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Local more than landscape parameters structure natural enemy communities during their overwintering in semi-natural habitats

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ABSTRACT

Semi-natural habitats (SNH) play key roles for arthropod natural enemy communities in agricultural landscapes. Positive relationship between landscape complexity and biological pest control is now well known and is assumed to mainly come from the fact that natural enemies use semi-natural habitats for overwintering. However, the respective role of each type of semi-natural habitats in the landscape in shaping natural enemy communities and pest control remains poorly studied. Moreover, the relative importance of environmental variables in structuring these communities remains largely unexplored. The main purpose of this study was to provide an insight into the types of SNH natural enemies use for overwintering as well as the effects of local and landscape characteristics in structuring their overwintering communities. Overwintering natural enemy communities were sampled in 7 types of SNH (i.e., forest interior (FI), South-facing forest edge (FES), North-facing forest edge (FEN), dry unmanaged grassland (UGD), wet unmanaged grassland (UGW), managed grass strip (CAP grass strip) either dominated by monocotyledonous plants (MGM) or by dicotyledonous plants (MGD)). Abundance, species richness as well as community composition of each group of enemies were then explained by local and landscape parameters to assess their relative importance. In our study, overwintering natural enemy communities differed markedly among types of SNH. Explanatory variables proved to have a decreasing influence in shaping natural enemy community compositions from the local (i.e. in the emergence trap perimeter, in 3 m- and 15 m-radius circular zones around it) to the immediat landscape (within 30 m- and 60 m-radius circular zones) and then the mid-distant one (within 120 m-, 250 m- and 500 m-radius circular zones). We particularly found that management intensity and vegetation height were very strong drivers of natural enemy diversity at the local scale. Managed CAP grass strips turned out as the main source habitat of beneficials in the spring while forests acted quite negatively on local abundances of most of the beneficials studied. On the opposite, medium arable land and grassland surface areas proved to be favourable for them as a whole in the immediat landscape, while in the mid-distant landscape, fallows favoured aphidophagous hoverflies and arable lands did so for spiders. Our results highlight the need for a more precise description of SNH in the landscape if we are to mechanistically understand the role of compositional landscape heterogeneity on zoophagous arthropod populations and to give relevant guidelines to design landscapes favouring natural biological pest control.

1. Introduction

Agricultural intensification, characterized by monocrops supplied with high amounts of agrochemical inputs, homogeneous landscapes and high fragmentation of semi-natural habitats, has been recognized as a main driver of biodiversity and ecosystem

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services losses (Robinson and Sutherland, 2002; Tscharntke et al., 2005). For instance, the harmful effects of pesticides on second pest outbreaks and biological control are well documented (Geiger et al., 2010; Jonsson et al., 2012). There is therefore a need to design a more ecologically sound form of agriculture relying on ecological functions and processes if we are to simultaneously secure food production while minimizing environmental impacts (Bommarco et al., 2013). There is a growing body of evidence suggesting strong positive relationships between landscape complexity (i.e., proportion of semi-natural habitats in the landscape) and biological pest control (Chaplin-Kramer et al., 2011; Veres et al., 2013). Semi-natural habitats (SNH) such as hedgerows, moors, natural grasslands, forests or field margins, display key ecological functions for natural enemies during the whole year because they are more stable and less disturbed habitats than cultivated ones. Indeed, overwintering arthropods are much more abundant and diversified in SNH than in arable fields (Pfiffner and Luka, 2000).

Several hypotheses have been formulated to explain the underlying mechanisms explaining their positive effects on natural enemies. SNH may provide alternative hosts or prey, pollen or nectar (Landis et al., 2000). They may also be overwintering habitats and refuges from disturbance (Pfiffner and Luka, 2000), allowing natural enemy populations to build-up and therefore enhance their impact on pest populations (Landis et al., 2000). Yet, very few studies have tested these hypotheses especially from a community perspective. Moreover, the majority of studies examining the effects of landscape complexity on biodiversity and associated ecosystem services, considered non-crop habitats as the same land use class assuming similar functions within and between SNH types (Chaplin-Kramer et al., 2011; Woltz et al., 2012). However, SNH can strongly differ over time and space due to variations in plant species richness, soil characteristics, vegetation structure or microclimate and can thus have different effects on natural enemy communities (Landis et al., 2000; Pywell et al., 2005). Moreover, the role of SNH types on overwintering natural enemies and the main local and landscape drivers of natural enemies distribution during the winter have been little explored (Schmidt et al., 2005; Griffiths et al., 2008; Geiger et al., 2009). Thus, refining categorization of land covers and gaining information about the role of SNH types on natural enemies and about the main local and landscape drivers of natural enemies distribution, would allow a better mechanistic understanding of ecological processes behind the patterns observed at both the farm and landscape scales (Veres et al., 2013). This is even more critical when considering the overwintering phase of natural enemies for which the majority is assumed to depend on SNH for overwintering (Häni et al., 1998). Thus, given that majority of arthropod pests are active as early as the spring, the spatial distribution of these overwintering habitats within the landscape is of major importance for early control of crop pests (Chiverton, 1986; Tenhumberg and Poehling, 1995). Knowing the exact role of well described overwintering habitats on population dynamics and community structure of natural enemies would allow to manipulate, at the farm level, SNH in agricultural landscapes to increase and optimize natural pest control services (Gardiner et al., 2009; Rusch et al., 2012).

The main purpose of our study was to provide an insight into the role of several SNH types considered at the farm scale, as reservoirs of overwintering natural enemies, and to investigate the effects of local and landscape characteristics on these communities. Particularly, we addressed the following questions:

(i) Does the structure of natural enemy communities differ among habitat types?
(ii) Are there key habitat types which can be considered as major providers of natural enemies on farmland?
(iii) Which local and landscape characteristics mainly drive natural enemy assemblages and diversity?

To do so, we conducted a study based on emergence data collected in various SNH in an agricultural landscape of South-Western France, with highly variable management intensity, soil characteristics and plant composition according to the different SNH types.

2. Materials and methods

2.1. Study area

The study was conducted from January to July 2006 in South-Western France (43°N, 1°E), in the “Gascony Hills and Valleys” site, straddling Gers and Haute-Garonne Departments, which is one of the long term observation sites of the European LTER Network (LTER-Europe). The study region is a hilly area (200–400 m alt.) within a sub-Atlantic climate exposed to Mediterranean and mountain influences. Thus, the area is characterized by hot summers (monthly means for May to July 2006 of 21 °C, maximum temperature 27.3 °C, minimum temperature 12.8 °C and precipitation 144 mm) and cool winters (monthly means for January and February 2006 of 3.7 °C, maximum temperature 9.7 °C, minimum temperature −1.8 °C and precipitation 59 mm). The landscape is mainly composed with crop fields (winter wheat, winter barley, sunflower, sorghum, oilseed rape) and grasslands either natural or sown. Scattered fragmented oak forests represent the minor part (less than 20%) of the landscape.

2.2. Sampling sites and study design

All sampling sites were located on three adjoining hilly farms, within a 1 km-radius, in order to assess the respective influence of both local and landscape characteristics. Local parameters concerned the trap scale: both inside the trap perimeter and within its immediat surroundings, i.e. in 3 m- and 15 m-radius circular zones. Landscape parameters were evaluated within 30 m- and 60 m-radius circular zones for the immediat landscape ones, and within 120 m-, 250 m- and 500 m-radius circular zones for the mid-distant landscape ones. By doing so, we could grasp the hierarchy of environmental conditions upon which farmers can have a hold over in their management. All the SNH we studied were included into four main categories of the level 2 of CORINE Land Cover (CLC) classification (Bossard et al., 2000): (i) pastures, (ii) heterogeneous agricultural areas (i.e. Annual crops associated with permanent crops, Complex cultivation patterns, Land principally occupied by agriculture with significant areas of natural vegetation, of level 3 of CLC classification), (iii) shrub and/or herbaceous vegetation associations (i.e. Natural grasslands, Sclerophyllous vegetation, Transitional woodland-shrub, of level 3 of CLC classification), and (iv) forests (i.e. Broad-leaved forests, of level 3 of CLC classification). A fifth category was present in the landscape but not studied, the arable land category (i.e. Non-irrigated arable land, of level 3 of CLC classification).

Seven types of SNH were studied: forest interior (FI), South-facing forest edge (FES), North-facing forest edge (FEN), dry unmanaged grassland (UGD), wet unmanaged grassland (UGW), managed grass strip (CAP grass strip) either dominated by monocotyledonous plants (MGM) or by dicotyledonous plants (MGD). Therefore they were representative of the great majority of the SNH that occur on farms of this LTER site. Apart forest-copse patches under 15 to 50 year-rotation management for fire wood, natural grasslands were the sole sampling sites under regular and direct management activities (lightly grazed by cattle) but they were unsown and unfertilized. Each of the 7 types of SNH was repeated 7