



Trait composition and functional diversity of spiders and carabids in linear landscape elements



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ABSTRACT

Agricultural intensification is a cause of global biodiversity decline. Seminatural linear landscape elements (LLE) within agricultural landscapes can considerably mitigate these declines, but their effects on functional properties of biodiversity are poorly known. We analyzed trait composition and functional diversity (functional dispersion) of spiders and carabids in woody and herbaceous LLE. We expected that species assemblages of woody LLE are more diverse and K-selected compared to herbaceous LLE, and that effects of environmental parameters vary between LLE types. We selected 58 LLE in an agricultural landscape in Northwest Germany. We sampled carabids and spiders by pitfall trapping and measured landscape connectivity, landscape-wide land-use diversity, local land-use diversity, and local plant richness as explanatory variables. The trait composition of arthropods in woody LLE was more K-selected (lower dispersal ability, a higher food specialization or trophic level) than in herbaceous LLE. Moreover, spider functional diversity was higher in woody LLE. Spider functional diversity and proportion of predatory carabids in woody LLE increased with increasing connectivity of the habitats. In contrast, in herbaceous LLE local plant richness and landscape-wide land-use diversity were most important drivers for spider and carabid diversity and traits. Our results show that species richness and functional diversity of spiders and carabids were differently affected by landscape and local factors. Therefore, the importance of landscape connectivity was higher in woody LLE, suggesting that their inhabitants are more sensitive to habitat fragmentation than the highly mobile generalist species living in herbaceous habitats.

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1. Introduction

Agricultural intensification is a major reason for global biodiversity decline (Sala et al., 2000). Intensive agriculture is correlated with increased fragmentation and decreased connectivity of natural and seminatural habitats (Fahrig, 2003; Fischer and Lindenmayer, 2007). Since the second half of the twentieth century, this has resulted in simplified landscapes in many agricultural regions worldwide (Stoate et al., 2001; Tschamtké et al., 2005) often associated with biodiversity loss and biotic homogenization (Norris, 2008; Gámez-Virués et al., 2015). Seminatural habitats are important for many species in agricultural landscapes and, therefore, essential for biodiversity

conservation (Marshall and Moonen, 2002; Merckx et al., 2012; Dainese et al., 2015).

In European agricultural landscapes, seminatural habitats are commonly situated along the border between crops. Such linear landscape elements (LLE) can generally be divided into woody elements like hedgerows and tree lines and herbaceous elements like field margins and grass strips (Holland et al., 2016; Marshall and Moonen, 2002; Robinson and Sutherland, 2002). Compared to crop fields they are less disturbed habitats and provide shelter, overwintering sites, reproduction habitats, a favorable microclimate and alternative food sources (Bianchi et al., 2006). Furthermore, LLE can act as dispersal corridors for many organisms and reduce habitat fragmentation (Haddad and Twesbury, 2005; Holzschuh et al., 2010; Marshall and Moonen, 2002; Thiele et al., 2008). LLE can therefore provide wide-ranging ecological benefits (biodiversity conservation, habitat for beneficials, corridors, etc.) even while occupying little area, through their large perimeter-to-

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area ratio, thus reducing the opportunity cost for taking land out of production (Grashof-Bokdam and Langevelde, 2005).

Diversity and species distribution patterns in agricultural landscapes depend on the spatial arrangements and connectivity of seminatural habitats (Fahrig et al., 2011; Tschardt et al., 2012). Additionally, the agricultural matrix is often not completely hostile to many organisms and may provide important resources (Fahrig et al., 2011; Tschardt et al., 2012). Species in agricultural landscape react to their environment at different spatial scales. In general, structurally complex landscapes (i.e. landscapes with a large variety of different cover types) often contain more diverse species assemblages than simple landscapes (e.g., Schmidt et al., 2008; Tschardt et al., 2012; Weibull et al., 2003; Weibull and Östman, 2003). In the same way, connectivity is known to have positive effects on diversity of multiple taxa (e.g. Holzschuh et al., 2009, 2010). In addition to these landscape effects, the local environment shapes species assemblages of seminatural habitats. Thereby, plant species richness, vegetation composition and habitat diversity explain community structure and diversity of many arthropods (Hendrickx et al., 2007; Liu et al., 2015; Schaffers et al., 2008; Thomas and Marshall, 1999).

The habitat templet theory (Southwood, 1977) assumes that the local habitat templates act as filters that sort species according to their traits. According to this, a species can only be part of the local community if it features appropriate traits to pass through the filters defined by habitat properties. Important environmental constraints acting on species and their traits are related to disturbance and stress (Grime, 1977; Southwood, 1977; Whittaker and Wilson, 1967). We expect more r-strategists occurring in herbaceous linear elements, because they are generally more disturbed than woody ones due to regular mowing and the absence of a protecting shrub or tree layer. Traits associated with r-strategists are often a small body size, high dispersal ability and lower specialization. Consequently, we expect more K-strategists in less disturbed woody linear elements.

Little is known about the functional diversity of arthropods in seminatural habitats and the importance of landscape and local effects in fragmented agricultural landscapes (but see Woodcock et al., 2010). This is a drawback since functional diversity provides insights into interactions of organisms with their environment (Petchey et al., 2009; Violle et al., 2007) and is often more sensitive to environmental changes than taxonomic diversity (Cadotte et al., 2009; Schirmel et al., 2012; Woodcock et al., 2014). In agricultural landscapes, investigations of functional diversity of beneficial organisms such as natural enemies allow us to better understand their potential for providing ecosystem services. In particular, functionally diverse predator communities may exert stronger top-down control on a wider range of prey than functionally more uniform predator communities (Hooper et al., 2005; Schuldt et al., 2014).

We analyzed landscape and local effects on ground-dwelling arthropods in woody and herbaceous linear landscape elements in an agricultural landscape in Northwest Germany. We used spiders and carabids because they are proven indicators for landscape and local effects in agricultural landscapes (Aviron et al., 2005; Liu et al., 2015; Purtauf et al., 2005; Schmidt et al., 2008) and are important components of natural enemy assemblages of crop pests (spiders: Marc et al., 1999; Schmidt et al., 2005; carabids: Sunderland et al., 1987; Kromp, 1999).

In a first step, we compared species and functional diversity of both taxa between woody and herbaceous LLE. In a second step, we disentangled the effects of landscape (i.e. landscape connectivity and landscape-wide land-use diversity) and local parameters (i.e. local land-use diversity and local plant richness) on functional diversity separately for woody and herbaceous elements. We hypothesized that: (i) Trait composition in woody LLE will be more

K-selected, i.e. lower dispersal ability, larger body size, higher food specialization and higher trophic level compared to more r-selected trait composition in herbaceous LLE. (ii) Species richness and functional diversity will be higher in less disturbed woody LLE than in herbaceous LLE. Furthermore, we expected that effects will vary between LLE types: (iii) Due to more K-selected communities, effects of landscape connectivity will be stronger in woody compared to herbaceous LLE. (iv) Oppositely, due to higher mobility, effects of landscape-wide land-use diversity will be stronger in herbaceous than in woody LLE.

2. Methods

2.1. Study region and site selection

The study was completed in 2012 in the region “Westfälische Bucht” in Northwest Germany (Fig. 1). The regional climate is temperate oceanic with an annual mean temperature of around 10 °C and annual precipitation around 800 mm (period 1981–2000; Klimaatlas Nordrhein-Westfalen, <http://www.klimaatlas.nrw.de>). The region is characterized by intensive agriculture and a relatively high proportion of LLE (hedgerows, tree lines, field margins).

Within the study region we selected eight study areas, each 1 km², selected by random points which were stratified by four natural regions (West-, Kern-, Ostmünsterland, and Hellwegbörden) using GIS (Supplementary data Table S1). We wanted to study areas that represent the prevailing agricultural landscapes of the region and, hence, excluded larger settlements, extensive forests, lakes, rivers, and areas of markedly different geology from random sampling based on Corine Land Cover and general soil maps (“Bodenübersichtskarte 1:200.000”). The landform of the study areas is mostly plain at altitudes between 40 and 80 m a.s.l., but slightly hilly in the southernmost area (“Herringser Höfe”) at 200–220 m a.s.l. Soils of the study areas are sandy in the western and northeastern part of the study region (West-, Ostmünsterland), loamy in the central part (Kernmünsterland) and loess dominated in the southern part (Hellwegbörden), but always lime-free. In the study areas, land use is dominated by intensive arable farming which occupied on average 70% of the area in 2009. Main crops in the study areas were cereals and maize. All farming in the study areas was conventional. The proportion of LLE in the study areas varied between 2.5 and 10%.

In each study area, we selected 6 or 8 plots ($N_{\text{total}} = 58$ plots) that were randomly located in LLE using random points in GIS. Half of the LLE was herbaceous (field margins, grass strips) while the other half were woody (hedgerows, tree lines). All LLE that were at least 2 m wide and adjacent to arable fields were considered for random sampling, whereas narrower ones were excluded. Plots were 1 × 25 m in size and at least 100 m apart from each other.

2.2. Landscape and local parameters

We mapped the land-cover of the study areas through visual interpretation from aerial images (20 cm ground resolution) of 2008 or 2009 in a Geographic Information System (GIS) discerning, e.g., arable fields, grasslands, forests, housing, and different types of linear landscape elements, such as tree rows and herbaceous field margins. Delineation of land parcels and landscape elements was unproblematic because of clear land-use boundaries and marked contrasts between adjacent land-uses and seminatural landscape elements in the study areas. Landscape-wide land-use diversity was analyzed in buffers of 500 m around the plot centers based on the land-cover maps. Landscape scales of 500 m radius are known to be relevant for spiders (Clough et al., 2005; Schmidt et al., 2005; Schmidt and Tschardt, 2005) and carabids (Aviron

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