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Beneficial insects in urban environments: Parasitism rates increase in large and less isolated plant patches via enhanced parasitoid species richness

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ABSTRACT

In urban habitats, plant resources for herbivorous insects and their parasitoids are spatially subdivided and embedded in a matrix of built environment. These conditions could affect insect colonization and persistence, leading to altered trophic interactions. Here we tested whether spatial attributes (size and isolation) of patches of an urban spontaneous plant (*Commelina erecta*) affect the parasitism rates on a specialist leaf miner (*Liriomyza commelinae*) from its diverse parasitoid assemblage. To achieve this goal we performed an observational study in Córdoba city (Argentina), by sampling 893 naturally established *C. erecta* patches on 18 neighborhoods. Overall parasitism rates of the leaf miner augmented at increasing patch size and decreasing patch isolation, and those effects were mediated by changes in parasitoid richness. Leaf miners in larger or less isolated plant patches supported more parasitoid species which, independently of host abundance, led to higher parasitism rates. Individual parasitoid species showed different responses to patch attributes, with some species being more efficient in large or less isolated plant patches whereas parasitism rates of other species were independent of patch attributes. Our results highlight the importance of spatial availability of urban plant resources for parasitoid diversity and for the key process of biological control in which they are involved. Understanding how natural enemies respond to the patchiness of herbivore resources in the urban context could contribute to the development of strategies to preserve beneficial insects in these highly modified landscapes.

1. Introduction

Urban areas are modified and complex landscapes, characterized by high levels of disturbance and fragmentation (Grimm et al., 2008; Pickett et al., 2001). Concrete buildings, asphalt paving and vegetation reduced to patches scattered in the landscape are distinctive features of urban areas (Niemelä, 1999; Rebele, 1994). Although the urbanization process usually has negative effects on the native biota (Czech et al., 2000; McKinney, 2008), green areas like gardens and wastelands may sustain a significant diversity of beneficial arthropods allowing for the maintenance of ecosystems services such as pollination, seed dispersal and insect pest regulation (McDonald and Marcotullio, 2011; Robinson and Lundholm, 2012).

Parasitoid insects are important biological control agents of herbivorous populations and have been found sensitive to urbanization (reviewed in Fenoglio and Salvo (2010)) at different spatial scales (Bennett and Gratton, 2012). Previous works have explored the influence of urban patches of vegetation on parasitoid communities (Christie and Hochuli, 2009; Christie et al., 2010; Gibb and Hochuli, 2006) applying a landscape perspective. For specialist herbivores and their parasitoids, the local habitat is essentially represented by the host plants, which in urban areas could resemble green islands within an inhospitable matrix of building environment. The spatial subdivision of the plant resource becomes then crucial to insect colonization and persistence (Hanski, 1999; Niemelä, 1999), with patch attributes such as size and isolation being particularly relevant. Although there is evidence of spatial attributes of local patches affecting host–parasitoid interactions in natural or agricultural environments (Cronin, 2003, 2004; Doak, 2000; Elzinga et al., 2005; Kruess and Tscharntke, 2000; Woodcock and Vanbergen, 2008), it remains unclear how those variables act in an urban context (Denys and Schmidt, 1998).

On urban plant patches, populations of insect herbivores and their parasitoid assemblages might function like metacommunities (Leibold et al., 2004; Swan et al., 2011) because insect dispersal, the key process linking local communities, can be low due to the

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presence of physical barriers but still large enough for long-term persistence. In this context, colonization, extinction and population abundance are expected to be affected by the area and isolation of patches (Hanski, 1999). Moreover, the differential susceptibility of herbivores and parasitoids to habitat patchiness could lead to altered trophic interactions (Holt et al., 1999; Kruess and Tscharntke, 1994).

In addition to metacommunity processes, spatial characteristics of plant patches can influence parasitoids through changes in the abundance or density of herbivore insects (Bach, 1988; Pareja et al., 2008). Direct effects of patch attributes on parasitism rates can also occur independently of the actual amount of host resources, for instance via differences in individual ability to find and/or exploit hosts. According to Sheehan and Shelton (1989), who proposed an extension of the resource concentration hypothesis (Root, 1973) to the third trophic level, parasitism rates would increase with increasing plant patch size since parasitoids may be more likely to find or less likely to leave large plant patches (see Esch et al., 2005; Kruess and Tscharntke, 2000; Pareja et al., 2008). In fact, larger green patches in a concrete urban matrix could constitute an easier target to detect for visually searching parasitoids (Chittka, 1996). At the same time, plant volatiles and herbivore-derived chemicals may play an important role in parasitoid foraging (Turlings and Wäckers, 2004). Olfactory and visual signals probably increase with increasing patch size, thus attracting more parasitoids.

On the other hand, parasitoids may be unable to track hosts in isolated patches because of restricted movement within the urban matrix (Denys and Schmidt, 1998; Raupp et al., 2010). Species susceptibility to habitat isolation not only depends on dispersal ability (Tscharntke and Brandl, 2004) or distance between plant patches, but also on the nature of the surrounding matrix (Ricketts, 2001). The urban matrix is typically hostile to less mobile species and the effects of isolation might therefore be higher than in simpler landscapes (Gilbert, 1989). Negative relationships between patch isolation and parasitism rates have been previously reported for other environments (Faeth and Simberloff, 1981; Krewenka et al., 2011; Kruess and Tscharntke, 1994, 2000) as well as for urban habitats (Denys and Schmidt, 1998; Peralta et al., 2011).

The majority of studies examining spatial effects of plant patches on host–parasitoid interactions have focused on pair-wise species systems (Esch et al., 2005; Pareja et al., 2008; Vanbergen et al., 2007). For herbivore insects supporting complex parasitoid assemblages, the effects of plant patch features on parasitism rates could be mediated by changes in parasitoid diversity, which could ultimately drive overall parasitism rates (Fenoglio et al., 2012; Tylianakis et al., 2006).

This study aims to understand parasitoid community responses to plant patchiness in urban environments. Particularly, we investigated the role of plant spatial availability on parasitism rates caused by a parasitoid assemblage on a specialist leaf miner, by performing an observational study in a populated city of Central Argentina. We previously found that neither parasitoid species richness nor parasitism rates were influenced by urbanization degree, leaf miner abundance or host diversity at landscape scale (Fenoglio et al., 2009). However at local scale, plant patch size positively affected the number of parasitoid species associated with the leaf miner (Fenoglio et al., 2010).

Here we specifically ask (i) whether size and isolation of urban plant patches affect overall parasitism rates of the leaf miner and, if so, (ii) whether the effects are mediated by the changes in parasitoid richness previously reported or just by differences in host abundance. We also look at parasitism rates caused by individual species, in an attempt to further understand the effects of spatial attributes of plant patches on this valuable ecosystem service.

2. Material and methods

2.1. Study system

The study system comprised the leaf miner *Liriomyza commelinae* (Frost, 1931) (Diptera: Agromyzidae), its parasitoid community and its host plant *Commelina erecta* L. (Commelinaceae). The neotropical *L. commelinae* has been recorded feeding on the genera *Commelina* and *Tradescantia* (Smith, 1987; Stegmaier, 1966), but appears to be specialized on *C. erecta* in central Argentina (Valladares, 1984) where mines are abundant in the summer, especially during February and March. The larvae burrow into the leaf parenchyma forming distinct serpentine mines (Fig. 1A) visible on the upper surface of the leaves, within which they pupate (Smith, 1987).

Parasitoids are an important source of mortality in this species, with 25 native Hymenopteran species (Fig. 1B) causing on average 50% mortality, being recorded in central Argentina (Fenoglio and Salvo, 2009). Most of these parasitoids are solitary and polyphagous, feeding on various leaf-miner species in the study region (Fenoglio and Salvo, 2009; Salvo and Valladares, 1999). To our knowledge, there are no records of hyperparasitoids associated with *L. commelinae*.

The host plant *C. erecta* is an herbaceous plant, common and widely distributed in the north and center of Argentina, frequently appearing as spontaneous urban vegetation. Leaves and flowers are available from November to April, but rhizomes are present all year (Sérsic et al., 2006). In urban areas, *C. erecta* typically shows a highly patchy distribution (Fig. 1C), growing in plant groups of variable size and distance from other patches (Fenoglio et al., 2010).

2.2. Survey

The research was conducted within Córdoba city, which is located in central Argentina (31°20′S, 64°10′W, elevation 440 m) and has a population of 1,329,604 inhabitants (Indec, 2010). The climate is subhumid, with an average annual precipitation of 790 mm, concentrated principally in summer (October–March). The city has an irregular topography and it is crossed by the Suquía River from west to east. Córdoba covers an area of 576 km^2 from which 39.75% correspond to urban development, 28.48% to rural area, 21.3% to industrial area and 10.5% to other uses (Observatorio Urbano Córdoba, 2007). Eighteen sites located in different neighborhoods spread across the city (Fig. 1D) were sampled during January and February 2006, corresponding to the peak period of *L. commelinae* activity. At each site, the pavements of one central and 8 adjacent urban blocks (about 2100 lineal meters per site, standard Córdoba blocks being 100 m × 100 m) were checked in order to find *C. erecta* plant patches. The sampling procedure was restricted only to pavements, as is commonly done in this type of studies (Piel et al., 2005), given the logistical problems of sampling private gardens and also due to pavements being potential corridors for *L. commelinae* and its parasitoids (Peralta et al., 2011).

The size of plant patches was calculated as covered area (cm^2) from their length–width measurements. Only mined plant patches were considered in the survey. Isolation, the distance (m) to the closest patch, was measured at field using a measuring tape since most of patches (95%) were located nearby (<50 m). All mined leaves in each plant patch were collected, placed in plastic bags, transported to the laboratory, and kept until flies and parasitoids emerged. Adult leaf miners and parasitoids were stored in glass vials plugged with cotton wool; once emergence had ceased, they were counted and identified (Salvo and Valladares, 1999). Voucher specimens of parasitoid and leaf miner species were deposited in the collection of the Entomology Department, Universidad Nacional de Córdoba, Argentina. The following variables were