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Relative effects of landscape composition and configuration on multi-habitat gamma diversity in agricultural landscapes

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ABSTRACT

Landscape composition and configuration are considered important factors influencing biodiversity in agricultural landscapes. Evaluating the relative importance of each component is complicated because they are often correlated. Overcoming this problem could lead to a better understanding of the mechanisms that drive biodiversity and help to determine effective actions. Usually, landscape-biodiversity relationships are studied at the local scale for a single habitat type (alpha diversity). However, for a better understanding of ecological processes at the landscape scale, it is also important to look at the overall diversity at the landscape level, including all habitat types. The present study was conducted to determine the relative effects of landscape composition and configuration on multi-habitat gamma diversity of carabid beetles and vascular plants in an agricultural region of western France. Twenty 1 km^2 landscapes were sampled for plants and carabids. Data from 10 sampling sites representing crop fields, grasslands and woody covers in each landscape were pooled to obtain the total multi-habitat gamma diversity. Results showed that both landscape composition and configuration influenced carabid communities, while only landscape composition affected plant communities. Carabid species richness increased with increasing length of edge between crops and grasslands. Plant richness was negatively and positively affected by the percentage of crops and grasslands respectively. Carabid species composition was more dissimilar between landscapes with increasing difference in percentage of woody covers and crops, and length of grassy-crop edge. Plant species composition was more dissimilar between landscapes with a greater difference in percentage of crops. These results suggest grassy-crop adjacencies may enhance processes of resource complementation between habitats for carabids, while habitat availability and quality are the main factors for plants. This approach provided new insights for sustaining overall biodiversity in agricultural landscapes: *e.g.* encourage adjacencies between grasslands and crop fields and continue to subsidise grasslands for plant diversity.

1. Introduction

As agriculture occupies approximately 75% of Europe, much of Europe's biodiversity is found in farmed landscapes (Benton et al., 2003; Robinson and Sutherland, 2002). Maintaining biodiversity and its associated ecosystem services in agricultural landscapes has become a major social, economic and political issue worldwide (Le Roux et al., 2008; Millennium Ecosystem Assessment, 2005; Robinson and Sutherland, 2002). Landscape composition, *i.e.* the relative proportion of habitat types, and landscape configuration, *i.e.* the spatial arrangement of these habitats, are thought to be important factors for sustaining and restoring biodiversity in agricultural areas (Fahrig et al., 2011).

Evaluating the relative effects of landscape composition and configuration on biodiversity allows an understanding of the mechanisms that drive landscape effects on biodiversity (Ewers and Didham, 2006; Fahrig, 2003; Fahrig et al., 2015), and allocation of limited conservation resources to the most effective actions, *i.e.* either increasing the areas of some important habitat types or targeting actions to achieve the optimum landscape configuration (Boitani et al., 2007; Fahrig et al., 2015; Lindenmayer and Fischer, 2007; Smith et al., 2009). However, in studies of landscape-biodiversity relationships that explicitly considered landscape

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configuration (*e.g.* Concepción et al., 2012; Hendrickx et al., 2007; Holzschuh et al., 2010), the landscape metrics used to measure it are usually "naturally" correlated with habitat amount (Fahrig, 2003). This impedes our ability to isolate the independent effects of landscape composition and configuration (Fahrig et al., 2011; Pasher et al., 2013). To overcome this problem, a few studies have used a pseudo-experimental design (Duflot et al., 2015; Fahrig et al., 2015; Flick et al., 2012), where study landscapes are chosen such that the correlations between the measures of composition and configuration are minimized (Pasher et al., 2013). However, this method is limited when more than two landscape descriptors are used, as it is extremely difficult to find a set of landscapes across which three or more landscape descriptors are not intercorrelated. Consequently, knowledge on the independent effect of landscape composition and configuration is scarce.

An additional issue in measuring the effect of landscape structure on biodiversity is the spatial scale at which biodiversity is measured. Most studies have evaluated local biodiversity, following the focal-patch approach (alpha diversity, see Thornton et al., 2011 for a review). In so doing, they measured the effect of the surrounding landscape on the biodiversity of individual patches or sample sites of a given cover type (Bennett et al., 2006; Ernoult and Alard, 2011; Thornton et al., 2011). However, it is also important, in a conservation perspective, to look at the overall diversity at the landscape scale, *i.e.* the gamma diversity (Bennett et al., 2006). Although several studies have assessed gamma diversity, in most cases it was assessed only in a single habitat type within the landscape (Grasslands: Dauber et al., 2003; Forests: Radford et al., 2005; Hedgerows: Ernoult et al., 2006; Millan-Pena et al., 2003; Crops: Concepción et al., 2012). Because species composition varies among habitat types, these approaches only partially reflect the total biodiversity in the landscape. To evaluate the effect of landscape pattern on biodiversity over the whole landscape, diversity needs to be measured in all habitat types (hereafter, 'multi-habitat gamma diversity'). To our knowledge only a few studies have done this (Duflot et al., 2015; Duflot et al., 2014; Hendrickx et al., 2007; Liira et al., 2008). Hence the relative effects of landscape composition and configuration on landscape-scale gamma diversity remain largely unknown.

The present study was conducted to determine the relative effects of landscape composition and configuration on multi-habitat gamma diversity of carabid beetles and vascular plants in an agricultural region of western France. We further analysed the data from Duflot et al. (2015), where we tested the influence of semi-natural covers. Amount and configuration of these semi-natural covers did not explain variation in multi-habitat gamma diversity of either taxon (Duflot et al., 2015). Here, we examine more complex functional landscape representation, using community-derived vegetation cover categories. Landscape composition was percentage of the landscape in woody covers, grasslands, and crop fields, while landscape configuration was the total length of edge between these three cover types. We tested the effects of these six landscape descriptors on two aspects of biodiversity: species number and species composition, measured respectively by total species richness and Sørensen dissimilarity index. Results are discussed in terms of ecological processes and potential relevant actions for increasing biodiversity in agricultural landscapes.

2. Methods

2.1. Study area and landscape selection

The study was located in an agricultural area in the Ille-et-Vilaine department (6 775 km^2), Brittany, western France (Fig. 1). The area is dominated by mixed dairy farming and cereal production. The farmlands are interspersed with woody elements (woodlands and hedgerows), and are comprised of annual crops (mostly winter cereals but also maize), and temporary and permanent grasslands. A land cover map of the study area, derived from remote sensing data (Hubert-Moy et al., 2012), was divided into square moving windows of 1 km^2, using Chloe 2012 (Boussard and Baudry, 2014). From among all candidate windows/landscapes, we selected 20 square 1 km^2 non-overlapping landscapes (Fig. 1). The edge-to-edge distance to nearest landscape varied from 2.0 to 28.0 km (mean = 5.9 km). The landscape selection aimed at minimizing the correlation between the percentage area of semi-natural cover (permanent grasslands, woodlands and hedgerows) and the length of edge between semi-natural cover and crops (including annual crops and temporary grasslands), while maximizing the extents of each of these gradients (Eigenbrod et al., 2011; Pasher et al., 2013). A detailed description of the maps and of the landscape selection procedure is in Duflot et al. (2015). The landscape size (1 km^2) was chosen as a

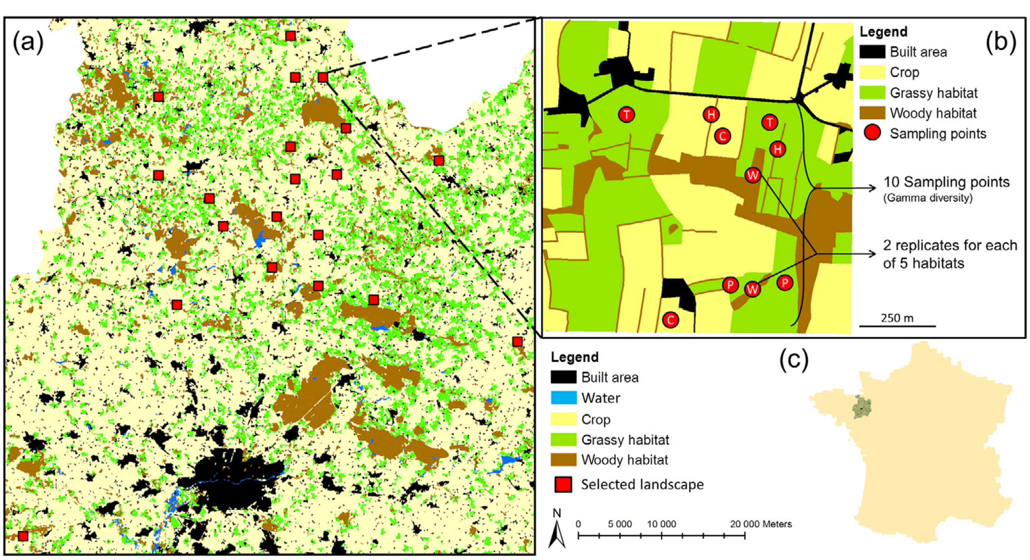

Fig. 1. (a) map of the study area, (b) representation of the sampling design for one of the 1 km^2 selected landscapes, and (c) location of the study area in France. The sampled cover types are W: woodland, H: hedgerow, P: permanent grassland, T: temporary grassland, C: crop.