne). Each dot represents one field.