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Abstract

Green roofs increasingly provide habitat for many insects in urban environments. Pollinators such as bees may utilize foraging and nesting resources provided by green roofs but few studies have documented which species occur in these novel habitats. This study identified bees from 26 species, 11 genera and 5 families collected from 7 green roofs using pan trapping methods over 2 years. Ten of these species have not previously been recorded on green roofs in the Chicago region. Although the majority of bee species collected were solitary, soil-nesting, and native to Illinois, the proportion of exotic species was high compared to previous collections from Chicago area green roofs and urban parks. Urban green roofs may enhance populations of both native and exotic bees, but their ability to support the same range of native diversity recorded from other urban habitats requires further investigation.

The construction of green roofs (rooftops designed to incorporate a layer of growing media and plants) has increased throughout North America over the past decade (Green Roofs for Healthy Cities 2012, greenroofs.com and LLC 2013) leading to an increase of potential insect habitat in many urban environments. Ants, beetles and spiders, including rare species, have been documented on green roofs in North America (MacIvor and Lundholm 2010, Coffman and Waite 2011) and Europe (Brenneisen 2005, Kadas 2006, Madre et al. 2013) but few studies have documented bees (Hymenoptera: Apoidea: Anthophila) on green roofs in North America (MacIvor and Lundholm 2010, Coffman and Waite 2011, Schindler et al. 2011, Ksiazek et al. 2012), and only two have identified these to species (Colla et al. 2009, Tonietto et al. 2011). More information about green roofs and the species which occur at these sites is needed to increase overall knowledge about urban bee ecology (reviewed by Hernandez et al., 2009). Chicago, Illinois, including its suburbs, is the leader in green roof quantity and coverage in the United States (Green Roofs for Healthy Cities 2012), and a previous study from this city and its suburbs reported 19 species from these novel habitats using bowl collection methods (Tonietto et al. 2011). Here, we report collections from 2009-2010 that included 14 of the 19 previously recorded bee species and ten species new to green roofs in the Chicago region.

Seven green roofs located within the city limits of Chicago and three from the northwest suburbs were chosen as collection sites (Fig. 1, Table 1). All of the

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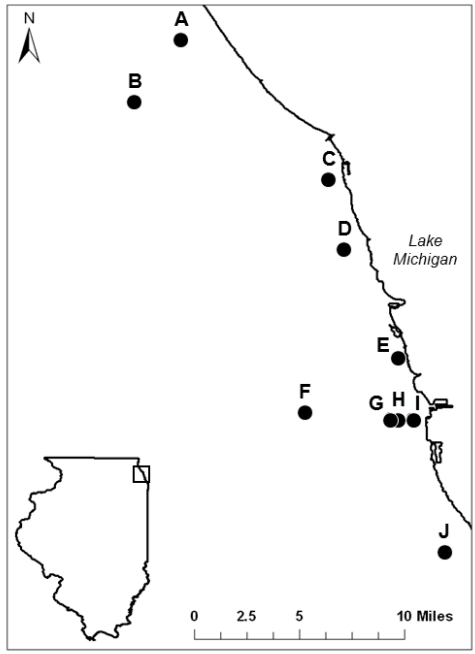

Figure 1. Collection sites in Cook County, Illinois. A: Chicago Botanic Garden Rice Center for Plant Conservation. B: Tyner Interpretive Center at Air Station Prairie. C: Optima Views Condominiums. D: S & C Electric Company. E: Peggy Notebaert Nature Museum. F: Chicago Center for Green Technology. G: Chicago Transportation Authority Headquarters. H: Chicago City Hall. I: Joffrey Ballet Building. J: University of Chicago Physics Building. Sites A-C are located outside the city limits of Chicago.

sites except two from the city and one from the suburbs were used by Tonietto et al. (2011) for previous collections (Table 1). Though all had floral resources available (blooming) during the collection period, the selected green roof sites ranged from intensively maintained gardens with over 200 plant species to typical shallow-substrate (extensive) roofs with very low plant diversity and minimal maintenance (Table 1). The habitat surrounding the roofs also ranged from extremely urban with few nearby parks or gardens to suburban, surrounded by gardens designed to mimic prairie landscapes (Table 1).

Bees were collected once per month between June and September in both years of the study using bee bowls; 88 ml plastic pan traps coated with UV-reflective blue, white or yellow paint and filled with a strongly diluted water/detergent solution (LeBuhn et al. 2003). Fifteen bowls (5 bowls of each color) were placed at least 5 m apart at each site for approximately 24 hours. Specimens were dried, pinned, and identified to genus using keys in Michener et al. (1994) and online at Discover Life (Droege et al. 2013) after which JSA identified most specimens to species or, in the case of difficult *Lasioglossum* (*Dialictus*) Robertson (Halictidae), to subgenus. The collection is currently stored at the Chicago Botanic Garden, Glencoe, Illinois.

The resulting collection contains 248 bee specimens representing 26 species, 11 genera and five families (Table 2). Over half of the species are native to Illinois (63.7%) and are polylectic with the exception of the oligolectic *Melissodes*

Table 1. Green roof properties. A plus sign (+) indicates sites not previously sampled by Tonietto, et al. (2011). Roofs with low floral diversity were planted with *Sedum* species and fewer than 10 other species, medium diversity with *Sedum* and up to 30 additional species, and high diversity with *Sedum* and over 50 additional species.

Site	Name	Floral diversity	Approx. size (m^2)	Height (stories)	Year of construction	Surrounding ground-level habitat
A+	Botanic Garden	High	1600	1	2009	suburban, prairie garden
B	Tyner	Medium	310	1	2006	suburban, prairie garden
C	Optima Views	Low	330	4	2004	urban
D	S & C Electric	Low	700	2	2009	urban
E	Notebaert	High	1350	2	2003	urban, prairie garden
F+	Green Tech	Low	250	2	2002	urban, prairie garden
G	CTA	Low	1740	15	2004	heavily urban
H+	City Hall	High	2500	12	2001	heavily urban
I	Joffrey Ballet	Low	410	4	2007	heavily urban
J	U of C	High	130	2	2006	urban

Table 2. Abundance, locations and life history characteristics of bees on green roofs. An asterisk (*) indicates species newly detected on green roofs in the Chicago region. See Figure 1 and Table 1 for locations and names of green roof sites. Small bees are <8 mm long, Medium 8 mm-11 mm, Large >11mm. Species are classified as native to North America including Illinois (N), exotic (E), or status uncertain (E?). Nesting preferences are categorized as cavity (C), hive (H) or soil (S) [but some unidentified *Lasioglossum* (*Dialictus*) may nest in soft wood].

Family	Species	Abundance females	Abundance males	Green Roof Sites	% of total	Size class	Native status	Nesting habit
Andrenidae	*Calliopsis andreniformis* Smith*	2		F	0.8	Small	N	S
Apidae	*Apis mellifera* (L.)	8		E F H	3.2	Large	E	H
	Bombus impatiens Cresson	1		D	0.4	Large	N	H
	Melissodes b. bimaculata Lepeletier	3		E H I	1.2	Large	N	S
	Melissodes desponsa Smith*	1		C	0.4	Large	N	S
Colletidae	*Hylaeus affinis* (Smith)*	2	2	B H	1.6	Small	N	C
	Hylaeus hyalinatus Smith	3		B C H	1.2	Small	E	C
	Hylaeus leptocephalus (Morawitz)	1		C	0.4	Small	E	C
	Hylaeus mesillae cressoni (Cockerell)*	1		I	0.4	Small	N	C
	Hylaeus punctatus (Brullé)*	1		C	0.4	Small	E	C
Halictidae	*Agapostemon virescens* (Fabricius)	5	2	C E	2.8	Medium	N	S
	Augochlorella aurata (Smith)*		1	H	0.4	Small	N	S
	Halictus confusus Smith	33	1	E F H	13.7	Small	N	S
	Halictus ligatus Say	29	2	A B C D E F G	12.5	Medium	N	S
	Halictus rubicundus (Christ)*	2		A B	0.8	Medium	N	S
	Lasioglossum anomalum (Robertson)	4		A B F	1.6	Small	N	S
	Lasioglossum illinoense (Robertson)	3		C	1.2	Small	N	S
	Lasioglossum pectorale (Smith)		1	E	0.4	Small	N	S
	Lasioglossum pilosum (Smith)*	5	1	F	2.4	Small	N	S
	Lasioglossum smilacinae (Robertson)*		1	C	0.4	Small	N	S
	Lasioglossum zephyrum Smith	13		C E	5.2	Small	N	S
	Lasioglossum (Dialictus) spp.		43	A B C D E F H J	17.3	Small	N	S
Megachilidae	*Anthidium m. manicatum* (L.)*	2		F H	0.8	Large	E	C
	Anthidium o. oblongatum (Illiger)	12	15	B C D F G H	10.9	Large	E	C
	Megachile centuncularis (L.)	1		H	0.4	Medium	E?	C
	Megachile rotundata (Fabricius)	36	11	A B E F H G J	19.0	Medium	E	C

desponsa Smith (Colletidae), a pollen specialist of *Cirsium* (thistle). Very few hive-nesting species were collected (3.6%: eight *Apis mellifera* (L.) (Apidae), one *Bombus impatiens* Cresson (Apidae)); the majority of the species collected are known or inferred to nest in soil (61.3%) or possibly soft wood in the case of some of the unidentified *Lasioglossum* (*Dialictus*). The remaining third are cavity-nesting species (35.1%). Urban sites outside of the heavily urbanized city center (sites C-F, J) had the highest proportion of individuals (mean 33.8/site). Suburban sites (A and B) had a higher proportion of individuals (mean 19/site) than heavily urbanized roof sites (mean 13.3/site).

Fourteen bee species from our collection are among the 19 species previously reported from green roofs in the Chicago region (Tonietto et al. 2011). The current collection also includes the honey bee *A. mellifera*, a species found by Tonietto, et al. (2011) during their collections in 2008 though not reported. Here we report 10 bee species new to green roofs records in the Chicago region (Table 2).

The most common species in this study was the exotic Alfalfa Leafcutter Bee *Megachile rotundata* (Fabricius) (Megachilidae), which was widely present in suburban, urban and heavily urban site types. Native, primitively eusocial sweat bees including *Halictus ligatus* Say (Halictidae) and species of *Lasioglossum* (*Dialictus*) were also very common and found at all site types as was the exotic, wool-carder bee *Anthidium oblongatum* (Illiger) (Megachilidae). The latter is associated with the plant genus *Sedum* which was available on all the green roofs.

Although the family Colletidae has been considered scarce in urban bee collections (Hernandez et al. 2009), we found five species of *Hylaeus* (19.2% of all species, although only 4.0% of individuals) on green roofs. Three of these were exotic, with a single female *Hylaeus punctatus* (Brullé) (Colletidae), providing a new record for the Chicago area (the others were also recorded by Tonietto et al. 2011). The proportion of exotic bee individuals on green roofs in our study (36.3%) and in the previous Chicago area study (27%, Tonietto et al. 2011) is high compared to urban parks in Chicago (17%, Tonietto et al. 2011), urban gardens in New York City (19%, Matteson et al. 2008), and in both green roofs and mixed urban green areas in Toronto (14.7% and 7.7% respectively, Colla et al. 2009). Although many bee species are present on green roofs, and some of these including exotic species are numerous and widely distributed, these engineered habitats may not currently support the same range of native diversity as other urban habitats. Future studies addressing the extent to which bees make use of these unique spaces and how plant, substrate and microhabitat diversity influence bee species abundance, richness and diversity are needed to demonstrate the ability of green roofs to act as foraging or nesting sites for a wide range of species.

A diverse bee community is now known to occur in newly constructed anthropogenic habitats such as the Chicago green roofs. These habitats are becoming increasingly prevalent and may enhance populations of bees and other arthropods, thereby potentially increasing ecosystem services for urban flora and wildlife but also increasing populations of exotic species.

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