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Research article

Time-lagged response of carabid species richness and composition to past management practices and landscape context of semi-natural field margins

Audrey Alignier [a, b, 1], Stéphanie Aviron [a, b, *, 1]

[a] INRA, UMR 0980 BAGAP, BP 84215, 35042 Rennes, France
[b] LTER - « Zone Atelier Armorique », Rennes, France

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ABSTRACT

Field margins are key features for the maintenance of biodiversity and associated ecosystem services in agricultural landscapes. Little is known about the effects of management practices of old semi-natural field margins, and their historical dimension regarding past management practices and landscape context is rarely considered. In this paper, the relative influence of recent and past management practices and landscape context (during the last five years) were assessed on the local biodiversity (species richness and composition) of carabid assemblages of field margins in agricultural landscapes of north-western France. The results showed that recent patterns of carabid species richness and composition were best explained by management practices and landscape context measured four or five years ago. It suggests the existence of a time lag in the response of carabid assemblages to past environmental conditions of field margins. The relative contribution of past management practices and past landscape context varied depending on the spatial scale at which landscape context was taken into account. Carabid species richness was higher in grazed or sprayed field margins probably due to increased heterogeneity in habitat conditions. Field margins surrounded by grasslands and crops harbored species associated with open habitats whilst forest species dominated field margins surrounded by woodland. Landscape effect was higher at fine spatial scale, within 50 m around field margins. The present study highlights the importance of considering time-lagged responses of biodiversity when managing environment. It also suggests that old semi-natural field margins should not be considered as undisturbed habitats but more as management units being part of farming activities in agricultural landscapes, as for arable fields.

1. Introduction

Old semi-natural field margins are key features of agricultural landscapes, especially in northwestern Europe where hedgerows are a predominant type of semi-natural habitats (Marshall and Moonen, 2002; van der Zanden et al., 2013). These field margins refer to the herbaceous strip situated between the limit of the arable field and the lines of trees (or shrubs) constituting the hedgerow (Le Coeur et al., 2002). They have a wide range of purposes, including agronomical, ecological and cultural functions (Burel and Baudry, 1995; Baudry et al., 2000; Marshall and Moonen, 2002; Marshall, 2004). They can benefit crop growth and husbandry by acting as windbreak and shelter respectively (Campi et al., 2009; Forman and Baudry, 1984; van Laer et al., 2014), and contribute to reduce soil erosion (Ali and Reineking, 2016) and pesticide drift from neighboring crops (Marshall and Moonen, 2002). Semi-natural field margins are also critical landscape features for biodiversity, agroecosystem functioning and associated ecosystem services (Morandin and Kremen, 2013; Morandin et al., 2014; Pywell et al., 2015; Vickery et al., 2009). They support farmland biodiversity by providing overwintering sites, food resources and shelters for flora and fauna (Hinsley and Bellamy, 2000; McCollin et al., 2000; Meek et al., 2002; Vickery et al., 2009). High levels of floral diversity and nectar resources in field margins have been especially shown to enhance beneficial arthropods such as pollinators and natural enemies of crop pests (Hannon and Sisk, 2009; Schweiger et al., 2005; van Rijn and Wäckers, 2010). Semi-

* Corresponding author. INRA, UMR 0980 BAGAP, BP 84215, 35042 Rennes, France.
E-mail address: stephanie.aviron@inra.fr (S. Aviron).
[1] Identical contribution of authors.

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natural field margins also contribute to species movements and spillovers by acting as corridors and ensuring connectivity through the landscape (Davies and Pullin, 2007; Dover and Sparks, 2000; Guiller et al., 2016; Hinsley and Bellamy, 2000). As a consequence, the conservation or establishment of field margins in agricultural landscapes has increasingly been advocated to promote biodiversity and the services it provides (Olson and Wäckers, 2007; Pywell et al., 2015).

The growing interest in field margins has lead to a body of research on the factors driving their local biodiversity. At local scale, these studies have mainly focused on assessing the biodiversity of newly established margins depending on their initial botanical composition (seed mixtures) and management regime (cutting, herbicide use) (Baines et al., 1998; Marshall et al., 2006; Meek et al., 2002; Smith et al., 2008; Vickery et al., 2009; Woodcock et al., 2005, 2007). At a larger scale, they have considered the role of landscape heterogeneity for field margin biodiversity (e.g. Balzan et al., 2016; Marshall et al., 2006). However, this research is of limited use to efficiently design land management strategies for existing, old semi-natural field margins, due to two important knowledge gaps regarding these specific landscape elements. First, the management of old semi-natural field margins is often not studied (but see Le Coeur et al., 2002), probably because they are considered as stable and undisturbed habitats. However, as the boundary of agricultural fields, semi-natural field margins are generally managed by farmers for which one of their primary maintenance objectives is weed control. Thus, herbicides or cutting are commonly used to manage the herbaceous layer of field margins (Kleijn and Verbeek, 2000; Marshall, 2004; Roy et al., 2003). Field margins are also subject to drift from adjacent farming operations, such as fertilizing, herbicide use as well as effects from ploughing and grazing (Kleijn and Verbeek, 2000; Marshall, 2004). These factors lead to high levels of disturbances and potential soil nutrient enrichment (Marshall, 2004; Marshall and Moonen, 2002) affecting local environmental heterogeneity. In addition, the effects on biodiversity of the various management regimes applied on field margins have rarely been investigated regarding the surrounding landscape heterogeneity. Landscape influence often exceeds those of local management practices, as demonstrated for agricultural fields (Maisonhaute et al., 2010; Purtauf et al., 2005; Trichard et al., 2013) and field margins (Le Coeur et al., 2002). As a consequence, negative effects of some management practices on semi-natural field margins might be compensated in heterogeneous landscapes, as suggested by Tscharntke et al. (2005) for the biodiversity of agricultural fields. Second, the historical dimension of local management and landscape on biodiversity is rarely considered in field margins' studies. Empirical evidence of time-lagged species responses to past changes in management practices or landscape heterogeneity has accumulated in recent years for various taxonomical groups such as plants (Alignier and Baudry, 2015; Ernoult et al., 2006), vertebrates (Lira et al., 2012; Metzger et al., 2009) and invertebrates (Bommarco et al., 2014; Hanski and Ovaskainen, 2002; Petit and Burel, 1998). There is now a consensus that management or landscape history can strongly affect the current distribution patterns of species in human-dominated landscapes (Essl et al., 2015; Metzger et al., 2009). Thus, the effects of past management practices and past landscape context should be considered, in addition to current local management and landscape context, when designing and optimizing conservation measures of field margins for biodiversity.

This paper assessed the relative influence of current and past management practices and landscape context on the local biodiversity of 101 semi-natural field margins of the Long-Term Ecological Research Site 'Zone Atelier Armorique', northwestern France. The study focused on the species richness and composition of carabid assemblages. Carabid beetles represent an important group among beneficial arthropods in agricultural landscapes and they have been extensively studied (Koivula, 2011; Kromp, 1999; Rainio and Niemelä, 2003). The positive role of field margins for these arthropods is widely recognized (Labruyere et al., 2016) and they respond to effects of both local management practices in fields (grazing, mowing and/or fertilization) (Sotherton, 1985; Woodcock et al., 2007) and landscape heterogeneity related to semi-natural elements (Duflot et al., 2015; Purtauf et al., 2005) or land-use diversity (Ekroos et al., 2010; Maisonhaute et al., 2010). We first hypothesized that including information about local management and landscape context over time improves the explanatory power of carabid species richness and composition models. More specifically, we tested whether there is a time lag in carabid assemblages' response to local and landscape factors, that is carabid species richness and composition should be more related to past field margin management and landscape context than the most recent ones. Second, we assessed the relative contribution of local management practices *versus* landscape factors in order to identify the key factors affecting carabid assemblages locally. Third, we tested the prediction of a stronger influence of landscape context on carabid species richness and composition than local field margin management.

2. Material and methods

2.1. Study area

The study was conducted in a hedgerow network landscape, namely “bocage”, in Brittany, north-western France. This area is located in the “Zone Atelier Armorique”, which is a long term ecological research (LTER) site. Agriculture in this area is mainly characterized by dairy production, the predominant land-uses being permanent and temporary grasslands, winter cereals and maize. Biological data were collected in hedgerow networks located in three sites (“A”, “B” and “C”; 5–10 km distant from each other) selected according to their hedgerow density, average field size and percent cover of annual crops vs. grassland (Burel et al., 1998).

2.2. Carabid sampling

Carabid sampling was conducted in 101 semi-natural field margins distributed in the three sites using pitfall traps. Sampling efficiency of pitfall traps has been found to vary according to several factors including activity of sampled arthropods, trap diameter, or vegetation structure and density (see e.g. Koivula et al., 2003; Topping and Sutherland, 1992). In the present study, such biases were limited as much as possible by using standardized traps (diameter: 9 cm; height: 10 cm) installed in similar vegetation conditions in field margins, i.e. using two pitfall traps (containing a formalin solution 5%) separated by 10 m, in the central part of field margins. Traps were opened continuously and emptied once a week from 19th June 2001 to 18th July 2001 (sites A and C) and from 18th April 2002 to 26th June 2002 (site B). To homogenize, the sampling year was referred as the year N. According to the sampling period, trapped species were mainly spring breeders. Carabid beetles were identified at the species level (Jeannel, 1941, 1942; Trautner and Geigenmuller, 1987), except for the genus *Amara*.

2.3. Monitoring of management practices of field margins

Presence-absence of management practices applied to the herbaceous layer of field margins was monitored every year in the three sites between 1995 and 2002. The focus was put on four types of management practices: grazing with or without cattle trampling,