Agriculture, Ecosystems and Environment 268 (2018) 34–43

Contents lists available at ScienceDirect

Agriculture, Ecosystems and Environment

journal homepage: www.elsevier.com/locate/agee

Connectivity of cropped *vs.* semi-natural habitats mediates biodiversity: A case study of carabid beetles communities

Stéphanie Aviron[a,b,*], Etienne Lalechère[a,c], Rémi Duflot[a,b], Nicolas Parisey[b,d], Sylvain Poggi[b,d]

[a] UMR BAGAP, INRA, Agrocampus Ouest, ESA, BP 84215, F-35042 Rennes, France
[b] LTER Zone-Atelier Armorique, F-35042 Rennes, France
[c] IRSTEA – Lisc, F-63178 Aubière, France
[d] UMR IGEPP, INRA, Agrocampus Ouest, Université de Rennes 1, F-35650 Le Rheu, France

ARTICLE INFO

Keywords:
Crop connectivity
Landscape context
Hedgerows
Carabid abundances
Dispersal ability

ABSTRACT

Green-veining policies aiming at restoring biodiversity in agricultural landscapes mainly focus on the connectivity of semi-natural habitats. However, little is known about the potential role of crop connectivity for the biodiversity using cropped habitats. The goal of the present study was to investigate the effects of habitat connectivity related to annual crops vs. semi-natural habitats (woody elements) on insect biodiversity (carabid beetles) in agricultural landscapes, considering contrasted groups of species in terms of habitat preference and dispersal ability. Results showed that the spatial configuration and connectivity of annual crops in the landscape (here, up to 500 m) can contribute to increased abundance of some groups of carabid species. Spatial continuities between spring and winter crops (in 250 m radius circles) had beneficial effects on farmland species with low mobility (brachypterous) in maize crops, possibly reflecting resource complementation processes. The connectivity of annual crops also had positive effects on abundances of dimorphic farmland species in maize crops and of forest species in woodland, but at contrasted spatial scales (in 250 m *vs.* 50 m radius circles respectively). The present study also revealed antagonistic effects of landscape patterns related to both crops (edge length between winter and spring crops) and semi-natural habitats (percent cover of woodland) on farmland and forest species, highlighting critical issues regarding the conservation of such contrasted ecological species groups in agricultural landscapes.

1. Introduction

Biodiversity loss is a worldwide concern. In agricultural landscapes, conserving farmland biodiversity is crucial not only to stop the overall loss of species, that occurred with land-use intensification (Donald et al., 2001; Benton et al., 2003), but also to ensure the maintenance of functional biodiversity involved in ecosystem services of socio-economic importance, like pollination or pest regulation (Kleijn and Sutherland, 2003; Millenium Ecosystem Assessment, 2005; Biesmeijer et al., 2006; Le Roux et al., 2008). Current society is thus facing a double challenge regarding biodiversity conservation in agricultural landscapes.

Habitat fragmentation - the reduction of habitat area and the increase of habitat isolation (Fahrig, 2003) - has been identified as a main driver of species extinction (Tilman et al., 2001; Fahrig, 2003; Krauss et al., 2010) and of the alteration of important ecosystem functions (Tscharntke et al., 2005a; Ricketts et al., 2008). In agricultural landscapes, semi-natural habitats have been fragmented since the 1950′s due to the loss of hedgerows, woodland or semi-natural grassland that occurred with land-use intensification (Stoate et al., 2001; Robinson and Sutherland, 2002; Hooftman and Bullock, 2012). The connectivity (Taylor et al., 1993) of remaining semi-natural habitat fragments is considered to be particularly critical for species survival in farming landscapes (Schweiger et al., 2005; Bianchi et al., 2006; Polus et al., 2006; Arponen et al., 2013). Connectivity depends on the amount and spatial configuration of habitat patches, and on the presence of elements enhancing (corridors or stepping stones) or impeding (filters or barriers) species movements between habitat patches (Baguette et al., 2000; Moilanen and Hanski, 2001; Ricketts, 2001; Tischendorf and Fahrig, 2001; Schneider et al., 2003; Dennis et al., 2013). Maintaining or restoring habitat connectivity is thus crucial to allow the movements of species between habitat fragments, and to ensure their persistence in fragmented landscapes.

In order to restore habitat connectivity for biodiversity,

* Corresponding author at: UMR BAGAP, INRA, Agrocampus Ouest, ESA, BP 84215, F-35042 Rennes, France.
E-mail address: stephanie.aviron@inra.fr (S. Aviron).

https://doi.org/10.1016/j.agee.2018.08.025
Received 22 December 2017; Received in revised form 22 August 2018; Accepted 28 August 2018

varyingpolicies have been developed and implemented in Europe (e.g. Natura 2000 network) and elsewhere to design "ecological networks" or "green-veinings" (Jongman et al., 2004; Bennett and Mulongoy, 2006). In agricultural areas, they focus on the connectivity of semi-natural habitats, assuming that it will promote both species of nature conservation value in semi-natural habitats (like forest or wetland species), and functional biodiversity (i.e. assuring ecosystem functions of socio-economic importance) in cropped habitats. By contrast, the farmland is mainly considered a "matrix" having negative or neutral impacts on biodiversity. Recently, some authors have investigated the role of spatial connectivity of ordinary, intensive grassland (Duflot et al., 2018), showing that amount and spatial proximity of woody habitats matter more than grassland connectivity for grassland biodiversity. The potential contribution of crop connectivity remains unexplored, in spite of the increasing amount of scientific literature showing that the configuration of the cultivated "matrix" also matters for the biodiversity using cropped habitats, such as natural enemies of pests (Fahrig et al., 2011; Burel et al., 2013; Vasseur et al., 2013). Whilst semi-natural habitats provide refuges or overwintering sites for these species (Bianchi et al., 2006), annual crops fulfill biotic (e.g. food) and abiotic (e.g. microclimate) resources that are ephemeral and change with crop phenology and cultural interventions (Vasseur et al., 2013). Thus the survival of the species using cropped habitats might depend on their ability to find and colonise fields offering resources at different times during their activity period, to supplement or complement resources (Dunning et al., 1992; Vasseur et al., 2013). A few studies have suggested that some insects effectively move between asynchronous crops depending on resource availability, that is from winter-sown to spring-sown crops after the harvest of the former (Men et al., 2004; Bressan et al., 2010; Burel et al., 2013). The connectivity of crops at the landscape scale might thus be an important driver of the biodiversity associated with cropped habitats, potentially more important than the connectivity of semi-natural habitats, but it remains unexplored. Moreover, despite a positive role of semi-natural elements for the biodiversity of cropped habitats (refuges, alternative habitats, and overwintering sites), they may also have detrimental effects on these species by reducing the availability and connectivity of crops and other open habitats (Duflot et al., 2018). By contrast, crop connectivity may have adverse effects on biodiversity associated with semi-natural habitats. Thus, it is unknown whether management strategies based on the promotion of semi-natural networks can really reach the ambitious goal of enhancing both biodiversity of nature conservation value and functional biodiversity in agricultural landscapes.

The goal of the present study was to investigate the effects of habitat connectivity related to annual crops vs. semi-natural habitats (woody elements) on insect biodiversity in agricultural landscapes, considering contrasted groups of species in terms of habitat preference and dispersal ability. Our study focused on carabid beetles, whose communities in agricultural landscapes simultaneously include crop species potentially involved in pest regulation services and forest species (Kromp, 1999; Eyre et al., 2009; Bohan et al., 2011; Duflot et al., 2015; Neumann et al., 2016). We tested the following hypotheses: (i) connectivity of annual crops, especially of those sown and harvested at different periods (winter and spring crops), enhances abundances of farmland species in crops to the detriment of forest species, (ii) connectivity of woody habitats reduce abundances of farmland species in crops whilst increasing abundances of forest species in woody semi-natural habitats.

2. Material and methods

2.1. Study area

The study was carried out in an agricultural area in the Ille-et-Vilaine department, Brittany, western France. The area is characterized by mixed dairy farming and cereal production. It is dominated by annual crops (mostly winter cereals but also spring maize), and intensively managed grassland (temporary and permanent grassland), interspersed with semi-natural elements, i.e. woodland and hedgerows.

In 2011, the study focused on the sampling of 80 woody elements (40 hedgerows and 40 woodlands) distributed in 20 landscape sites (1 km^2) (i.e. with two replicates of each type of woody element within each site). Landscape sites were selected in order to maximize the variation in the percentage of woody habitats (from 4.5 to 28.2%) and the variation in their spatial configuration (edge length woody - farmland from 5.0 to 24.8 km) (Duflot et al., 2015, 2017). In 2012, sampling was performed in 80 annual crops (40 winter cereals and 40 spring maize crops) distributed in 20 landscape sites (1 km^2) selected in order to maximize the variation in the composition (ratio winter to spring crop from 0.6 to 5.2%) and spatial configuration (edge length winter - spring crops from 0.02 to 2.20 km) of the crop mosaic (Duflot et al., 2016). Sampled crops were all managed under conventional farming. A more detailed description of the landscape selection procedure is available in Duflot et al. (2015) and Duflot et al. (2016).

2.2. Sampling of carabid beetles

Carabid beetles were sampled using pitfall traps in four habitat types: two woody habitats (hedgerow, woodland) and two annual crops (winter cereal, spring maize). In 2011, one sampling point composed of two traps (distant of 1 m) was installed in each woodland and hedgerow. In 2012, two sampling points, each composed of two traps, were located in each crop to account for intra-field heterogeneity. The traps were positioned at least 10 m from the habitat border, except for hedgerows. Traps were collected every two weeks, after being open for seven consecutive days. There were two sampling seasons each year to encompass the two main periods during which carabid beetles emerge (Kromp, 1999): one from May to June (containing four sampling periods), and the second from August to September (containing two sampling periods in 2011, and three sampling periods in 2012), except for winter cereals that were harvested in June-July.

Carabid beetles were identified to the species level following Roger et al. (2013). Species were classified according to their habitat preference (forest vs. farmland) and dispersal ability according to Neumann et al. (2016). In agricultural landscapes, very few carabid species can be considered as habitat specialists, because most species are known to utilize different habitat types. Some species are consensually classified as forest specialists (like *Abax parallelepipedus* (Piller & Mittterpacher)), but many other carabid species are alternately classified as grassland, crop, or generalist species depending on the study under consideration. For this reason, in the present study, habitat preference referred to higher occurrence of species rather than habitat specificity, only distinguished between forest and farmland species (which include species not strictly associated with farmland habitats, but more often trapped in either grassland, crop or open habitats). Wing morphology was selected as an indicator of species dispersal ability (Lövei and Sunderland, 1996; Kotze and O'Hara, 2003): brachypterous species have no or short, unusable wings, and are the less mobile species; macropterous species, with long wings, are the most mobile species; dimorphic species have both short and long winged individuals. Species were then classified into four groups combining habitat preference and wing morphology: (1) brachypterous farmland species, (2) dimorphic farmland species, (3) macropterous farmland species, and (4) brachypterous forest species. Macropterous and dimorphic forest species were too scarce to be considered in analyses. Species for which ecological data were not available were also excluded. Fifty one species were included in analyses, representing 96% of the total number of trapped individuals. The list of species and total number of catches for each carabid species group are given in Appendix A.

2.3. Landscape description

Land-cover maps of the landscape sites were digitized from aerial