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Land use at different spatial scales alters the functional role of web-building spiders in arthropod food webs

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ABSTRACT

Web-building spiders are abundant generalist predators in agroecosystems that primarily forage on insects including economically important pests. Local management and landscape composition influence spider and prey communities and thereby their trophic interactions and functional role in arthropod food webs. We compared predator-prey interactions between organically managed cereal fields and sown flower-rich fields, both supported by agri-environmental schemes. The surrounding landscape of twelve study sites differed in the percentage of arable crops within a radius of 500 m around each site. We analyzed 1036 hand-collected web-building spiders with 5270 prey items from webs and 6777 potentially available prey items sampled by fenced suction sampling. Thysanoptera significantly dominated prey composition of web-building spiders in cereal fields located in landscapes with low percentages of arable crops, while Nematocera dominated prey composition in sown flower-rich fields. The captured prey numbers per spider web, irrespective of taxonomic identity, increased with the availability of potential prey, independent of habitat type or landscape composition. We did not find any effect on the compositions of web-building spiders and potential prey. Our results suggest that spider webs act as traps for prey that depend on prey density. However, this simple interpretation is only valid for the overall prey quantity, while capture success of single prey taxa may be habitat-specific and depend on landscape features. The impact of land use at different spatial scales on the functional role of web-building spiders should caution us towards density-based estimates of predation processes, e.g. when assessing the impact of agri-environmental schemes on arthropod food webs.

1. Introduction

Spiders are abundant generalist predators in agroecosystems (Nyffeler and Sunderland, 2003). Several species have adjusted their life cycle to periodical disturbance by agricultural management in arable fields, such as these species reach adulthood and reproduce during the growing season of arable crops, so called "agrobiont" (Samu and Szinetár, 2002). In European agroecosystems, small linyphiid spiders dominate the spider fauna (Nyffeler and Sunderland, 2003). In contrast to ground-dwelling spiders, web-building spiders use webs to catch prey (Nyffeler et al., 1994) and, in agricultural habitats, they almost exclusively feed on insects (Birkhofer et al., 2013; Nyffeler, 1999). The most common prey taxa of spiders in agroecosystems are Hemiptera, Diptera, Hymenoptera, Coleoptera, Lepidoptera, Collembola, Araneae, Orthopteroidea and Thysanoptera (Birkhofer et al., 2013; Nyffeler, 1999); including economically important pests (Nyffeler and Benz, 1982). Aphids, for example, are a dominant insect pest of food crops in temperate climate (Dedryver et al., 2010) and often comprise high percentages of total prey numbers in spider webs (Alderweireldt, 1994; Nyffeler and Sunderland, 2003; Pekár, 2000). Web-building spiders also contribute to biological pest control if they do not consume pests, but catch them in their webs (Sunderland, 1999). The prey composition of spiders partly depends on local prey density (Nyffeler et al., 1994), its spatial distribution (Birkhofer et al., 2011) and prey behavior (e.g., swarming, Jeschke and Tollrian, 2007). Web-building spiders

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further actively select web sites in prey-rich habitat patches (Harwood et al., 2001), a behavior that directly results in reproductive benefits (Jurczyk et al., 2012).

Web-site selection is constrained by the availability of suitable web attachment structures, which in turn depends on vegetation characteristics (McNett and Rypstra, 2000). Moreover, local management can alter the diversity and the composition of spiders' prey (Diehl et al., 2013). Thus, intensive management of agricultural fields reduces the density of web-building spiders due to the impoverishment of vegetation complexity and furthermore reduces prey order richness of web-building spiders, e.g., due to tillage or lower plant species richness (Birkhofer et al., 2007; Diehl et al., 2013). Management extensification holds the potential to promote spider abundances (e.g., organic farming; Birkhofer et al., 2008). Semi-natural habitats provide suitable attachment sites for spider webs due to higher habitat complexity (Langellotto and Denno, 2004). To facilitate the overall positive effects of reduced management intensity on farmland biodiversity (Tuck et al., 2014), organic farming and the establishment of semi-natural habitats (e.g., sown flower-rich fields) are supported by agri-environmental schemes in Germany (HMUELV, 2010, StAnz 51/2010).

Agri-environmental schemes almost exclusively focus on local management, but tend to ignore the composition of the surrounding landscape. This is a serious shortcoming, since the landscape matrix may critically affect the composition of predators and prey as well as their trophic interactions (e.g. Rand et al., 2012; Woltz et al., 2012). Complex landscapes with a large proportion of semi-natural habitats generally support high densities of arthropod predators and therefore hold a high potential for pest control (Bianchi et al., 2006). High proportions of non-crop habitats in the surrounding landscape can differently affect spider assemblages. Both, positive effects on spider abundances are reported (Schmidt and Tscharntke, 2005) and also negative effects, e.g., on species densities of certain Linyphiidae and Tetragnathidae that might favor arable habitats (Schmidt et al., 2008) and therefore represent "losers" of organic farming in contrast to conventional farming (Birkhofer et al., 2014). The proportion of semi-natural source habitats at larger scales affects other spiders positively (Clough et al., 2005; Öberg et al., 2007, 2008), encompassing juvenile spiders, that can overwinter in these habitats as many arthropods (Pfiffner and Luka, 2000) and disperse from semi-natural habitats into crop fields in spring by ballooning (Suter, 1999). Effects of local management on web-building spiders and their contribution to biological control may depend on landscape characteristics, as for example aphid predation can be most effective under organic farming in complex, but not in simple, homogeneous landscapes (Winqvist et al., 2011). Positive responses of generalist predators to landscape complexity alone might not necessarily lead to more efficient pest suppression (Chaplin-Kramer et al., 2011). Landscape effects on the potential of pest control (cf. Sunderland and Samu, 2000) provided by web-building spiders based on capture rates of (pest) prey remain largely unknown and only a few previous studies focus on prey composition or prey use of web-building spiders (but see for forest-stream ecotone, Kato et al., 2004) in arable habitats concerning prey availability as well (but see for management intensity, Diehl et al., 2013).

This study investigates how both local land-use and the composition of the surrounding landscape affect trophic interactions of web-building spiders with regard to their actual and potential prey composition in agricultural systems under agri-environmental schemes located in simple and complex landscapes. We hand-collected web-building spiders with prey remains in six sown flower-rich fields and six organically managed cereal fields to study the effect of local management and landscape composition on trophic interactions between spiders and prey. The surrounding landscape of the study sites differed along a gradient of percentages of arable crops within a radius of 500 m. We hypothesized that habitat type and landscape composition (1) alter the compositions of web-building spiders and their potential prey with higher densities of agrobiont spiders and potential agricultural pests for cereal fields and landscapes with a high percentage of arable crops and (2) affect the composition of actual prey communities with pronounced higher dominances of potential pest prey in cereal fields and landscapes with a high percentage of arable crops (e.g., aphids, thrips). We further expected that (3) the overall prey quantity in spider webs is closely related to the overall density of potential prey.

2. Materials and methods

2.1. Study sites and landscape analysis

The twelve study sites were located within an area of approximately 25 km around the city of Marburg (50.806152 N, 8.766649 E) in central Hesse, Germany (Fig. 1). Study sites were selected according to local habitat type and percentages of arable

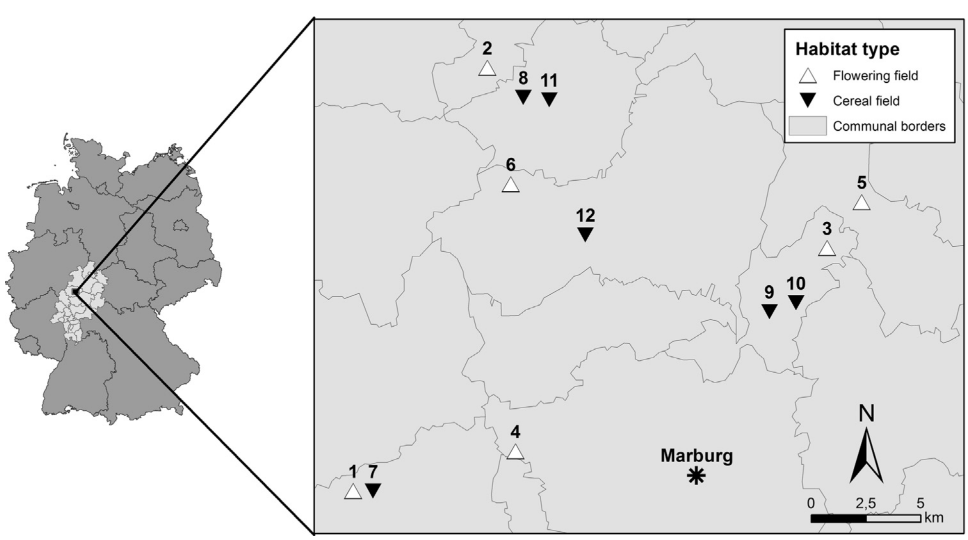

Fig. 1. Location of study sites around the city of Marburg in Hesse (light grey), Germany.