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ORIGINAL PAPER

More insect species are supported by green roofs near public gardens

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Abstract

Rapid urbanization is among the factors that decrease insect diversity. However, by offering suitable habitats, green roofs could lessen this adverse effect. Certain factors, like a nearby public garden, could be useful predictor variables to analyze to what extent green roofs can support insect communities. The study aimed to measure the insect diversity on intensive green roofs located near public gardens and on more isolated green roofs, within an urban setting. Insect species richness, abundance, and assemblages on the green roofs near public gardens differed from those on isolated green roofs. Results indicate that green roofs near public gardens will host more species, especially pollinators, consequently lessening urbanization's negative effect. To properly understand how landscape factors impact insect communities on green roofs, future studies on green roofs' biodiversity should consider public gardens and their influence on urban biodiversity.

Implications for insect conservation

The planning and establishment of a green roof near public gardens would probably enhance biodiversity conservation in an urban setting.

Keywords Green roof · Public garden · Urbanization · Pollinators · Urban biodiversity · Vienna

Introduction

During the last decade, studies on plants (Köhler 2006), birds (Fernández Cañero and González Redondo 2010), and various arthropod taxa including Araneae, Coleoptera (Kadas 2006), and Hymenoptera (MacIvor et al. 2015; Kratschmer et al. 2018) have supported the idea that green roofs are essential for preserving nature and promoting biodiversity in the urban setting (Hoeben and Posch 2021). For rare and endangered insect species adversely affected by urbanization, well-designed green roofs can offer secondary habitats. This has been shown by research projects examining the enormous potential of green roofs for ecological compensation: for example, in Basel (Brenneisen 2009) and London (Jones 2002; Kadas 2002).

Particularly in urban settings, public gardens generally contain a mixture of native and non-native plants, support insect species, and offer important ecosystem services. Studies by Smith et al. (2006) and Owen (2010) demonstrated that public gardens established with appropriate plant taxa can maintain high insect diversity. However, little is known about the significance of public gardens in supporting insect diversity on green roofs.

The aim of this study was to understand the relation between public gardens and insect diversity on green roofs by documenting some of the insect diversity associated with green roofs near and far from public gardens in Vienna as a first step to understanding insect distribution patterns. This will enable us to optimize the biodiversity potential of green roof designs. It is well known that plant, bird, and pollinator diversity is high in public gardens (Shwartz et al. 2014). Assuming public gardens may act as a source habitat, we expected that insect diversity would be higher on green roofs near public gardens than on more isolated green roofs.

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Methodology

Study site

The study was conducted in the capital of Austria, Vienna (48.2082° N, 16.3738° E), which has a total area of 414.9 km^2. The capital is characterized by a dry continental climate with an average precipitation of 535 mm per year. It ranges from 30 mm in the driest months (January and February) to 60 mm in the wettest ones (June and July) (Central Institute for Meteorology and Geodynamics 2016). We selected eight intensive green roofs (they have greater substrate depth than the extensive green roofs) having comparable vegetation structures (grasses like *Andropogon gerardii*, *Bouteloua gracilis*, *Schizachyrium scoparium* were commonly found on intensive green roofs; Supplementary Materials S1). The ages of the selected green roofs ranged between 10 and 30 years. Of these, four were located close to public gardens (within a 500-m radius) while the other four were more isolated (distance to the next public garden ranged from 2 to 5 km; Fig. 1). We chose a 500-m radius because roads may act as barriers to the movement of bees and wasps, especially for small species with poor dispersal ability (Andersson et al. 2017), and eventually restrict their activity range. In this study, public gardens are defined as urban green spaces containing ornamental and native plant species (Rakow 2011). The selected public gardens were highly managed for recreation. Thus, they comprised several old and large trees, large lawns that cover at least one-third of the garden area, and several highly managed flowerbeds with native and non-native ornamental flowers. They also contained some children's recreation areas. The selected public gardens were of similar size (~1 ha) and spatially independent of each other, typically separated by large buildings and streets. The green roofs studied contained a range of biophysical conditions, including variations in roof area (61–399 m^2) and roof height (17–107 m; Supplementary Materials Table A2).

Insect sampling

In 2021, insect collection was performed by a semi-quantitative and hand netting method on each green roof (Kratschmer et al. 2018). Insect sampling was conducted in four sessions of 60 min in each month (May to August), when weather conditions were suitable (warm, windless, and dry). Within each session, we actively searched the

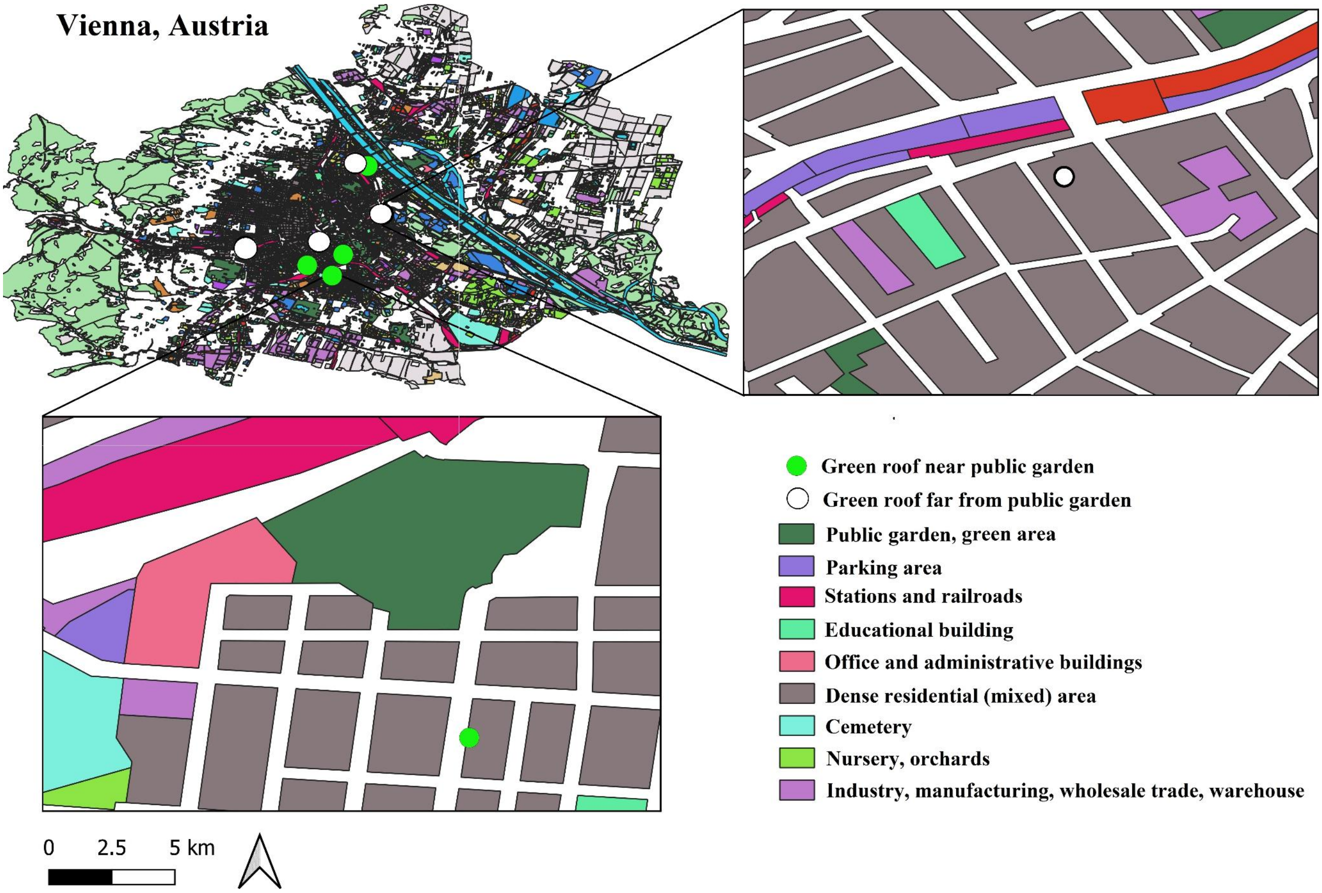

Fig. 1 Map of green roofs near public gardens and far from public gardens. The color codes represent the different habitat classes (Land Use of Vienna: modified after Pendle et al. 2022)

Table 1 Results of ANOVA for species abundance and richness of insects collected on the studied green roofs. Significant differences are shown in bold

Abundance		Df	Sum Sq	Mean Sq	F value	P
	Studied green roof type	1	1540	1540.1	8.948	**0.0243**
	Residuals	6	1033	172.1		
Richness	Studied green roof type	1	253.1	253.12	6.818	**0.0401**
	Residuals	6	222.8	37.12		

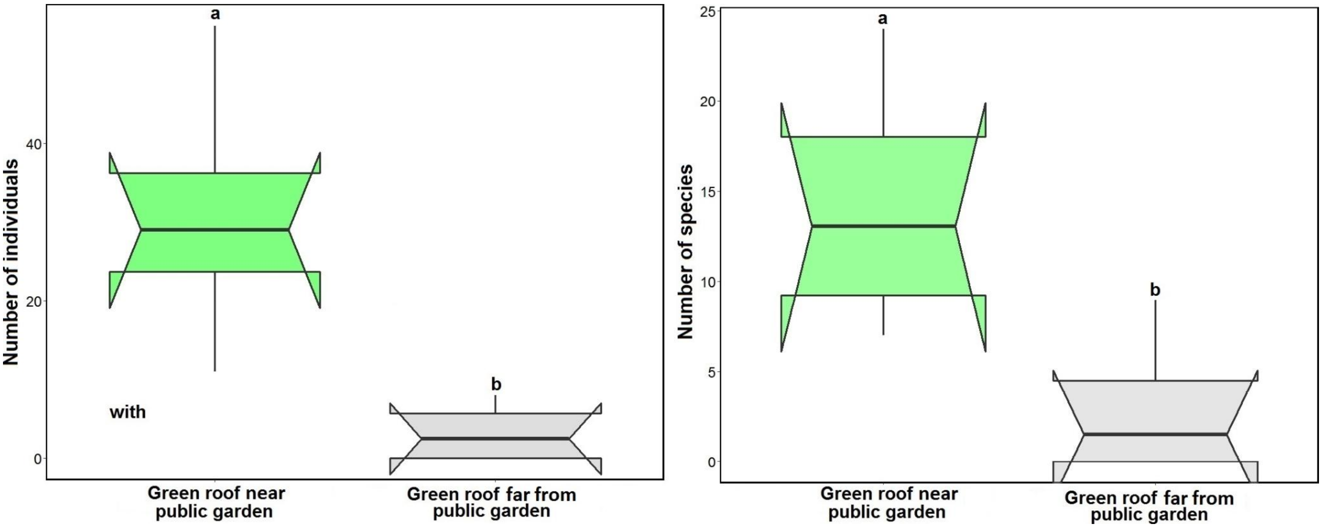

Fig. 2 Number of individuals and species on green roofs near (located within 500 m) and far (located more than 500 m) from a public garden. Boxplots show the medians, the 25% and 75% percentiles, and the 10% and 90% percentiles, and notches. Different letters (a, b) indicate significant differences between studied roof gardens

green roof and documented all observed insect species. Only insects that were observed to interact with the green roof were recorded. The insect taxa ant, bumblebee, heteropteran bug, syrphid, wasp, and wild bee were collected and afterwards prepared and identified to species level using relevant literature (e.g., Wagner 1967; Schmid-Egger and Scheuchl 1997; Gokcezade et al. 2010; Veen 2010). Most bumblebee individuals were identified on site and released afterwards.

Statistical analysis

For analysis, the numbers of species and individuals among all insect taxa were summed from multiple observations per month. The Shapiro test and QQ plots were used to examine the data for normal distribution. The Bartlett test was used to assess homoscedasticity, or homogeneity of variance. To evaluate differences between response variables (richness and abundance) and predictor variables (habitat type: green roof near and far from a public garden), we performed analysis of variance (ANOVA).

To assess differences in species assemblage, we calculated PERMANOVA (Bray-Curtis dissimilarities, 999 permutations) using the function *adonis* from the R package vegan (as performed in Hussain et al. 2022). The *betadisper* function was used to check the initial data for equal multivariant dispersion. Later, multilevel pairwise comparison was applied using *pairwise.adonis* to evaluate the species assemblage differences between green roofs near and far from public gardens. Further, an ordination plot of principal component analysis was made to visualize the species assemblage patterns. For statistical analysis, R software (version 3.5.1) was used (R Core Team 2018).

Results

A total of 124 individuals from the 6 insect taxonomic groups were observed. In total, 106 individuals were observed on green roofs near public gardens and 18 individuals far from public gardens. There were 21 wild bee and eight syrphid species, and two species each of ants, bumblebees, heteropteran bugs, and wasps, totaling 37 species (Supplementary Materials Table A1). The numbers of individuals (ANOVA: $F=8.948$, $p=0.0243$; Table 1; Fig. 2) and species (ANOVA: $F=6.818$, $p=0.0401$; Table 1; Fig. 1) were significantly higher on green roofs near public gardens than on the more isolated green roofs. Insect species assemblages differed significantly between green roofs with public gardens and the more isolated green roofs (PERMANOVA: $R^2=0.15$, $p=0.0385$; Table 2; Fig. 3).

Table 2 PERMANOVA table showing effect of nearby public gardens on insect assemblages on studied green roofs in dependence of closeness to public gardens

Assemblages		Df	Sum Sq	Mean Sq	R^2	P
	Studied green roof type	1	0.3142	0.31425	0.15	**0.0385**
	Residuals	6	1.8050	0.30083	0.85	
	Total	7	2.1192			

Discussion

Green roofs near public gardens showed 50% more species and total individual insects compared with isolated green roofs. Insect abundance may increase on green roofs over time (Kadas 2006), although this is not always the case (Kyrö et al. 2018). All insect groups were present on green roofs, with generalists (that can live in diverse environments) being the most abundant and diverse. Our findings imply that green roof location should be considered prior to installation in order to preserve biodiversity, trophic level interactions, and ecosystem services in urban settings (Lundholm 2015).

In general, rapid urbanization is associated with a loss of species diversity and homogenization of insect assemblages (Groffman et al. 2017). The impacts of different local site attributes and habitat quality on insect assemblages are significantly more complex at the scale of a yard, park, or neighborhood (Adams et al. 2020). In general, insect responses to green roofs indicate that the character of the nearby urban setting is likely an important predictor of local insect assemblage structure, especially for wild bees, a group that is highly mobile and might not be hampered by barriers (Haskell 2000; Baxter-Gilbert et al. 2015; Muñoz et al. 2015).

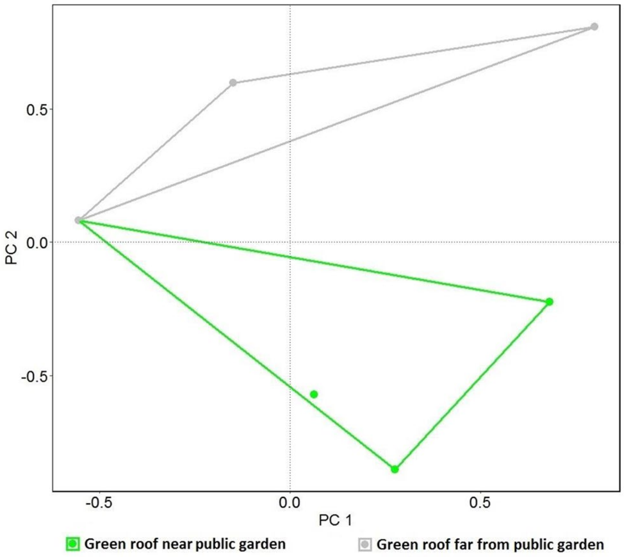

Fig. 3 Principal component analysis based on species assemblages of observed insects on green roofs

Diverse vegetation in public gardens usually presents more suitable habitat conditions, is higher, and/or offers more resources than green roofs (Holt 2016). This is in line with studies arguing that habitats with greater plant diversity enhance the growth and activity of natural enemies (Letourneau et al. 2011; Hussain et al. 2021). Even though the predictions made by these studies are frequently observed in agricultural systems (Landis et al. 2000; Maas et al. 2021), the influence of plant diversity on insect habitat quality has rarely been considered in regard to green roofs. This study's results indicate that, for the six observed insect taxa, the resources provided by a diverse plant community in nearby public gardens might be more relevant (mentioned in Schunko et al. 2021), as many generalist insect species can thrive in the small habitats of nearby green roofs.

In the past, researchers thought that only the most migratory insect species could make use of the ecosystems found on green roofs (Dunnett and Kingsbury 2008). We discovered a similar pattern, in which numerous insects, including medium, large, and even flightless insects, spontaneously populated the green roofs. The source habitat of such insect groups could be the nearby public gardens, because the literature shows that these insect groups—especially carabids and heteropteran bugs, which are sensitive to environmental stress—are found predominantly at the soil surface of ground level urban habitats (Niemelä et al. 2000).

We present preliminary results because we acquired just four replicates, leading to a comparably low number of observed individuals. The current study has a few caveats that should be considered. For instance, the sampling of insects was done only on green roofs and according to a specific method, because of the study's preliminary character and limited funding. Additional sampling methods with increasing sampling duration can help to determine how many insect species are actively using green roofs. Each isolated green roof was in close proximity to some green spaces that could have influenced its biodiversity. Further, factors like urban construction and green roof structure (e.g., vegetation mixture, type of soil, soil depth, construction age, and specific maintenance) may also affect green roof biodiversity (Andersson et al. 2017). Future studies considering these limitations would be valuable in fully understanding how nearby landscape conditions shape insect communities on green roofs. However, our study provides additional information with which to build strategies for biodiversity conservation in the urban setting.

Supplementary Information The online version contains supplementary material available at https://doi.org/10.1007/s10841-023-00510-x.

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Author contributions Raja Imran Hussain led the data collection and analysis as well as the writing of the manuscript, Sophie Kratschmer supported bee's identification, and Thomas Frank helped revise the manuscript. All authors contributed critically to the manuscript and gave final approval for publication.

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Declarations

Conflict of interest The authors declare that there is no conflict of interest.

Consent to participate The authors have provided their consent to participate to the work.

Consent for publication The authors have provided their consent for publication.

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