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Original Articles

Habitat structure and neighbor linear features influence more carabid functional diversity in olive groves than the farming system

Pedro Martins da Silva[a,b,*], Joana Oliveira[c], Alberto Ferreira[a], Felícia Fonseca[c], José A. Pereira[c], Carlos A.S. Aguiar[b], Artur R.M. Serrano[b], José Paulo Sousa[a], Sónia A.P. Santos[c]

[a] *Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Calçada Martins de Freitas, 3000-456 Coimbra, Portugal*
[b] *Centre for Ecology, Evolution and Environmental Change, Faculty of Sciences, University of Lisbon, Rua Ernesto de Vasconcelos Ed. C2-5°Floor, Campo Grande, 1749-016 Lisbon, Portugal*
[c] *Mountain Research Centre, School of Agriculture, Polytechnic Institute of Bragança, 5300-253 Bragança, Portugal*

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ABSTRACT

The effects of land-use management and environmental features at different scales on carabid beetle diversity and trait structure were assessed across olive groves in northeastern Portugal. We selected organic and integrated olive groves that were distinct in terms of specific management practices, local linear features and landscape configurations. Besides the management intensification levels, differences in carabid diversity and community traits were mainly due to local habitat and ecological linear structures at a finer spatial scale. Carabid community traits related to disturbance, namely traits of body size and species dispersal ability, responded to land-use intensity and particular olive grove features were influencing diversity patterns. Within the olive grove patches, larger and brachypterous species were associated to plots with more dense vegetation cover while macropterous and small-sized species were more associated to open areas. Also, larger carabid species benefitted from higher patch size heterogeneity within the landscape mosaics. Our findings indicate that the effects of farming system is contingent on the specific management practices, local and linear features present in agroecosystems such as olive groves. Particularly, the influence of local features on carabid diversity patterns and community traits linked to dispersal and movement may be crucial in maintaining pest control at a landscape scale.

1. Introduction

Land-use changes and agriculture intensification are among the main drivers of species diversity in Western Europe since the end of the Second World War (Puech et al., 2014; Stoate et al., 2009; Woodcock et al., 2005). High pesticide and fertilizer inputs, tillage operations, intensive grazing and the increasing simplification of agricultural landscapes, have shaped biodiversity patterns at local and regional levels (Flohre et al., 2011).

Negative effects of intensification are especially critical for elements of biodiversity supporting key ecosystem functions, such as carabid beetles with regards to the pest control service in agroecosystems (Kotze et al., 2011; Kromp, 1999). However, the effects of management practices may vary across different taxa and functional groups (e.g. Bengtsson et al., 2005; Flohre et al., 2011), depending on particular species traits (e.g. Barbado and van Halder, 2009; Guerrero et al., 2014). Inconsistent results have been found in the literature concerning the beneficial effects of agroecosystems with lower levels of land-use management in relation to conventional agriculture (Ponce et al., 2011; Puech et al., 2014). In fact, several studies have shown that carabid beetles are influenced by agricultural practices, occurring generally in higher abundance or diversity in less intensive land-use systems, such as organic farming (e.g. Döring and Kromp, 2003; Kromp, 1999). Yet, some species may benefit from higher prey availability in highly productive conventionally managed farms (Diekötter et al., 2010; Martins da Silva et al., 2008; Vanbergen et al., 2005).

Other environmental factors, besides management practices or the farming system, may influence community structure of carabid beetles within agroecosystems.

Recent studies have pointed out that microhabitat conditions within agricultural fields and the context of the surrounding landscape may influence carabid communities in agroecosystems (Bengtsson et al., 2005; Cardarelli and Bogliani, 2014; Dauber et al., 2003; Diekötter et al., 2010). For instance, linear structures within the agricultural patches, such as field margins or hedgerows may provide shelter (breeding sites, overwintering habitats, etc.) for several species (Cole

* Corresponding author at: Centre for Functional Ecology, Department of Life Sciences, University of Coimbra, Calçada Martins de Freitas, 3000-456, Coimbra, Portugal.
E-mail address: pedrogpmartins@gmail.com (P. Martins da Silva).

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et al., 2010; MacLeod et al., 2004; Werling and Gratton, 2008; Woodcock et al., 2005).

Moreover, carabid community structure and functional diversity in agroecosystems may also depend on the levels of heterogeneity and the specific configuration of an agricultural landscape (Barbado and van Halder, 2009; Diekötter et al., 2010; Woltz et al., 2012; Woodcock et al., 2010). For instance, good dispersers or species with a preference for open habitats may be favored by agroecosystems dominated by homogenized open areas (Döring and Kromp, 2003), while more sensitive species with large-sized bodies and/or poorer dispersal ability may undergo a negative impact due to landscape simplification (Cardarelli and Bogliani, 2014; Kotze and O'Hara, 2003; Martins da Silva et al., 2008; Petit and Usher, 1998). Also, a landscape configuration driving dispersal limitation among local communities have been increasingly recognized to play an important role in structuring community composition of carabid beetles at larger spatial scales (Driscoll et al., 2010; Niemelä and Spence, 1994; Ulrich and Zalewski, 2007).

Local and landscape features may be particularly important in complex landscape mosaics, such as the case of the traditionally managed olive grove agroecosystems. In these landscapes functional diversity is crucial for the maintenance of key ecosystem services, such as the pest control (e.g. Santos et al., 2007). For example, carabid beetles play an important role as predators of *Bactrocera oleae* (Rossi), the major pest of olives in most commercial olive growing regions worldwide (Daane and Johnson, 2010; Dinis et al., 2016). Carabid beetle diversity in olive groves may depend on the direct effects of land-use management, but also on particular features of the landscape mosaic (Fernández-Escobar et al., 2013; Martins da Silva et al., 2011; Romero-Alcaraz and Ávila, 2000). Yet, no attempts have been made to study the relative influence of management intensity and environmental factors at local and landscape levels on carabid beetle communities.

The aim of this study was to assess the effects of environmental factors related to microhabitat conditions and features of the surrounding landscape on carabid beetle diversity and community (trait) structure in olive groves of northeastern Portugal. To accomplish that, we selected organic and integrated olive groves along an intensity gradient of farming practices to investigate which factors (management intensity or local or landscape features) were affecting carabid beetle communities. Our hypothesis is that, despite the importance of the farming system, carabid diversity and community trait will be mainly influenced by specific management practices and particular local and landscape features across the different olive groves.

We predict that carabid response traits related to higher sensitiveness to land-use management (larger sized and poorer dispersers) will benefit from olive grove features supporting refuge habitats: be they provided by the configuration of the surrounding landscape (e.g. contiguous woodland patches) or linear structures (e.g. hedgerows) providing microhabitat conditions at finer spatial scales within the olive grove patches.

2. Material and methods

2.1. Study sites

The study was conducted in 2011 (in spring and autumn seasons), in nine olive groves in the area surrounding Mirandela municipality, Trás-os-Montes region, northeastern Portugal (Fig. 1). The study sites were in average 5 km apart (2 km minimum, 15 km maximum), belonging to the same climatic zone (typically Mediterranean, characterized by hot and dry summers and mild and moist winters), and with similar site conditions in terms of altitude (mean altitude of 393 m), mean annual rainfall (about 524 mm) and temperature (the mean maximum temperature is 22.7 °C and the mean minimum temperature is 9.6 °C). Main characteristics and management data of all olive grove sites were obtained from interviews with farmers after the growing season (Appendix A, Tables A1 and A2 in Supplementary material). Selected olive groves represented a gradient of land-use intensity of the most common farming practices followed by olive growers in the region of Trás-os-Montes. From the nine study sites, four represented organic farming systems and five were olive groves under integrated production (Appendix A, Table A2 in Supplementary material).

2.2. Sampling of carabid beetles

Sampling was done in the first week of May (spring) and in the last week of October 2011 (autumn). Although shorter periods of pitfall trapping may miss some carabid species due to the lack of a whole period of carabid beetle activity, it has been argued that for comparative purposes, the number of traps may have more influence on the results than the length of the trapping period (Lövei and Magura, 2011; Niemelä et al., 1990). This may be especially true in relatively homogeneous systems such as the case of olive groves.

At each site, a regular square grid of 4 × 4 sampling points was laid-out within the center of the olive grove patch. A pitfall trap was set up in each sampling point, totalizing 16 pitfall traps at each study site and thus 144 sampling points across the 9 study sites. Pitfall traps consisted of plastic cups with a top-diameter 115 mm and 130 mm height, which were dug into the ground so that the border of the cup was leveled with the soil surface. Pitfall traps were filled with 250 ml of ethylene glycol (anti-freeze liquid); a lid supported by iron wires was placed to exclude rain, debris and small vertebrates. Traps were spaced 45–50 m from one another and eight traps were placed in the plantation row and the other eight were placed in the between-row area, alternating in two plantation rows and two between-rows (sampling scheme in Fig. 1), and were left in the field for seven nights. Traps in the plantation row were placed in the south side of the canopy at 50 cm from the tree trunk. All captured individuals were sorted and determined to the species level (when possible).

2.3. Carabid community traits

To understand changes in carabid beetle communities along the land-use intensification gradient we analyzed the differences in species trait values, particularly of body size and dispersal ability, which are related to species sensitivity and response to disturbance (Kotze and O'hara, 2003; Ribera et al., 2001).

Species flight ability, as a proxy of dispersal ability, was classified according to their possession of full wings (macropterous = 1; brachypterous/apterous = 0; dimorphic = 0.5). According to what is theoretically expected (e.g. Desender et al., 2010; Etienne and Olff, 2004) we established a gradient of dispersal ability power from the macropterous species (best dispersal within the species pool) to the brachypterous/apterous species (poorest dispersal ability within the species pool).

Information on all carabid beetle response traits (body size and flight ability) was collected from different sources (Appendix B). We calculated a community weighted trait mean, i.e. the mean trait value per sampling plot, to assess the impact of land-use intensification and/or other environmental factors at different scales on carabid beetle communities. The community trait weighted means (CWM, hereafter) of both body size and dispersal ability were calculated as the relative abundance of a certain species multiplied by its trait value, summed over all species in the community (Garnier et al., 2004; Vandewalle et al., 2010).