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Research Paper

Different responses of bees and hoverflies to land use in an urban–rural gradient show the importance of the nature of the rural land use

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HIGHLIGHTS

- Hoverfly abundance and diversity reduced in urban sites, not in agricultural sites.
- Bee abundance and diversity reduced in agricultural sites, not in urban sites.
- Nature of rural end of urban–rural gradient is key for response of pollinators.

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ABSTRACT

Most studies focusing on the effects of urban land use on pollinators have compared urban sites with one type of rural site. However, there is a lot of variation in the amount of natural habitats or intensive agriculture in rural areas. The position of urban areas within that continuum in terms of pollinator communities remains unclear. In this work, we studied bee and hoverfly communities (abundance, diversity, and species composition) in three site types along two river systems crossing urban areas, rural areas dominated by agriculture (termed rural-agricultural) and rural areas with high amounts of semi-natural land use (termed rural-natural). Pollinators were caught in August 2011. Abundance and diversity were highest in rural-natural sites for both taxonomic groups. Our data also indicate that hoverflies and bees responded differently to the surrounding land use, with bee abundance and diversity only significantly reduced in rural-agricultural sites but not in urban sites, and hoverfly abundance and diversity only significantly reduced in urban sites but not in rural-agricultural sites. The observed differences in the response of pollinators point out the importance of incorporating different types of rural land use and clearly defining the rural end of an urban–rural gradient in getting a clear view on how urban land use affects a specific pollinator group. Year-round sampling of these pollinators would, however, probably enable a more accurate view on these responses.

1. Introduction

During the last decades, insect pollinator faunas have suffered significant declines across the globe (Potts et al., 2010). Kearns, Inouye, and Waser (1998) introduced the term 'pollination crisis' to describe the declines of honeybees and native, wild bees. Since the vast majority of flowering plants (up to 87.5% of the angiosperms worldwide) are pollinated by animals (mostly insects) (Ollerton, Winfree, & Tarrant, 2011), it can be expected that a large amount of plant species may suffer from such overall reductions in pollinator abundances. In this context, Biesmeijer et al. (2006) and Fontaine, Dajoz, Meriguet, and Loreau (2006) highlighted not only the need of pollinator conservation per se, but also warned about the potential ramifications of pollinator declines for insect pollinated plant species.

One of the major causes of pollinator declines are anthropogenic land use (Winfree, Aguilar, Vázquez, LeBuhn, & Aizen, 2009) and the associated loss and fragmentation of (semi-)natural habitats (Potts et al., 2010). In general, increasing intensity of human land use is negative to most insect pollinators around the globe (Winfree, Bartomeus, & Cariveau, 2011). The two most intensive,

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anthropogenic land uses are agricultural and urban land use. While the response of insect pollinators to increasing amounts of agricultural land use at the expense of semi-natural land use is fairly well studied (Billeter et al., 2008; for recent reviews, see Garibaldi et al., 2011; Hendrickx et al., 2007; Ricketts et al., 2008; Winfree et al., 2009), the effect of increasing amounts of urban land use at the expense of semi-natural land use on pollinator communities is far less understood. In recent years though, a handful of studies have also focused on pollinator faunas in relation to urban land use (Ahrné, Bengtsson, & Elmqvist, 2009; Bergerot, Fontaine, Julliard, & Baguette, 2011; Deguines, Julliard, de Flores, & Fontaine, 2012; Matteson, Ascher, & Langellotto, 2008) and some patterns are emerging (see further; for a review see Hernandez, Frankie, & Thorp, 2009).

The most common approach for investigating the effects of increasing amounts of urban land use on pollinators is to compare their diversity and abundance over a gradient of urbanization, i.e. from urban to rural sites. However there may also be a lot of variation in the rural countryside, ranging from highly natural to intensive agricultural areas, and it is largely unknown how urban land use compares to such variable types of rural land use with respect to pollinator abundance, species richness, and species composition. Studies that compare urban with non-urban sites, mostly found a decrease in abundance and species richness of pollinators in the urban sites (Bates et al., 2011; Hernandez et al., 2009; McIntyre & Hostetler, 2001). However, some studies documented positive effects of moderate urbanization on pollinators (Osborne, Martin, Shortall, et al., 2008) and pollination services (Cussans et al., 2010), indicating that their response is probably more subtle than generally assumed and largely dependent on which types of land use are compared and also on which pollinator species are studied.

Because most studies only focused on one type of rural site or did not make a differentiation in rural sites, it remains unclear how pollinators respond when urban sites are compared with rural areas containing more or less semi-natural habitat or agricultural land use within the same landscape. Our study explicitly incorporated the variability in the rural area into the rural-to-urban gradient. In the present study, we investigated hoverflies and bees along the banks of two rivers that connect two cities in Belgium. Both river systems cross a wide range of landscapes with varying land uses. By comparing river bank habitats we kept the local factors of the study sites as constant as possible while the landscape around the sites varied.

We therefore investigated two important pollinator groups, bees and hoverflies, in three common landscapes in the Flemish region of Belgium: 1: urban land, 2: rural land with high amounts of agricultural land use, and 3: rural land with high amounts of semi-natural land use. Bees are generally considered the most important pollinators worldwide (Klein et al., 2007; Neff & Simpson, 1993). Hoverflies are another important flower visiting group (Larson, Kevan, & Inouye, 2001), and also function as efficient pollinators for at least some plant species (Fontaine et al., 2006; Jauker, Bondarenko, Becker, & Steffan-Dewenter, 2012; Jauker & Wolters, 2008). Bees and hoverflies differ in an important aspect of their life-cycle, which may cause differences in their response to different disturbances resulting from different land uses. Bees forage from a central nesting site (central place foragers) where they deposit their eggs and accumulate pollen as a food resource for their larvae. Both nesting site and forage resources therefore need to be within a bee's foraging range to be able to support its life cycle (Kremen et al., 2007; Westrich, 1996). Hoverflies, on the other hand, have larvae that feed on a range of plant or animal material without the help of their mother (Meyer, Jauker, & Steffan-Dewenter, 2009). This allows hoverflies to forage further from their ovipositing sites than bees, and therefore potentially be less sensitive to anthropogenic land use compared to bees (Jauker, Diekötter, Schwarzbach, & Wolters, 2009).

The aims of this study are to compare the abundance, diversity and composition of both bees and hoverflies in a complex gradient from urban to rural land use with the explicit incorporation of the variability in rural land use (ranging from mainly agricultural to semi-natural). We hypothesize that the abundance and diversity of both bees and hoverflies are significantly reduced in both urban sites and rural sites with high amounts of agricultural land use compared to rural sites with high amounts of semi-natural land use. We further hypothesize that species composition also differs between the different land uses with rural sites with high amounts of semi-natural land use containing species that do not occur in the other sites.

2. Material and methods

2.1. Study area and design

In order to obtain a land use gradient that was representative of the Flemish landscape, we chose to position transects on the banks of two river systems (Dijle-Demer and Canal Leuven-Mechelen) in Flanders, Belgium. These river banks offer a relatively constant habitat which is comparable throughout the whole study area (flower-rich grassland vegetation that is mown twice a year). The study area is located between the cities of Mechelen and Leuven and continues south of Leuven to Huldenberg (Fig. 1). It is characterized by an alternation of predominantly agricultural landscapes and landscapes that contain more semi-natural areas and forests and the presence of two intermediate-sized cities (Mechelen: 1230 inhabitants/km^2, 65.19 km^2 (Mechelen, 2013) and Leuven: 1690 inhabitants/km^2, 57.51 km^2 (Leuven, 2013)) and some smaller urbanized areas. Preliminary inspections of a land use map (2003, National Geographic Institute, Belgium) allowed us to select sites along these river systems with considerable variation in surrounding land use practices. We sampled pollinators in 53 sites each containing one transect of 50 m by 2 m (Fig. 1).

2.2. Land use

We reduced the 26 original land use types of the land use map (2003, scale: 1:10,000, National Geographic Institute, Brussels) to 8 more general types: sealed surfaces, semi-natural (non-forest) areas, agricultural land (arable land + heavily fertilized pastures), forests, domestic gardens, orchards, public lawns (including sport fields) and water surfaces (Fig. 1, Appendix A). Both highly productive agricultural grasslands with few species and species-rich semi-natural grasslands are coded simply as grassland on this land use map, yet they differ greatly in the availability of food resources to pollinators. By using the Biological Valuation Map (BVM version 2, scale: 1:10,000, Wils et al., 2006) we additionally assigned highly productive species-poor grasslands to the agricultural land use and the species-rich grasslands to the semi-natural land use (see Appendix A). In an additional step, we calculated the amounts of these 8 types of land use in 5 radii of varying size (100, 500, 1000, 1500, and 2000 m, Appendix C) around the most southern point of each transect in ArcGis 10. We calculated these amounts at different scales because different bee and hoverfly species may respond to changes in land use at different scales. For example, small solitary bees generally have a smaller foraging range than bumblebees (100–600 m compared to more than 1500 m) (Gathmann & Tscharntke, 2002; Osborne, Martin, Carreck, et al., 2008). The maximum radius was set on the basis of the foraging ranges of bumblebees, which are among the largest of wild bees (Osborne, Martin,