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THE DIVERSITY OF POLLINATORS ON GREEN ROOFS

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Abstract – The aim of this research was to survey green roofs for pollinator abundance and diversity. The research was conducted in 2019 on green roofs in Ljubljana and Škofja Loka (Slovenia). During the whole flowering season, we counted the number of honeybees, bumblebees, other wild bees, hoverflies, and butterflies. Results showed that various pollinators forage on blooming green roofs. The structure of flowering plants and pollinator communities also changed greatly during the season. During June and July, wild bees dominated, while in August and September, honeybees had the highest numbers. The results show that green roofs are important not only for domesticated honeybee or beekeeping, but also for biodiversity conservation. Based on the results, we also suggest improvements to make these roofs an even better food source for pollinators.

KEY WORDS: green roofs, green infrastructure, pollinators, honeybee, wild bees, bumblebees, hoverflies, urban ecology, biodiversity

Izvleček – PESTROST OPRAŠEVALCEV NA ZELENIH STREHAH

Cilj raziskave je bilo ugotoviti številčnost in pestrost opraševalcev na zelenih strehah. Raziskava je potekala leta 2019 na strehah v Ljubljani in Škofji Loki. V času cvetenja smo spremljali število medonosnih čebel, čmrljev, drugih divjih čebel, muh trepetavk in metuljev. Rezultati so pokazali, da se na strehah hranijo različni opraševalci. Cvetenje streh in združbe opraševalcev se preko sezone tudi precej spreminjajo. Junija in julija so prevladovale divje čebele, avgusta in septembra pa medonosna čebela. Rezultati kažejo, da zelene strehe niso pomembe samo za medonosno čebelo in čebelarstvo, ampak tudi za varovanje biodiverzitete. Na podlagi rezultatov predlagamo tudi izboljšave, da bi bile strehe za opraševalce še boljši vir hrane.

KLJUČNE BESEDE: zelene strehe, zelena infrastruktura, opraševalci, medonosna čebela, divje čebele, čmrlji, muhe trepetavke, urbana ekologija, biodiverziteta

Introduction

Pollinators provide one of the key ecosystem services – pollination, important for biodiversity and agriculture. Among insects, the main pollinators are bees, flies, butterflies, moths, wasps, beetles and thrips (Potts et al. 2016). The net worth of insect pollination is estimated to be around 10% of the total worth of agricultural production. This adds up to around €153 billion globally (Gallai et al. 2009), and up to €22 billion in Europe every year (Potts et al. 2015).

In recent decades, the populations and diversity of pollinators has declined rapidly (Potts et al. 2010, Hallmann et al. 2017, Wagner 2020). For instance, 9.2% of bees in Europe are threatened with extinction. However, for 56.7% of bees, there is not enough scientific information to evaluate their risk of extinction (Nieto et al., 2014). The main drivers for this decline are changes in land use, pesticide use, disease, and climate change. One of the biggest threats to pollinators is lack of food due to intensive farming, urbanisation, and climate change (Nieto et al., 2014, Gogala, 2014, Bevk et al. 2016). Increasing development of urban environments also puts pressure on green spaces, having a potential negative impact on biodiversity and ecosystem services (Braaker et. al 2017).

This problem can be partially alleviated by green infrastructure such as green roofs. A variety of native bee species can use green roofs as foraging and/or nesting sites (Colla et al., 2009; Ksiazek et al., 2012; Maclvor et al., 2015). Although pollinators are present on green roofs in lower abundances and species richness than in natural habitats and ground-level sites, roofs are potentially valuable sites for pollinator conservation in urban areas, particularly if planted with a diverse range of native plants (Tonietto et al., 2011; Braaker et. al 2017). Subsequently, the integration of green roofs in cities has great potential to enable higher connectivity among green spaces (Braaker et. al 2014). Green roofs become even more important under changing temperature conditions, as they can mitigate the negative effects of increasing temperatures on wild bees (Papanikolaou et al., 2017).

The aim of this research was to survey Urbanscape green roofs for pollinator abundance and diversity, and to determine their potential as food resource for pollinators in urban areas.

Methods

Investigation of pollinator foraging activity was conducted in 2019 on two Urbanscape green roofs. The first roof (700 m^2) was in Ljubljana, near the city centre on residential building Y (7th floor). There were three apiaries present within a radius of 500m, and another three within 1000m. The second roof (100 m^2) was in Škofja Loka, on the edge of the industrial zone on Knauf Insulation Experience Center (3rd floor). There was one apiary within a radius of 500m, and another five within 1000m.

We counted the number of honeybees, bumblebees, other wild bees, hoverflies and butterflies. Pollinator activity was monitored during the whole flowering season (June – September), three to five-times a month on each location, solely in sunny

Figure 1: Green roof in Ljubljana.

weather when pollinators are most active. Firstly, we looked at which plants were blooming and estimated the percentage of flowering roof area. We then defined five sampling sites. One sampling site represented one square meter of flowering plants. Pollinator activity was monitored on sampling sites for two hours between 8 a.m. and 11 a.m. Twenty monitoring counts on each sampling site were carried out per day (totalling 100 across the five sampling sites). After the last count was carried out, up

Figure 2: Green roof in Škofja Loka.

to three specimens that could not be determined in the field were caught with nets. Effort was made to catch samples of morphologically different specimens. These were prepared for later idenfication, to determine the species. In total in whole season, we caught 19 bees and one hoverfly in Ljubljana and 12 bees and three hoverflies in Škofja Loka.

Based on the obtained data, we calculated the structure of pollinator communities, density of pollinators and the dynamic of flowering on the roof across the season (composition of flower communities).

Results

In Ljubljana, the flowering period (established when at least part of the plants on the roof started to come into bloom, until the end of the blooming period) lasted from the middle of June to the end of September. During this period, 14 observation days were conducted and 869 pollinators were counted altogether. The most abundant pollinator observed was the honeybee (463, Figure 3), followed by "other wild bees", i.e. wild bees other than bumblebees (392). There were also some hoverflies recorded (6), butterflies (4) and bumblebees (4). In total, seven species of wild bees and one species of hoverfly were found (Table 1).

In Škofja Loka, the flowering period lasted only from the middle of June to the beginning of July. Therefore, only three observation days were conducted altogether, and 403 pollinators were counted. The most numerous pollinators by far were "other wild bees" (377). There were also some honeybees (19), hoverflies (6), one butterfly

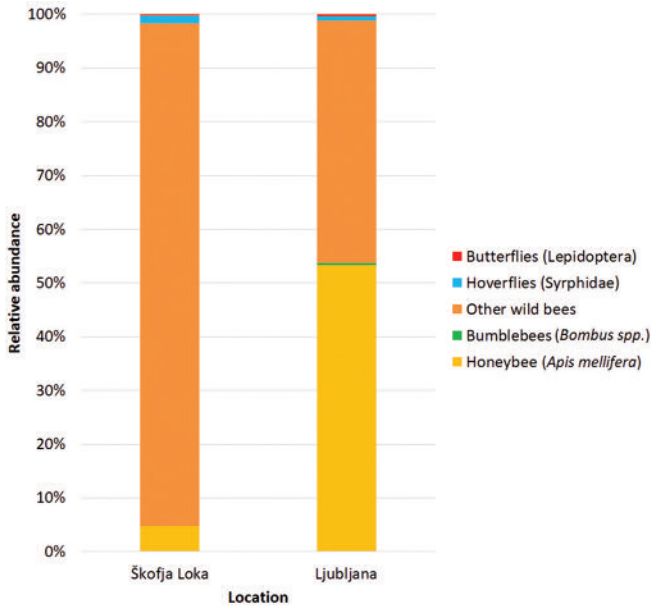

Figure 3: The structure of pollinator communities recorded on each green roof.

recorded, and no bumblebees. Together, five species of wild bee (Table 1) and three species of hoverfly were found. Two species of bee were found across both green roofs in Škofja Loka and Ljubljana

Table 1: List of bee and hoverfly species found on each green roof.

Ljubljana	**Škofja Loka**
Bees	
Andrena subopaca	*Andrena subopaca*
Lasioglossum politum	*Lasioglossum politum*
Hylaeus punctatus	*Lasioglossum laticeps*
Megachile willughbiella	*Lasioglossum lineare*
Megachile pilidens	*Lasioglossum malachurum*
Anthidium oblongatum	
Bombus terrestris/lucorum	
Hoverflies	
Eristalis tenax	*Helophilus trivittatus*
	Sphaerophoria sp.
	Eupeodes corollae

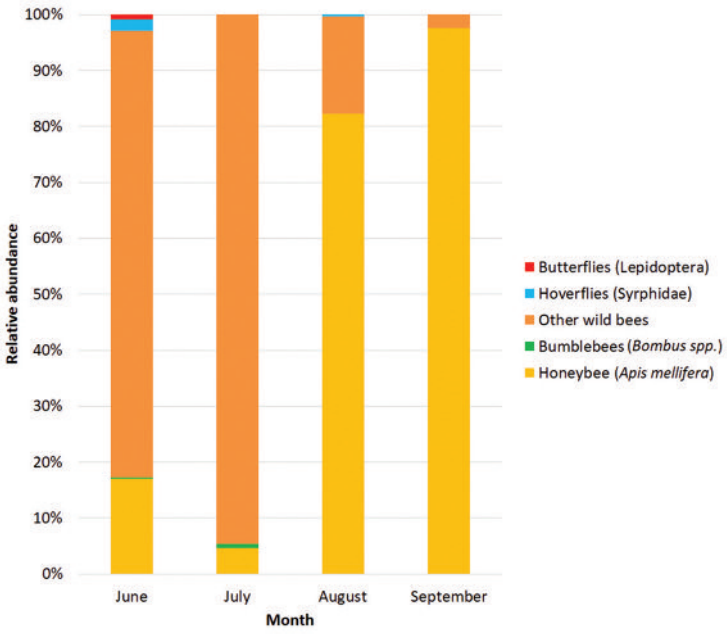

Figure 4: The structure of pollinator communities recorded by month (both locations together).

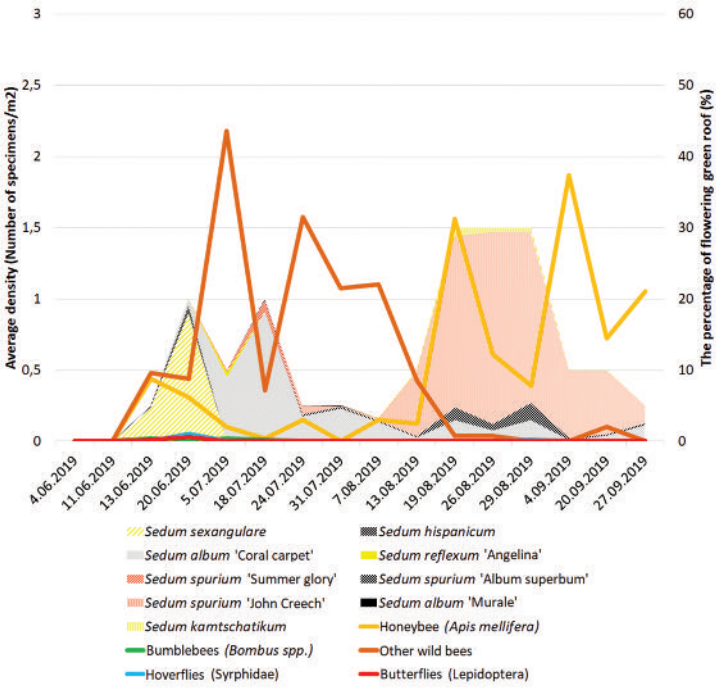

Figure 5: Pollinator density and flowering of the green roof in Ljubljana. The percentage of flowering green roof is presented on the secondary y-axis. The colour of the flowers is in line with the colour of the graphs (yellow, red, and white). Lines represent average density of pollinators (primary y-axis).

The structure of the pollinator communities changed greatly during the season. Wild bees dominated in June and July, while in August and September, honeybees dominated (Figure 4). Accordingly, the density of honeybees increased, and the density of wild bees decreased during the season. The average density in Ljubljana was 1,02 pollinators per square meter of flowering plants and 1,34 in Škofja Loka. The density of solitary bees was highest in June and July, in contrast to honeybees that had the highest density in August and September (Figure 5 and 6).

The flowering of *Sedum* spp. was very dynamic. In Ljubljana – where flowering lasted three and a half months, there were three peaks of blooming: in the middle of June (20% of roof), middle of July (20% of roof) and in the second half of August (30%, Figure 5). On the contrary, in Škofja Loka the flowering period lasted only one month, with peak of blooming (20%) at the end of June (Figure 6).

There were also differences in the species composition of flowering plants. We found nine different *Sedum* species on roofs. In Ljubljana (Figure 5), *Sedum sexangulare* (yellow) dominated in the beginning, then *Sedum album* 'Coral carpet' (white), followed by *Sedum spurium* 'John Creech' (red). In Škofja Loka (Figure 6), two

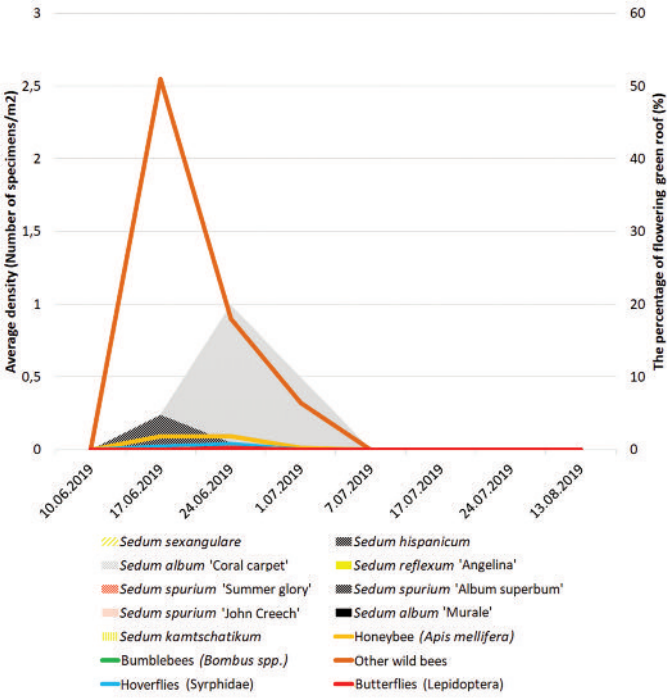

Figure 6: Pollinator density and flowering of the green roof in Škofja Loka.

species of white-flowered *Sedum* dominated (*Sedum album* 'Coral carpet' and *Sedum hispanicum*).

Discussion

Results show that green roofs can provide additional or alternative food sources for pollinators during the blooming period. Considering the lack of food being one of the main causes for pollinator decline, flowering green roofs can contribute to solving this problem.

Contrary to our expectations, with Slovenia having one of the highest densities of honeybee colonies in the European Union (Chausat et al. 2013), wild pollinators were more numerous than honeybees. This shows that green roofs are important not only for domesticated honeybees or beekeeping, but also in the aspect of biodiversity conservation.

Among wild pollinators, solitary bees were by far the most numerous. Their densities were surprisingly high. Hoverflies, butterflies, and bumblebees were rare. According to lepidopterists (Barbara Zakšek, pers. comm.), the low diversity of butterflies were expected, however, we expected much more bumblebees. The low number of bumblebees can at least partly be explained by smaller populations of bumblebees being present in 2019, due to a very rainy spring. As a result of the small number of

bees sampled (31) as well as hoverflies (4), species diversity is probably underestimated.

The structure of flowering plants and pollinator communities changed greatly during the season. In June and July, wild bees dominated, while in August and September honeybees had the highest numbers. A decrease in the number of solitary bees later in the season was expected, as most of these species are active in spring and early summer. As most Slovenian beekeepers have stationary apiaries, changes in the number of honeybees are probably not a consequence of moving bee colonies. The increase in the number of honeybees in late summer are more likely to be a consequence of decreases in nectar and pollen sources at this time of year. In June, honeybees probably prefer to forage on lime (*Tilia* spp.) and chestnut (*Castanea sativa*) trees and turn to alternative sources on green roofs when these are no longer in bloom. However, to obtain better understanding, longer research on more locations is needed.

According to our results, green roofs can play an important role in developing more pollinator and biodiversity friendly cities in general. Of course, biodiversity on rooftops cannot be compared to biodiversity of flowering meadows, but green roofs are one of the solutions for biodiversity and more environmentally friendly urbanization.

Based on the results, we suggest some improvements to make roofs an even better food source for pollinators. We recommend planting a selection of plants that provide good sources of nectar and/or pollen, and a combination of plants that provide food during the whole summer. We also recommend using a higher diversity of plants and the use of native plants.

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