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Research paper

Enhancing pollination supply in an urban ecosystem through landscape modifications

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HIGHLIGHTS

- We test the pollination module of InVEST in an urban environment (Chicago, USA).
- The model predicts 46% of the native bee richness ($p = 0.008$, $n = 14$).
- The model suggests that pollination supply is highly variable across Chicago.
- We model various land cover change scenarios' effect on pollination supply.
- Of the scenarios tested, increasing floral resources around urban agriculture sites is best.

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ABSTRACT

Although urban agriculture is growing in popularity, little is known about the distribution of insect pollinators across urbanized landscapes. We used the pollination module of InVEST (a suite of software models used to map and value ecosystem services), along with fine-scale land cover data and empirical data on bee distributions, to assess different scenarios of urban pollinator management in Chicago, Illinois (USA). Specifically, we simulated the partial conversion of lawn/turf-grass to floral resources in city parks only, in gardens managed by individual households only, and in any available turf grass within buffer distances of 250–1000 m of urban farms, community gardens, and home gardens across Chicago. We found that the output of InVEST's pollination model was significantly related to empirical measures of bee richness (explaining 46% of the variation) but not bee abundance in Chicago. To increase pollination supply at urban farms and community gardens, our results indicate that, out of the scenarios presented here, the best strategy for the City of Chicago would be to concentrate floral resources nearby (within a 250 m buffer rather than within a 1 km buffer). In contrast, for home gardens, the model indicates that it may be better to increase floral resources throughout the city. This discrepancy may be due to the smaller size of home gardens and their more dispersed spatial arrangement throughout the city. Generally, our results indicate that converting turf grass to a more florally-rich land cover would support increased supply of pollinators and urban agriculture.

1. Introduction

In recent years, interest in residential food gardens, community gardens, and urban farms, aka urban agriculture, has been growing (Tornaghi, 2014). The crops grown in these gardens may increase urban sustainability and food security (Colasanti, Hamm,

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& Litjens, 2012). However, many urban crops, such as cucumbers and squash, depend on pollination services provided by insects (Matteson and Langellotto, 2009), and several studies have shown not only a decrease in pollinator diversity with urbanization or human population density (Ahrne, Bengtsson, & Elmqvist, 2009; Bates et al., 2011; Matteson, Grace, & Minor, 2013) but also a shift in species composition (Banaszak-Cibicka & Żmihorski, 2012;Cane, Minckley, Kervin, Roulston, & Williams, 2006). Other research suggests that pollination services and seed set may be limited (Leong, Kremen, & Roderick, 2014; Pellissier, Muratet, Verfaillie, & Machon, 2012) or variable (Lowenstein, Matteson, & Minor, 2015) in urban areas, possibly due to the distribution of floral resources or to low pollinator abundance. Efforts to conserve urban pollinators could also boost productivity of urban agriculture.

Wild insects can be highly effective pollinators of agricultural crops (Garibaldi et al., 2013). Studies from rural systems indicate that high quality habitat in the surrounding landscape benefits the wild pollinator community (Kennedy et al., 2013; Ricketts et al., 2008). Nearby floral resources and nesting sites have been linked to increased pollinator diversity (Potts, Vulliamy, Dafni, Ne'eman, & Willmer, 2003; Potts et al., 2005) and pollination services (Blanche, Ludwig, & Cunningham, 2006; Holzschuh, Dudenhöffer, & Tscharntke, 2012). In urban areas, wild bees are often more abundant than honey bees (Leong et al., 2014; Lowenstein et al., 2015), but high quality bee habitat may be scarce or distributed in ways that do not benefit urban agriculture. For instance, Matteson and Langellotto (2010) found that only 10–32% of the landscape surrounding urban gardens in New York City had vegetation of any type, with most of this being sparsely distributed street-trees, heavily-managed gardens, or urban parks. However, bee diversity in heavily developed landscapes may be maintained to some degree by ornamental flowers in urban gardens and other managed habitats (Fetridge, Ascher, & Langellotto, 2008; Frankie et al., 2005; Lowenstein, Matteson, Xiao, Silva, & Minor, 2014; Matteson & Langellotto, 2011). Increasing floral resources may provide an important mechanism for counteracting the negative impacts of urban development on pollinators. One common land cover which could be potentially modified to provide increased floral resources is turf grass or lawns.

Turf grass is a common land cover in residential, commercial, industrial, and recreational areas in U.S. cities. Turf grasses cover approximately 163,800 km^2 (+/− 35,850 km^2) of the conterminous U.S., an area three times larger than that of any irrigated crop (Milesi et al., 2005). In Franklin County, Ohio (USA), residential lawns were estimated to cover 23% of the county (Robbins & Birkenholtz, 2003). If a small amount of turf grass was modified or converted to floral resources, the benefits to urban bees and pollination services could be substantial (Blackmore & Goulson, 2014).

Using information on pollinator nesting resources and floral resources, Lonsdorf et al. (2009) predicted the relative abundance of pollinators available to pollinate farm crops. This approach, based on the suite of software models used to map and value ecosystem services called *InVEST* (Sharp et al., 2014), has not been tested in urban systems. However, it could potentially provide a useful approach for evaluating scenarios and developing land-use plans that promote and improve urban agriculture. We used InVEST to examine the potential for converted urban lawns to enhance pollination supply in Chicago, Illinois (USA). We first tested whether the InVEST pollination model (Sharp et al., 2014) can predict pollinator abundance and richness in an urban area and validated the spatially explicit model output against empirical field data. We then modeled the supply of pollination provided to approximately 4000 urban farms, community gardens, and home food gardens within the city limits. With different scenarios and spatial configurations, we converted areas of turf grass to flower gardens and evaluated the effect on pollination supply. The scenarios mimic three different management approaches by which to increase floral resources in the city. The first scenario mimics a city-led effort which focuses on city parks, the second scenario targets private yards managed by individual households, and the third is a combination of the first two but is a scale-dependent assessment. These scenarios were intended to evaluate the success of various strategies for enhancing urban pollination supply in Chicago, Illinois, USA.

2. Methods

2.1. Study area

Chicago, Illinois is the third largest city in the United States, with just over 2.5 million residents (2010 U.S. Census). Approximately 21.3% (126 km^2) of the city is covered by turf grass (Fig. 1). Turf grass in this study refers to intensely managed grass that is treated with insecticides and herbicides and mowed frequently (e.g., most golf courses) as well as lawns that contain lawn weeds such as dandelions (*Taraxacum officinale*) and white clover (*Triofolium repens*) which provide floral resources for pollinators in urban areas (Larson, Kesheimer, & Potter, 2014). Common lawn species in this area include Kentucky bluegrass (*Poa pratensis*), perennial ryegrass (*Lolium perenne*), and fine and tall fescues (multiple species including *Schedonorus arundinaceus*), although these vary depending on specific management.

We used the location of urban farms, community gardens, and home food gardens as identified from Google Earth imagery by Taylor and Lovell (2012). In their study, Taylor and Lovell differentiated between various types of urban agriculture, e.g., urban farms, community gardens, and home gardens, among others. An urban farm was defined as a "large garden comprising more than one vacant lot, with no apparent internal divisions except those created by crops, suggesting unified management by a single gardener/farmer or group"; while a community garden was defined as "a garden apparently divided into individual plots" (Taylor & Lovell, 2012). In the present study, we consider community gardens and urban farms as one type of urban agriculture (larger in extent), as opposed to residential food gardens which are smaller and managed by individual households. The distribution of these two garden types (community/urban gardens versus residential gardens) across Chicago can be seen in Fig. 1. We assumed that these various types of urban agriculture grow similar crops and thus would have similar per area pollination requirements, and that they did not keep honey bee (*Apis mellifera*) hives on the premises.

2.2. Field work for model validation

Pollinator specimens were collected at 15 community gardens across Chicago (Fig. 2). The sites were chosen opportunistically, based on the garden manager's interest in the project, accessibility of the garden, and presence of an open area to set up the sampling grid. We have no reason to think that the gardens we studied were significantly different from other gardens in terms of floral resources or pollinators. We collected pollinators at each garden using pan traps (4 oz. soufflé cups painted white, yellow, or blue and filled with a detergent solution) placed on the ground in a 3 m x 3 m grid, with all pan traps one meter apart and not immediately adjacent to a pan trap of the same color. The grid placement was based on the available space in the garden and located away from footpaths when possible. Floral resources were not measured at the gardens. One of the sites bordered a golf course and the bee bowls were placed near tree canopy. Very low bee abundance and richness were observed at this site and it was removed from subsequent modeling (n = 14).