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Domestic gardens as favorable pollinator habitats in impervious landscapes

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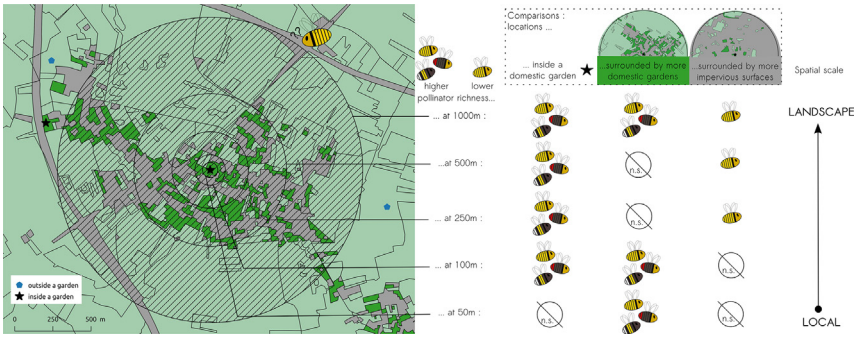
HIGHLIGHTS

- Citizen science provided access to domestic gardens, understudied urban green spaces.
- Impervious surfaces limit pollinators presence at landscape level.
- Sufficient critical amount of gardens increased pollinator diversity at local scale.
- Critical amount of gardens' knowledge may favor coordinated decisions by gardeners.
- Pollinators may benefit from patches of domestic gardens in an urban matrix.

GRAPHICAL ABSTRACT



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ABSTRACT

Urban expansion is correlated to negative biodiversity trends. The amount of impervious surfaces in urban areas is a determinant of pollinator species assemblages. While the increase in urbanization and impervious surfaces negatively impacts pollinators, cities also encompass urban green spaces, which have a significant capacity to support biodiversity. Among them, domestic gardens that represent a non-negligible fraction of green spaces have been shown to benefit pollinators. Domestic gardens may form habitat clusters in residential areas, although their value at a landscape scale is still unknown. Here, we investigate the combined effects of impervious surfaces and domestic garden areas on pollinator richness. Due to the difficulty of accessing privately owned domestic gardens, we chose to use citizen science data from a well-established French citizen science program known as SPIPOLL. Using regression tree analysis on buffers located from 50 m to 1000 m around the data points, we show the importance of pollinators being in close proximity to domestic gardens as locally favorable habitats that are embedded within a landscape, in which impervious surfaces represent unfavorable areas. We highlight the inter-connection between local and landscape scales, the potential for patches of domestic gardens in residential areas, and the need to consider the potential of gardeners' coordinated management decisions within a landscape context.

1. Introduction

Urban areas now contain more than half of the world's population and will continue to grow (United Nations, 2014). As urban expansion leads to an increasing number of former natural and semi-natural areas becoming urbanized, urbanization is now considered to be a

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major threat to biodiversity (Grimm et al., 2008). General findings stress the negative impact of urban areas on biodiversity through habitat loss, reduced habitat quality, and habitat homogenization (McKinney, 2008), as well as their impact on native species extinction (Czech et al., 2000). The increasing proportion of impervious surfaces in urban areas is a possible proxy for urbanization level. It is also a major determinant for several species assemblages, such as bees (Fortel et al., 2014; Geslin et al., 2016) and amphibians (Parris, 2006), as well as for urban ecosystem functions, such as water resources and flow regulation (Arnold and Gibbons, 1996).

Cities encompass urban green spaces (UGS), such as cemeteries, urban wasteland, public gardens, community gardens, and domestic gardens (Lepczyk et al., 2017). These UGS account for a variable percentage of a city's area, ranging from 2 to 46% in European cities (Fuller and Gaston, 2009). Their ability to support biodiversity has been recently acknowledged (Aronson et al., 2014; Beninde et al., 2015), and there is now a call to effectively integrate UGS in biodiversity planning and management to ensure their full inclusion in biodiversity conservation (Lepczyk et al., 2017). They may constitute a diversification of land usages given the general impervious surface and thus support increased levels of biodiversity (McKinney, 2008). Moreover, UGS benefit human health and well-being (Tzoulas et al., 2007).

Domestic gardens are an understudied type of UGS, mainly because of their limited accessibility to researchers and their supposed non-relevance to conservation (Cameron et al., 2012; Cook et al., 2012; Goddard et al., 2010). Yet domestic gardens may account for a large part of UGS and are thus worth considering in terms of their contribution to biodiversity conservation. Their estimated areas in cities vary from 16% in Stockholm, Sweden (Colding, 2007) to 22–27% in the UK (Loram et al., 2007) and 36% in Dunedin, New Zealand (Mathieu et al., 2007). Their distribution is heterogeneous within cities and surrounding regions: in Flanders, there is a lower concentration of gardens in city centers, but a higher proportion in the areas surrounding the centers and peri-urban areas (Dewaelheyns et al., 2014). Various organisms have been found to benefit from urban or peri-urban domestic gardens (Goddard et al., 2010), such as birds (Daniels and Kirkpatrick, 2006; van Heezik et al., 2008) and invertebrates (Smith et al., 2006a, 2006b; Sperling and Lortie, 2010), including pollinators (Pardee and Philpott, 2014).

In this study, we chose to focus on pollinators because of their role in ecosystem functioning (e.g. Potts et al., 2010 but also Kleijn et al., 2015), but also because of their adaptation to urban environments and the challenge associated with the low mobility of many small solitary bee species (Greenleaf et al., 2007; Zurbuchen et al., 2010). We thus consider pollinator richness as a surrogate for domestic gardens biodiversity. Indeed, grouped domestic gardens, i.e. patches, may represent more favorable habitats to pollinators with small flight ranges, as they are able to take advantage of the nearby resources, either inside the garden or in adjacent gardens (Lerman et al., 2018). As urban perturbation is particularly high on small spatial scales and eliminates close living species (McKinney, 2008), suitable habitat patches such as domestic gardens could serve as refuges for pollinators. Hinners et al. (2012) found that resources are insufficient to maintain high pollinator diversity in suburban habitats <80,000 m^2, while in habitats around 200,000 m^2, richness was comparable to semi-natural areas: a threshold value for pollinator conservation might lie between these two figures. However, these areas are already considerably greater than the average domestic garden size, estimated to be 571 m^2 in Belgium (Dewaelheyns et al., 2014) and 190 m^2 in the UK (Davies et al., 2009). Yet the peripheries of many Western cities consist of extended suburban areas comprising residential areas with detached houses and private gardens. Consequently, the combined surface of neighboring domestic gardens might attain the threshold value of habitat patch size. When identifying actions to reduce the impact of urbanization on pollinators, the attained threshold surface may be an indicator of their efficiency.

In this context, pollinators are an interesting choice when studying domestic gardens as their decline is made visible to citizens, and individual actions in favor of pollinators are accessible to garden owners. While urbanization adversely affects pollinators by destroying floral resources and nesting sites (McKinney, 2002), the installation of "bee hotels" (artificial structures with materials that bees can use as a nesting site, such as wooden blocks with holes, paper tubes, etc.) has a variable impact on pollinator richness and abundance depending on the pollinator species (Gaston et al., 2005; MacIvor and Packer, 2015). The planting of pollinator-friendly flowers likewise has a variable impact depending on the chosen flower species and targeted insect species (Garbuzov and Ratnieks, 2014; Salisbury et al., 2015). A more precise determination of the scale of effect of domestic garden patches on pollinator richness in peri-urban areas would make an important contribution to biodiversity planning and management.

Because of their privately owned status, domestic gardens are not easily accessible and are thus less often the subject of research compared to other types of UGS (Hernandez et al., 2009). While obtaining regular access to gardens is difficult, long-term data gathering from domestic gardens is still possible through citizen science programs. The French citizen science program known as SPIPOLL was launched in 2010 (Deguines et al., 2012) by the National Museum of Natural History (MNHN) and Office for Insects and their Environment (OPIE) with a focus on flower-visiting insects, most of which are insect pollinators. Using a short protocol, SPIPOLL allows participants to take photographs of insects seen on flowers and send them to an internet database. The collected photographs result in an understanding of insects and their land-use preferences (Deguines et al., 2012).

SPIPOLL is a nation-wide program, although we choose to focus on the Île-de-France region in this study. Île-de-France is a densely populated region and is representative of urban areas in Western industrialized countries with their organization around a metropolis. The Parisian metropolis is located approximately in the center of the Île-de-France region and is surrounded by successive urban belts with decreasing urbanization, with a higher urban concentration around transportation networks (Fig. 1). Semi-detached or detached houses surrounded by domestic gardens are more frequent on the Paris periphery. Overall, the region allows us to study an urbanization gradient with a variable proportion of built-up, residential, and garden areas.

Determining a threshold for cumulative domestic garden areas that benefit pollinators relative to urban impervious surfaces on a given scale could help urban planners in the decision-making process. Moreover, regarding citizen science programs such as SPIPOLL, participants' knowledge of this threshold and the geographic situation of their garden could help them to better appreciate pollinator diversity as well as local pressures, and thus consider this diversity relative to the local urbanization stage and processes, especially as the inhabitants may also experience these to some extent.

The present study aims to understand the effect of urbanization and domestic gardens on pollinator richness and their relative importance. It includes several spatial scales relevant to the flight distances of pollinators and the size of domestic garden patches in peri-urban residential areas. Our hypotheses are as follows: (1) the effects of gardens on pollinator richness will be limited in densely urbanized areas, in which domestic gardens may not be determinants of pollinator richness; and (2) in areas where domestic gardens do have an influence on pollinator richness, the latter will be higher in areas with a low proportion of impervious surfaces and a high proportion of gardens.

2. Methods

The use of a French citizen science program focusing on pollinators allowed us to gather a large amount of data from locations that are usually difficult to access, i.e. domestic gardens. As we used citizen science data, several factors out of our control and irrelevant to this study may be related to data variability, such as temperature and cloud coverage