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Landscape composition affects parasitoid spillover

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ABSTRACT

The intensification of agriculture has led to a severe simplification of agricultural landscapes, resulting in a marked reduction in the diversity of insect natural enemies. However, how this simplification shapes the movement of insect parasitoids between crop and non-crop habitats (i.e., spillover) is still unclear. We examined the potential spillover of tachinid parasitoids from semi-natural habitats into apple orchards across different landscapes. We sampled commercial apple orchards localized in three landscape types (forest-, grassland- or apple-dominated landscapes) to first evaluate if landscape composition affects the local species richness in apple orchards. Second, we tested whether the contribution of forest and grassland habitats to the local tachinid community composition of apple orchards changes according to landscape composition. We found that landscape composition did not affect local tachinid species richness in apple orchards, while it affected the species spillover. Independently of the landscape, we found highly nested communities of tachinids between apple orchards and forest habitats suggesting a strong spillover of tachinids between these habitats. In contrast, tachinids in apple orchards were nested with grassland habitats only in landscapes dominated by apple orchards. Our results have important implications for the conservation of insect parasitoids in agricultural landscapes, as the spillover of species in the crop can be affected by the type and the area of semi-natural habitats in the surrounding landscape.

1. Introduction

In the last decades, the intensification of agriculture has led to a severe simplification of agricultural landscapes (Swift et al., 1996; Tilman et al., 2001). This simplification has been caused by an increase of the size of crop fields and a marked reduction of the remaining natural and semi-natural habitats (Robinson and Sutherland, 2002; Tscharntke et al., 2012). The simplification of agricultural landscapes has resulted in a marked reduction of the diversity of insect natural enemies with possible negative effects on pest control (Wilby and Thomas, 2002; Bianchi et al., 2006; Thies et al., 2011; Jonsson et al., 2012; Inclán et al., 2015). Although the overall negative effects of landscape simplification on the species richness of natural enemies are relatively well known (e.g., Letourneau et al., 2012; Macfadyen and Muller, 2013; Inclán et al., 2014; Martinson and Fagan, 2014), how this process shapes the species composition and movement of important natural enemies such as parasitoids is still unclear.

The structural contrast between habitats within intensive agricultural landscapes is expected to be an important factor determining the movement of species between habitats (hereafter referred to as spillover). Therefore, the contrast between agricultural and semi-natural habitats can determine species immigration and emigration (Polis et al., 1997; Schellhorn et al., 2014). Several authors have found species spillover from natural habitats into adjacent crop fields (e.g., Landis et al., 2000; Geiger et al., 2008; Rusch et al., 2010; Blitzer et al., 2012; Macfadyen et al., 2015), but movements in the opposite direction have also been observed (e.g., Tscharntke et al., 2005; Rand et al., 2006; Blitzer et al., 2012; Frost et al., 2015; Macfadyen et al., 2015). This spillover of parasitoids has also been shown to affect important ecosystem services such as natural pest suppression (Landis et al., 2000; Macfadyen and Muller, 2013; Gagic et al., 2014). Although it is clear that the spillover of organisms like parasitoids can affect trophic interactions in both source and sink habitats (Tscharntke et al., 2005; Rand and Louda, 2006; Rand et al., 2006; Klapwijk and Lewis, 2012; Macfadyen and Muller, 2013; Martinson and Fagan,

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2014), how the spillover of parasitoids changes in relation to specific habitats within different landscapes is still a little understood topic.

Studies about spillover of natural enemies from natural habitats into adjacent agricultural fields have focused on predators with limited dispersal range such as ground-dwelling predators (e.g., see review of Blitzer et al., 2012) and less attention has been paid to the spillover of more mobile organisms such as parasitoids (but see Olson and Wäckers, 2007; Macfadyen and Muller, 2013; Frost et al., 2015). Furthermore, the majority of these studies has focused on the effects on species richness, ignoring the response of species composition (but see Gagic et al., 2014; Macfadyen et al., 2015). In this work, we used tachinid flies (Diptera: Tachinidae) as a model group to investigate the spillover of a highly mobile and diverse group of parasitoids. The family Tachinidae, with almost 8,500 species, ranks second in diversity within the Diptera and is the most diverse group of non-hymenopteran parasitoids (Stireman et al., 2006; O'Hara, 2013). Tachinids can be very important natural enemies because of their predominance in attacking major groups of insect herbivores such as lepidopterans, coleopterans and hemipterans (Stireman et al., 2006; Cerretti et al., 2014). In this study, we examined the spillover of tachinid parasitoids from two semi-natural habitats into agricultural land in landscapes with contrasting habitat composition. Specifically, we sampled commercial apple orchards localized in landscapes dominated by either forests, grasslands or apple orchards. Specifically, we tested three main hypotheses. First, we expected that the landscapes dominated by either forests or grasslands will increase the local species richness in apple orchards. Second, as we expected that the spillover varies across different habitats, we tested the contribution of forest and grassland habitats to the local diversity of apple orchards located in the three landscape types. Third, due to the high mobility and relatively low specialization of tachinids, we expected that the spillover of tachinids will not be limited by distance. In particular, we tested the role of dispersal limitation in shaping the spillover of species by testing the distance-decay of similarity within habitats across different landscapes.

2. Methods

2.1. Study area

The research was conducted within an area of c. 160 km^2 in the province of Trento, NE Italy. Specifically, the sites were located between 450 and 600 m across the Valsugana Valley (southern European Alps). The study region is in one of the major apple production areas of Europe with ~~12,000 ha of intensive orchards. In recent decades, there has been a dramatic landscape homogenization that has created large areas covered exclusively by apple orchards (Marini et al., 2012). Within these homogenous landscapes, it is still possible to find some scattered orchards located in a non-crop landscape composed mainly of grasslands and forests. Apple orchards, forests and grasslands represented the main land uses in the region. Apple orchards (mainly the variety 'Golden Delicious') were characterized by a highly specialized conventional management with only very few organic or traditionally managed orchards. Grassland habitats were usually heavily fertilized (>150 kg N ha^{-1} year^{-1}) and mown 2–4 times per year resulting in dense swards dominated by grasses and with low forb abundances (see Marini et al., 2008). Forest habitats were mainly composed of Scots pine mixed with broad-leaf tree species (mainly *Fraxinus ornus* L. and *Ostrya carpinifolia* Scop.).

2.2. Sampling design

Twenty-one commercial apple orchards were selected in landscapes characterized by different dominance of crop and non-crop habitats. We selected seven orchards in landscapes (0.5 km radius) dominated by apple orchards, seven in landscapes dominated by forests and seven in landscapes dominated by grasslands (Table 1). Landscapes were selected to be separated by at least 1 km (mean minimum distance = 2.2 km) and only three landscapes were separated by a shorter distance (0.8 km). Within each landscape three sites representing apple, forest and grassland habitats were selected (Fig. 1). The three sites were separated by no more than 60 m and were located around the center of each landscape (Fig. 1c). We identified the habitats embedded in the three landscape classes by quantifying the landscape composition within a 500 m radius around the centroid of the three selected habitats using detailed land-use maps (Servizio Urbanistica, Provincia di Trento) in ArcGIS 10 (ESRI®). For each selected landscape, we quantified the cover of apple, forests and grasslands. For each landscape, we selected the habitats with about the same local management and elevation such that the management and temperature did not differ among the three landscape types.

2.3. Insect sampling

A pan-trap sampling was conducted in the 63 sites across the 21 landscapes. Within each landscape, the three habitats were sampled using three clusters of pan-traps. Within each habitat, each cluster of traps was separated by 25 m. Each cluster of traps consisted of one standard yellow and two UV-reflecting yellow plastic bowls (500 ml, 16 cm diameter) filled with a solution of water and 3% dishwashing detergent (Sole™). Within each cluster, pan-traps were placed on the ground, each one separated about one meter from each other. The cluster position was kept fixed within each habitat, leaving a distance of at least 10 m from the borders and avoiding areas completely covered by shrubs. The sampling was conducted between July and September 2013. A total of four sampling rounds were performed covering the season during which the insects were active. During each sampling round, traps were set for a period of 48 h after which insects were collected and stored in alcohol (70%) for sorting and identification. The specimens belonging to the Tachinidae (Diptera) were identified to species level using Cerretti (2010) and Cerretti et al. (2012). All the specimens were housed in the insect collection of P. Cerretti at the Museo di Zoologia, Sapienza Università di Roma, Rome, Italy (MZUR).

Table 1
Habitat cover by each type of landscape. The mean and SE were calculated from the percentage of coverage of each habitat within a 500 m radius.

Landscape type	Apple orchard		Forest		Grassland	
	mean ± SE	min–max	mean ± SE	min–max	mean ± SE	min–max
Apple-dominated	52.8 ± 6.1	43.8–81.4	19.1 ± 5.1	2.2–20.6	14.3 ± 4.4	0.9–26.8
Forest-dominated	9.2 ± 2.6	0.8–21.6	65.7 ± 5.5	49.9–84.7	20.2 ± 6.0	3.3–25.3
Grassland-dominated	11.9 ± 3.2	0.8–35.0	10.9 ± 3.4	0.4–36.5	67.8 ± 2.9	58.7–79.8