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Exotics on exotics: Pollen analysis of urban bees visiting *Sedum* on a green roof

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Abstract Numerous bee species were collected from a single green roof over the blooming period of the dominant exotic plant type, *Sedum*, a succulent stonecrop widely used in the green roof industry. As green roofs become more common in cities, an understanding of the potential positive and negative impacts of widespread use of this exotic but useful plant is needed. In this study we sampled bees visiting a green roof in downtown Toronto and compared the proportion of *Sedum* pollen in the loads they were carrying back to nesting locations. It was found that smaller bees (e.g. *Lasioglossum, Hylaeus*) were significantly less common on the roof compared with medium (e.g. *Apis*, *Megachile*) and large-sized bees (e.g. *Bombus*, *Andrena*). The proportion of *Sedum* pollen in the pollen loads of foraging bees collected was high amongst all bees (average of 80.5 % of total pollen load), but significantly greater for exotic bees compared to native bees. Moreover, native bees had significantly greater numbers of non-*Sedum* pollen types comprising more than >20 % of their pollen loads, meaning bees could be visiting flowers at ground level and on the roof in the same foraging bout. As the number of green roofs in cities increase, the characteristics of their designs, including the vegetation type and diversity, could have a significant impact in shaping local urban bee communities.

Keywords Pollination · Urban · Native · Vegetated roof · Enhancement · Extensive · Diversity · Habitat design

Introduction

Green roofs are installed on new and existing buildings as components of low-impact development to reduce stormwater runoff, improve building cooling and mitigate the urban heat island effect (Oberndorfer et al. 2007). Many green roofs are designed to be lightweight, cost-effective and require low levels of maintenance. This often results in green roofs with shallow and low-organic substrates, as well as drought-tolerant, risk-adverse vegetation, referred to as 'extensive green roofs' (Dunnett and Kingsbury 2004). The dominant plant types on extensive green roofs around the world are horticultural varieties of succulents in the

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genus *Sedum* (Crassulaceae), a group of low-growing, xeric plants, many of which flower in early summer (with some exceptions, see Clausen 1975). In some cities, incentive programs promoting green infrastructure have resulted in thousands of square meters of extensive green roof installed per year, in some cases with bylaws mandating their installation (e.g. Toronto, Canada; Basel, Switzerland). The impact of these additional foraging resources for urban wildlife is understudied and requires investigation.

Different species and horticultural varieties of *Sedum* are popular plants for green roof installations because many are attractive and flower, survive better and live longer than other plants without the need for supplemental irrigation (Rowe et al. 2012). Although there are numerous species native to North America (Clausen 1975), almost all used in green roof applications are native to dry and rocky European habitats (Dvorak and Volder 2010). *Sedum* can be grown to maturity off-site on 'pre-vegetated' mats (similar to grass sod mats) for ease of transport to the site providing 'instant greening' (Dunnett and Kingsbury 2004). Many aspects of *Sedum* survival and performance have been well-researched on green roofs, including their establishment (Getter and Rowe 2008), water retention (Villarreal and Bengtsson 2005), the quality of water runoff (Czemiel Berndtsson 2010), irrigation requirements (VanWoert et al. 2005), carbon sequestration (Getter et al. 2009), thermal properties (Lundholm et al. 2010) and the economic feasibility for retrofitting buildings (Castleton et al. 2010).

With much focus on the survival and drought tolerance of *Sedum* on green roofs, there have been only a few studies that investigate the ecology of *Sedum* and implications for urban wildlife on green roofs. Kadas (2006) found numerous ground-dwelling invertebrates such as beetles and spiders both on and under *Sedum* vegetation. Similarly, Schrader and Böning (2006) noted high densities of collembolan species on *Sedum*-based roofs. The fleshy vegetation retained water in the substrate longer, thereby promoting a more suitable habitat for these species even in the warmest and driest times of the year (Schrader and Böning 2006). Additionally, comparisons between *Sedum*-based green roofs and those with more diverse plantings find the latter to contain more invertebrate diversity (Madre et al. 2013). Despite some effort to examine the habitat created by *Sedum*, there has been little work on its contribution to urban wildlife in the context of green roofs, including pollinating insects.

Many *Sedum* species used on green roofs grow stoloniferously or perennially from rootstock and pollination by insects is not essential for reproduction. However, many ant, beetle, fly and bee species have been observed visiting *Sedum* (Knuth 1906; Spongberg 1978; Wyatt 1981) due to its simple, small, open, and often numerous flowers per plant (Clausen 1975). *Sedum* generally have a short flowering duration (Snodgrass and Snodgrass 2006; Bosch et al. 1997) but have been identified from the pollen loads of numerous bee species in nature, including honey bees (Jato et al. 1994), bumble bees (Fussell and Corbet 1992) and various solitary bees (Lovell and Cockerell 1906; Dingemans-Bakels 1972; Clausen 1975; Pilar et al. 2005). *Sedum* is also a source of nectar for many bee species. For example, Bosch et al. (1997) notes *Sedum sediforme* as a species with high nectar volumes, making it rewarding for bees in Mediterranean plant communities. On green roofs, bees and flies especially are frequent observed on *Sedum* flowers (Snodgrass and Snodgrass 2006). Documenting the visits to *Sedum* by pollinators can be important for the green roof industry to convey the habitat value of the green roofs installed (Williams et al. 2014). Although one study investigated the pollen limitation of various forbs on green roofs in Chicago (Ksiazek et al. 2012), there have been no investigations of pollen loads from bee species frequenting green roofs.

Bees (Hymenoptera: Apoidea) have been sampled on green roofs in numerous studies (Brenneisen 2006; Colla et al. 2009; MacIvor and Lundholm 2011; Tonietto et al. 2011; O'Brien et al. 2012; Braaker et al. 2014; Ksiazek et al. 2014) but little information has been collected on their use of green roofs as habitat (Williams et al. 2014). Bees are presumed to benefit more from green roofs than other insect species because they are highly mobile in search of flowers and can forage vertically between green roofs and ground level (Braaker et al. 2014). While some pollinators are negatively affected by human land use (Winfree et al. 2011), bees are frequently recorded in cities and in one study, most often in sunny gardens in densely populated residential areas (Lowenstein et al. 2014). Like managed residential gardens, green roofs might also augment floral and nesting opportunities for bees in cities, while simultaneously contributing to wider socio-economic benefits (Oberndorfer et al. 2007; Loder 2014).

As green roofs become increasingly popular in cities like Toronto, understanding the impact of widespread plantings of exotic *Sedum* on local urban wildlife is essential if these novel habitats continue to be promoted as support for urban biodiversity conservation. In this study, we examine the relative proportion of *Sedum* pollen grains in the pollen loads of native and exotic bees visiting an extensive green roof during the *Sedum* flower bloom to better understand the relevance of this plant type for urban bee pollinators. Exotic bees in North America are all polylectic (Cane 2003). Also, although some studies demonstrate exotic flowers hosting both native and exotic bees (Frankie et al. 2005; MacIvor et al. 2014), other studies find exotic bees visiting almost exclusively (Stout et al. 2002), and in general the number of exotic pollinators increases with increasing numbers of exotic plants (Chittka and Schürkens 2001; Morales and Aizen 2002). Thus, we hypothesize that the number of exotic bees visiting the roof is greater than native bees and the proportion of *Sedum* pollen in the pollen loads of bees captured on the green roof is significantly greater among exotic bees.

Methods

The study took place at the Green Roof Innovation Testing (GRIT) lab on the on the fifth floor roof (approximately 15 m from ground level) of the Daniels School of Architecture, Landscape, and Design at the University of Toronto (See MacIvor et al. 2013 for additional details about the site) (Fig. 1). The building is in one of the most populated areas of the city at the southwest corner of St. George campus near the heart of downtown. At the site, bees having visible pollen loads and flying over *Sedum* plantings were hand-netted, identified to species and grouped by status (native or exotic), sociality (social or solitary) and by body size (small, medium, large). Sampling occurred between 12-2 pm over a 5 day period (June 22, July 5, July 9, July 10, July 14) coinciding with when *Sedum* was in full flower. *Sedum* flowers were the most abundant of all flower types on the roof during the blooming period and consisted of approximately 75 % of all flowers available as determined through visual assessment. Although 28 species and cultivars of *Sedum* were originally planted on the roof (MacIvor et al. 2013), >80 % of the *Sedum* remaining on the roof after 3 growing seasons were *S. kamtchaticum, S. sexangulare, S. album, S. spurium* and *S. acre*. Other species in flower on the green roof during the *Sedum* bloom and their approximate proportion of the total number of flowers in bloom included: Black-eyed susan (*Rudbeckia hirta* L.) (10 %), Yarrow (*Achillea millefolium* L.) (5 %), White clover (*Trifolium repens* L.) (5 %), Red clover (*Trifolium pratense* L.) (2 %), Purple coneflower (*Echinacea purpurea* L.) Moench. (2 %), Boneset (*Eupatorium perfoliatum* L.) (<1 %), Bird's foot trefoil (*Lotus corniculatus* L.) (<1 %), Horse weed (*Conyza canadensis* Cronquist) (<1 %) and Sow thistle (*Sonchus* sp.) (<1 %).

Pollen was collected both from the bees sampled and from each of the flowering plant species on the green roof to create a synoptic collection. Pollen loads were removed from each bee by washing the specimen in ethanol and passing the solution through a fine coffee filter,

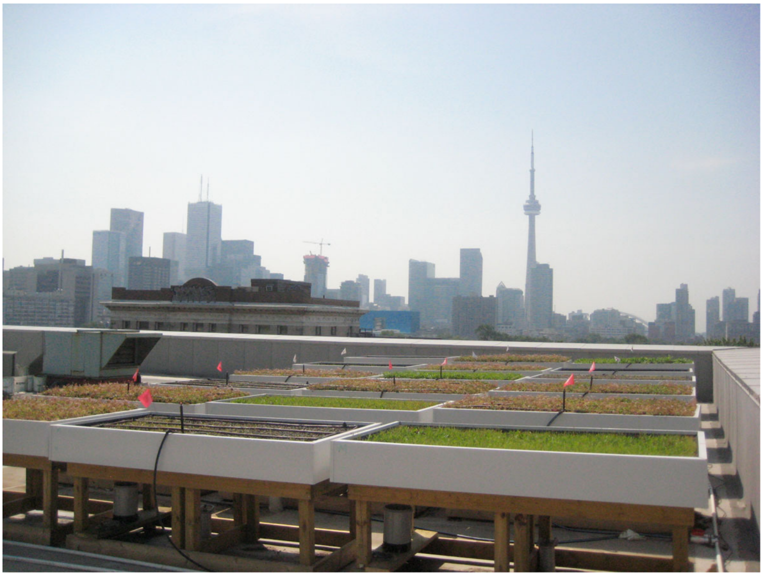

Fig. 1 The Green Roof Innovation Testing (GRIT) lab at the University of Toronto. The 'green roof' consists of thirty-three test beds containing various substrate and irrigation scenarios to compare the performance of *Sedum*-based plantings and forb/grass combinations

which was dried, and pollen was gently scraped off and onto the specimen specific microscope slide. Each slide was stained with fuschin solution, and photographed for identification and pollen counting. For flowering plant species on the green roof, a single flower was collected from each during the bloom period. Each flower was individually opened with forceps under a dissecting microscope. The pollen grains were exposed and a square of fuschin jelly (see Kearns and Inouye 1993) was dabbed with a pair of forceps to the surface, then added to a microscope slide. The slide was heated and a cover slip mounted to spread the sample across the microscope slide before solidifying. Plant pollen samples, bees and corresponding pollen loads were stored in the Packer Collection at York University (PCYU).

The microscope slides containing the pollen loads of the bees collected were then imaged using a Canon 5D Mark II DSLR camera with a Canon 65 mm lens, using 5x magnification with an additional teleconverter (1.4x mag.). Depending on the density of pollen grains on the microscope slide, up to three fields of view (each field: 5.70 x 3.80 mm) were photographed to maximize the number of grains visible using the camera setup. Photos were processed in Adobe Lightroom to sharpen images and enhance identification. The photographs were then imported into ImageJ v 1.47 (http://rsb.info.nih.gov/ij/), a program used for counting pollen grains (Costa and Yang 2009). A grid composed of 35 equal area squares was overlaid onto each photograph. A random number generator was used to arbitrarily decide which grid squares would be used to count pollen grains. Following this, the cell counter function was used to count the number of *Sedum* pollen grains and the number of non-*Sedum* grain morphotypes within each grid square. A minimum of five grid squares was sampled per field of view photographed. If fewer than 400 grains were present in the initial five grid squares, additional squares were sampled at random until a total of 400 grains was counted (as in Cane and Payne 1988). Despite there being five dominant *Sedum* species on the roof, the pollen grains were grouped by genus due to uncertainty in distinguishing differences between them using the synoptic collection. For analysis, the proportion of *Sedum* pollen was calculated for each of the bee species from the total number of *Sedum* grains counted in the sample. Numerous morphotypes were identified from the pollen loads at less than 1 % of the total grain abundance from several bee species. It is presumed that these grains arrived on the flowers by other pollinators visiting other species on or off the roof, and finding their way into the loads of the bees collected in this study.

The bee community collected on the roof was analyzed using one-way chi square tests to determine whether visitors to the green roof were biased by status (native or exotic), sociality (social or solitary) or body size [small (<0.8 cm), medium (>0.8 cm but <1.5 cm), large (>1.5 cm but <3 cm). The type and number of non-*Sedum* pollen grain types were also counted. An analysis of variance (α=0.05) in SPSS v21 was used to elucidate differences in the proportion of *Sedum* pollen collected by bees grouped by sampling day, status or sociality, as well as by body size and bee species using a Tukey HSD post-hoc analysis. Analysis of variance testing was also carried out to determine these effects on the total richness of non-*Sedum* morphotypes in the pollen loads, as well as the proportion of non-*Sedum* morphotypes comprising more than 20 % of the entire sample per bee, since this amount would reflect enough to account for a unique visit.

Results

During the sampling period on the green roof, the pollen loads of 67 bees from 17 species in 5 families were collected (Table 1). The most commonly collected bee species were the exotic solitary leaf cutter bee, *Megachile rotundata* (N=16), and the native social bumble bee, *Bombus griseocollis* (N=12). Seven of the bee species collected in the study had not yet been recorded on green roofs in the literature: *Andrena commoda, Andrena vicina*, *Bombus griseocollis, Hylaeus modestus, Hylaeus punctatus, Lasioglossum lineatulum* and *Lasioglossum ephialtum,* the last of which is a newly recorded species first identified just several hundred meters from the green roof site (Gibbs 2010) (Table 1). Twelve species out of 17 collected in this study were native bees but there was no significant difference between the abundance of native and exotic bees collected (χ^2=0.92, df=1, p=0.332) or the proportion of social to solitary bees (χ^2=2.38, df=1, p=0.123) but small bees were significantly less collected on *Sedum* than were medium and large bees (χ^2=17.68, df=2, p=0.0001).

Of all the bees collected, 39 individuals in 9 species had pollen loads sufficiently large enough to be included in the study, with *B. griseocollis* representing 30.8 % of the sample and *M. rotundata* representing 20.5 %. There was no significant difference in the proportion of *Sedum* pollen collected among bee species (with *Lasioglossum* grouped by genus due to singletons) (df=7, F=1.876, p=0.108), nor the number of non-*Sedum* pollen morphotypes (df=6, F=1.223, p=0.321). However, there was a significant increase in the proportion of *Sedum* pollen collected by exotic bees compared to native ones (df=1, F=7.203, p=0.011) (Fig. 2) but not in the number of non-*Sedum* pollen morphotypes (df=1, F=2.536, p=0.120). The highest number of morphotypes identified from a single pollen load was 6 (*Bombus griseocollis*), but 5 (all but *Sedum*) comprised less than 1 % of the total sample.

Overall, *Sedum* pollen represented 80.5 % of the loads of the bee species collected. Other pollen types from the green roof identified from the pollen loads included the exotics *Lotus corniculatus* and *Trifolium repens*, and the native, *Rudbeckia hirta*. Comparing among the 6 bee species having two or more individuals collected there were no significant differences in the proportion of *Sedum* in the pollen load (df=5, F=1.418, p=0.245). However, naturalized exotic bees, including *Apis mellifera*, *Megachile rotundata*, and *Halictus rubicundus,* collected proportionally more *Sedum* grains compared with the native bee species in the sample,

Table 1 Bee species collected on the green roof during the 2013 *Sedum* flowering period [(1) June 22, (2) July 5, (3) July 9, (4) July 10, (5) July 14]. Status was determined to be either native (N) or exotic (including 'naturalized' species) (E). Species abundances are noted by sampling date and the number of samples from which pollen was collected for each is beside in brackets. Literature pertained to surveys that collected the species on a green roof previously

Family	Species	Status	Sampling date						Literature
			1	2	3	4	5	Total	
Andrenidae	*Andrena commoda* Smith	N	0	0	0	1(1)	2(2)	3(3)	-
	Andrena vicina Smith	N	1	0	0	0	0	1	-
Apidae	*Apis mellifera* Linnaeus	E	0	4(4)	1(1)	0	1	6(5)	Brenneisen 2006; Colla et al. 2009; Ksiazek et al. 2014
	Bombus griseocollis DeGeer	N	1	7(6)	2(2)	4(4)	0	14(12)	-
	Bombus rufotinctus Cresson	N	4(2)	2(2)	2(2)	0	0	8(6)	Colla et al. 2009
	Melissodes desponsa Smith	N	0	0	0	1(1)	0	1(1)	Colla et al. 2009; Ksiazek et al. 2014
Colletidae	*Hylaeus hyalinatus* Smith	E	5	0	0	0	0	5	Brenneisen 2006; Tonietto et al. 2011
	Hylaeus modestus Say	N	2	0	0	0	0	2	-
	Hylaeus punctatus (Brullé)	E	1	0	0	0	0	1	-
Halictidae	*Agapenstemon virescens* Fabricius	N	1	0	0	0	0	1	Colla et al. 2009; Ksiazek et al. 2014
	Halictus rubicundus Christ	E	0	2(2)	0	0	0	2(2)	Brenneisen 2006; Colla et al. 2009; Ksiazek et al. 2014
	Lasioglossum lineatulum (Crawford)	N	0	0	0	1(1)	0	1(1)	-
	Lasioglossum ephialtum Gibbs	N	0	0	1(1)	0	0	1(1)	-
	Lasioglossum zephyrum (Smith)	N	0	0	1	0	0	1	Colla et al. 2009; Tonietto et al. 2011; Ksiazek et al. 2014
Megachilidae	*Megachile latimanus* Say	N	1	0	0	0	0	1	Colla et al. 2009
	Megachile rotundata Fabricus	E	7	5(3)	4(4)	0	1(1)	17(8)	Brenneisen 2006; Colla et al. 2009; Tonietto et al. 2011; Ksiazek et al. 2014
	Megachile texana Cresson	N	1	0	0	0	1	2	Colla et al. 2009

including *Bombus gristeocollis*, *Bombus rufotinctus* and *Andrena vicina* (df=1, F=8.319, p=0.007). Moreover, post-hoc analysis revealed that there were more occurrences of pollen loads containing greater than 20 % non-*Sedum* pollen grains in native bees than exotic bees (df=1, F=8.625, p=0.006).

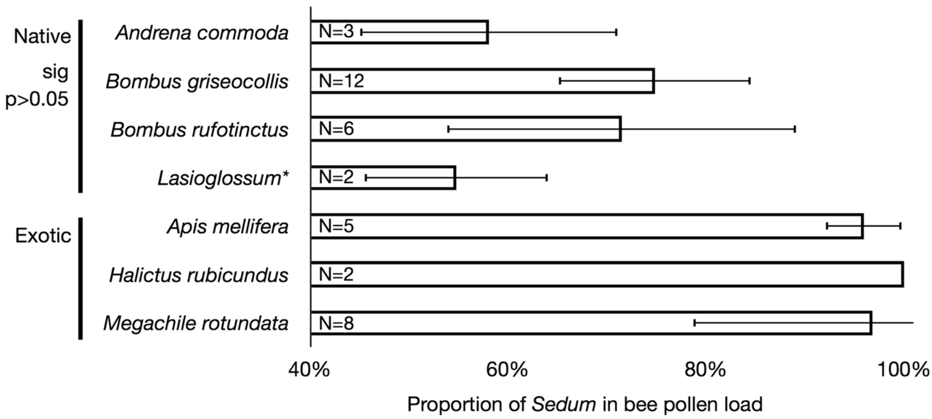

Fig. 2 Proportion of *Sedum* pollen in the loads of the six most collected bee species having analyzable pollen loads from the green roof. The bars and error bars signify the mean ± standard error and the asterisk (*) signifies that the Lasioglossum group includes two different species (N=1 each)

The sampling date also had a significant effect on the proportion of *Sedum* pollen collected among all bees (df=4, F=13.541, p<0.05) (Fig. 3), but no impact on the number of pollen morphotypes in the pollen loads of the bees sampled. Significantly greater amounts of *Sedum* pollen were found in the pollen loads on Day 2 and 3 (July 5th and 9th), which coincided with the week the most *Sedum* blooms on the roof of any of the sampling days (MacIvor, pers. observ.).

Discussion

Many bee species and other insects visit green roofs in urban landscapes in search of habitat. The value of exotic pollen types on novel habitats like green roofs will vary by bee species, and certainly, only a fraction of the expected 250+ bee species (see Grixti and Packer 2006) in

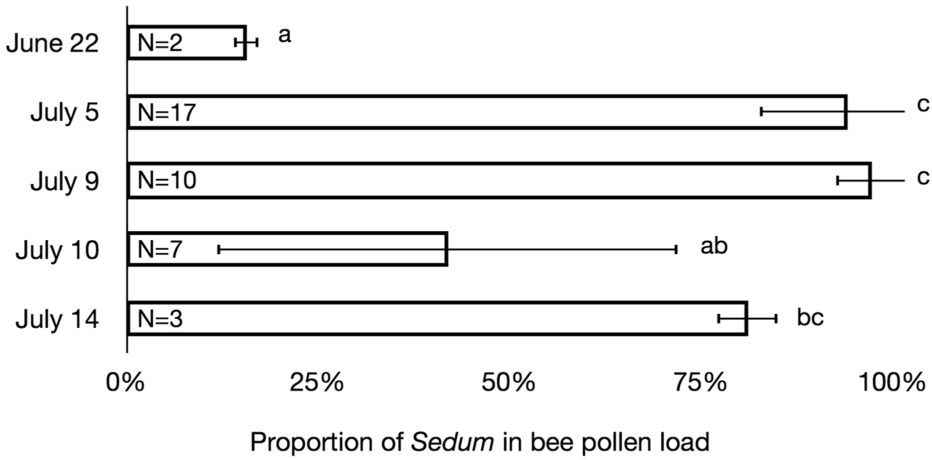

Fig. 3 The proportion of *Sedum* in the pollen loads of bees over the five sampling days during the *Sedum* blooming period. The bars and error bars signify the mean ± standard error

and around the city of Toronto were found visiting the *Sedum* in our study. Most green roofs contain *Sedum* plants, which dominate the green roof industry (Dvorak and Volder 2010; Sutton et al. 2012). Despite this, no studies to date have examined the direct effects that exotic *Sedum* has on urban wildlife. Determining the relative contribution of exotic pollen sources for both native and exotic bee pollinators are important to broaden the context of urban biodiversity conservation strategies to include or exclude exotic 'beneficial' species.

In this study, it was found there was no significant difference in the number of native and exotic bees sampled from *Sedum* mats on a fifth storey green roof. Thus our first hypothesis that the number of exotic bees on a green roof dominated by exotic flowers would be higher than the number of natives was rejected. Further, native bee richness was greater than that of exotics in the entire sample (12 of 17 species) as well as when subset to those from which pollen was analyzed (6 of 9 species native). The proportion of *Sedum* pollen in the loads of foraging bees was high among all bees visiting the roof, but significantly greater in exotic bees than native bees. These findings agree with our second hypothesis that the amount of *Sedum* in the pollen loads of exotic bees will be greater than native bees. Thus, although exotic bees appear to forage more from *Sedum* for pollen, native bees could also benefit, especially when the alternative is conventional tarred, asphalt or other roofing membrane containing no substrate or vegetation. Additionally, *Sedum* could act as a source of nectar for both exotic and native bees, which was not examined in this study.

Not only was *Sedum* significantly more abundant in the pollen loads of exotic bees, but also native bees had significantly greater numbers of non-*Sedum* pollen types comprising more than >20 % of their pollen loads. This suggests the native bees could have been attracted by the *Sedum* flowers but still visited other flower species on the green roof (*Lotus corniculatus*, *Trifolium repens, Rudbeckia hirta*) and also at ground level. Other pollen morphotypes were distinguished from the samples but not found in the synoptic collection, and thus from sources not found on the roof. Although in general, bees tend to forage on the closest plants (Zurbuchen et al. 2010) or within a few hundred meters of the nesting site (Greenleaf et al. 2007), some bees can forage at greater distances (>1 km) (Seeley 1985; Goulson and Stout 2001) and so could potentially include both ground level and green roof pollen sources in a single foraging bout.

The proportion of *Sedum* in the loads of the bees sampled was presumably high because we sampled during the *Sedum* blooming period and where they were the dominant flower type (~75 % of the flowers in bloom on the roof). Our findings demonstrated that the proportion of *Sedum* pollen in the pollen loads of bees increased from Day 1 to Day 3, then declined somewhat towards the end of the blooming period, indicating the brevity of the floral resource. Individual *Sedum* species are in flower for a short period of time, and thus on green roofs will be part of regional floral resource for bees in the urban space that might include street trees, landscape plantings around buildings and home and community gardens. Given the short bloom time of some species, green roof designers may be encouraged to plant with multiple species of *Sedum* not only for insect pollinators, but also for green roof aesthetics associated with blooming flowers (Dunnett and Kingsbury 2004).

The density at which *Sedum* is planted on green roofs (e.g. in mats; see Oberndorfer et al. 2007) could have also contributed to the proportion in the pollen loads. On *Sedum*, bees tend to move between inflorescences on the same plant (especially large bees like bumble bees that crawl between flowers) (Clausen 1975) and so could move among interwoven individual *Sedum* plants typical of mats using the same motions. Bees respond to concentrations of pollen availability, frequenting these locales to maximize pollen collection (Harder 1990). The pollen loads examined from bees in these kinds of environments are often dominated by the locally abundant flowering plant, for example over 95 % in the loads of bees in blueberry bushes during bloom (Cane and Payne 1988; Tuell et al. 2009), or common, lawn-invading white clover (*Trifolium repens*) in the brood cells of spring-emerging mason bees (MacIvor et al. 2014). *Sedum* is not pollinator-dependent for reproduction, but still exotic bees could facilitate the invasion of *Sedum* from green roofs into the wider urban landscape. Native plants tend to receive fewer visits by pollinators in the presence of exotic plants (Ghazoul 2004; Larson et al. 2006) and since both native and exotic bees visited *Sedum* in our study, to what extent patches of *Sedum* might attract native (and exotic) bees away from native pollinator-requiring plants is not known. Further, since we sampled only during early afternoon, it is not known whether these exotic plant-pollinator interactions play out similarly in the morning or other times of the day.

The bee species collected in the study were surprisingly varied, representing 5 of 6 bee families found in the region. However, from the sample of all bees collected on the green roof, it was found that smaller bees (e.g. *Lasioglossum, Hylaeus*) were significantly less common compared to medium (*Apis*, *Megachile*) and large bees (*Bombus*, *Andrena*). Smaller bees, especially those nesting at ground level, might have a more difficult time reaching a green roof, than would a larger bee that is better equipped for wind and the complex urban landscape (e.g. navigating the building envelope). In our study, some of the most abundant species on the roof were social bees, including bumble bees, which forage further than most other species and alert colony mates to visit quality foraging areas when found (Dornhaus and Chittka 2004) and honey bees, which use the 'waggle dance' to recruit and orient nest mates to foraging sites (von Frisch 1967). *Megachile rotundata*, the exotic but naturalized Alfalfa leaf cutter bee was also very abundant on the roof and has been commonly recorded in other studies of urban bees (Matteson and Langellotto 2010; Banaszak -Cibicka and Żmihorski 2012).

Even though numerous other flowering plant species are being tested for green roof installations in different region around the world (Dvorak and Volder 2010), and there is a push by researchers (Sutton et al. 2012) and municipalities (Torrance et al. 2013) to include more different types of non- *Sedum* flowers and grasses on green roofs. Combining *Sedum* with other green roof plant types that require pollination and are attractive to pollinators is likely the best strategy to include habitat value for urban wildlife, as well as maintain aesthetic and educational benefits in the design of green roofs (Oberndorfer et al. 2007). Plant functional diversity too can increase green roof stormwater and thermoregulatory benefits; as determined in Lundholm et al. (2010) where it was found combining *Sedum* with flowering forbs and grasses performed best. There is also a need to consider other aspects of urban wildlife habitat such as nesting analogues (like logs, rocks and nesting boxes for wild bees) as well as more native and regionally specific flora and substrate mixes (Brenneisen 2006) although these require more study.

Conclusion

Sedum is the most widely used green roof plant, as it can survive the deleterious conditions present on green roofs, especially those with shallow substrates, little to no irrigation, simple maintenance regimes, and those in full and direct sun (Dunnett and Kingsbury 2004; Rowe et al. 2012). This study demonstrates that *Sedum* are also suitable foraging plants for pollen seeking bees; however, the data show these exotic plants to be more valuable to exotic bees, as have other studies examining the impact of exotic plants in shaping pollinator communities (Goulson and Stout 2001). As the number of green roofs in cities increase, the continued use of de-facto *Sedum* plantings could have a significant impact in shaping local urban bee communities.

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