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Multi-scale effects of agri-environment schemes on carabid beetles in intensive farmland

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ABSTRACT

Agri-environment schemes (AESs) were implemented to reduce the loss of biodiversity in agro-ecosystems. This study aimed to assess whether AESs at either local or landscape scale increase the carabid abundance-activity and species richness. Carabids were sampled in 496 fields in a 430 km^2 study area of central-western France. Based on the extensiveness of the agricultural practices involved, the different AES types were aggregated into three categories (AES_{EXT+}, AES_{EXT++} and AES_{EXT+++}) forming a gradient of extensiveness in farming practices. We sampled 20 fields in each of the three AESs categories. Each AES fields was paired with conventional fields. A series of statistical models were built to test the balance between the effects of AESs on either the carabid abundance-activity or species richness. AESs affected carabid abundance-activity and species richness both locally and at landscape scale (local characteristics having a greater effect than landscape composition). Carabid diversity benefited from AESs only when the most extensive practices were implemented, i.e. organic farming in cereal crops and delayed cutting in alfalfa. In addition, the local effects of organic farming and delayed cutting coverage interacted positively with these AESs at landscape scale. These results demonstrate that non-targeted organisms can benefit from AES management. They further emphasize the need to consider both local and landscape conditions when studying the effects of AESs on biodiversity. As only the most extensive practices had significant effects at both local and landscape scales, management must be planned strategically in space to ensure that AESs are distributed within the landscape to amplify their positive effects.

1. Introduction

Major changes have altered European agricultural landscapes since the Common Agricultural Policy (CAP) aimed to increase food production (Godfray et al., 2010; Pe'er et al., 2014). While crop yields have been improved by generalised use of fertilisers and pesticides (Tilman et al., 2002), there has been a significant loss of biodiversity and negative environmental impacts (such as soil erosion, water pollution) in farmland landscapes (Geiger et al., 2010; Robinson and Sutherland, 2002; Tscharntke et al., 2005). Agri-Environment Schemes (AESs) were introduced by the European Union in 1992 (Henle et al., 2008) to counter such negative environmental impacts. AESs provide financial incentives to farmers in order to promote the adoption of environmentally friendly farming practices adapted to each region (Kleijn et al., 2006a; Whittingham, 2007). Agreements covered by AESs include various intensity reduction measures including management of low-intensity pasture systems, integrated farm management, organic farming, conservation of high-value habitats and conservation of target flagship species (Peach et al., 2001; Perkins et al., 2011).

Evaluating the effect of AESs on taxonomic functional biodiversity is of critical importance in order to promote and increase the effectiveness of AESs (Whittingham, 2007). AESs have been reported to significantly enhance biodiversity (Bengtsson

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et al., 2005; Hole et al., 2005; Kleijn et al., 2006b; Kleijn and Sutherland, 2003). This influence however seems to vary depending on the taxa of interest and the studies. Some studies failed to detect any effects of AESs on biodiversity while other studies detected a decrease of biodiversity (Bradbury and Allen, 2003). The effect of AESs on biodiversity may also be influenced by the characteristics of the landscape, such as composition and configuration (Fuentes-Montemayor et al., 2011; Smith et al., 2010), and heterogeneity (Whittingham, 2011) at various scales. Indeed, AESs located in heterogeneous landscapes and in areas supporting high levels of biodiversity are likely to yield greater benefits than those in more homogeneous landscapes (Concepción et al., 2008). Consequently, studies should consider both field and landscape scales in order to give a more balanced and a more relevant assessment of the effects of AESs on biodiversity (Tuck et al., 2014). However, little research has been undertaken yet to determine the effects of the different AESs at landscape scale compared to their local effect (Henckel et al., 2015).

This study used carabids to assess whether AESs increase species abundance and species richness in farmlands. Carabids are known to be highly sensitive to changes in habitat (Magura et al., 2004; Melnychuk et al., 2003). Carabids are not directly targeted by any AES in France, except as a food resource for birds (Vickery et al., 2004). They are potentially important components of functional biodiversity in agro-ecosystems, either as natural enemies of pests or as components of trophic chains sustaining biodiversity (Thiele et al., 1977). In addition, an increase in beetle abundance or species richness may improve ecosystem resilience (Hooper et al., 2005). Crop pest consumption by carabids was found to be positively correlated to prey abundance (Menalled et al., 1999), while species richness may improve community functional resilience as well as biodiversity conservation (Tilman, 1996; Woodcock et al., 2014). Agricultural practices such as tillage or pesticide use have been shown to affect carabid abundance either directly, through mortality and emigration, or indirectly, by changing local microhabitat conditions (Cole et al., 2002; Hatten et al., 2007; Kromp, 1999). A recent meta-analysis comparing organic and conventional practices (Tuck et al., 2014) showed that organic farming had an overall positive effect on arthropods including carabids, although results varied between studies (Eyre et al., 2012; Garratt et al., 2011; Hole et al., 2005).

We evaluated the effect of a broad set of AESs on carabid abundance-activity and species richness in a study area (430 km^2) located in central-western France. Half of this study area was designated as a NATURA 2000 site (since 2003). In 2010, there were agreements in 10 different AES contract types implemented in our study area. The variety of AES types and the large area under contract (over 9000 ha) allow investigating the effects of AESs at local (field) and landscape scales, while taking into account the local environmental factors and landscape structure as in previous studies (Concepción et al., 2012, 2008). We classified AESs a priori, according to their degree of extensiveness (in terms of farming practices), and analysed, in addition to AES effect at local scale, the landscape structure at different spatial scales and the possible influence of AES present in the landscape. Consequently, the aims were (i) to quantify the local effect of the different categories of AESs (AES_{local}) on carabid diversity; (ii) to determine whether the age of AES and the landscape structure modulate the effect of AES_{local} and (iii) to determine whether the area covered by AESs at landscape scale ($AES_{landscape}$) interacts with the local effects on carabid diversity.

2. Materials and methods

2.1. Study area and AES classification

The study was conducted in the LTER Zone-Atelier "*Plaine & Val de Sèvre*" which covers an area of about 43,000 ha in central-western France (46.11°N, 0.28°W). This is an agricultural area with about 12,500 fields mainly used for the production of cereals (wheat: 36.38% ± 0.41 of the total area—mean value ± SD in 2009–2010). Perennial crops represented 11.44% ± 0.03, including alfalfa (3.14% ± 0.02) and grassland (8.30% ± 0.02). Land use has been recorded annually since 1995 and mapped onto a GIS (ArcGis 9.3—ESRI Redlands, CA, USA). Since 2004 a large number of agri-environment measures of various types have been implemented in the entire study site by the CNRS research laboratory of Chizé (Bretagnolle et al., 2011), covering up to one third of the study area (in 2013). Overall, 10 different types of AESs have been implemented (see Table 1 for details) and were compared to conventional management.

Based on the extensiveness of the agricultural practices involved, the different AES types were aggregated into three categories for each category of crop (AES_{EXT+}, AES_{EXT++} and AES_{EXT+++}, Table 1; see also (Brodier et al., 2014)), creating a gradient of

Table 1
Average characteristics (mean ± standard deviation) of AESs implemented, their categories and the mean carabid diversity per field.

Practices	AES category	Number of fields sampled	Field area (ha)	AES age (years)	Carabid abundance-activity	Carabid species richness
Conventional (no AES)	Conventional	Wheat: 147 Alfalfa: 64 Meadow: 46	Wheat: 5.9 ± 4.6 Alfalfa: 2.9 ± 1.4 Meadow: 2.7 ± 2.8	–	Wheat: 64 ± 123 Alfalfa: 61.4 ± 78.8 Meadow: 10.4 ± 13.2	Wheat: 7.4 ± 3.5 Alfalfa: 8.0 ± 4.0 Meadow: 3.9 ± 2.7
Reduction of herbicides Reduction of fertilisers Reduction of herbicides and fertilisers	AES_{EXT+}	57	4.7 ± 2.5	3.0 ± 09	50.6 ± 46.8	75 ± 3.7
no-tillage	AES_{EXT++}	52	5.9 ± 4.3	5.1 ± 0.7	50.5 ± 78.9	7.41 ± 3.4
Organic farming	AES_{EXT+++}	35	5.6 ± 3.8	2.4 ± 1.7	98.6 ± 107.5	9.6 ± 4.4
Arable reversion to meadow Arable reversion to alfalfa	AES_{EXT+}	Alfalfa: 34 Meadow: 9	Alfalfa: 3.8 ± 7.1 Meadow: 2.9 ± 1.5	Alfalfa: 3.5 ± 1.1 Meadow: 3.0 ± 1.4	Alfalfa: 60 ± 100.1 Meadow: 20.1 ± 36.4	Alfalfa: 8.0 ± 4.1 Meadow: 4.0 ± 3.3
Low-intensity meadow management	AES_{EXT++}	Alfalfa:5 Meadow: 13	Alfalfa: 2.3 ± 2.2 Meadow: 2.4 ± 1.9	Alfalfa:– Meadow: 4.5 ± 1.0	Alfalfa: 27.8 ± 23.3 Meadow: 11.2 ± 12.3	Alfalfa: 6.8 ± 4.2 Meadow: 4.0 ± 2.3
Delayed cutting Set-aside	AES_{EXT+++}	Alfalfa: 10 Meadow: 24	Alfalfa: 3.4 ± 3.0 Meadow: 1.8 ± 1.2	Alfalfa: 4.7 ± 1.2 Meadow: 4.7 ± 0.9	Alfalfa: 94 ± 87.4 Meadow: 8.3 ± 11.2	Alfalfa: 9.1 ± 4.2 Meadow: 3.8 ± 2.2