Bee Richness and Abundance in New York City Urban Gardens

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ABSTRACT We describe the richness, abundance, and ecological characteristics of bees in community gardens located in heavily developed neighborhoods of the Bronx and East Harlem, NY. In total, 1,145 individual bees, representing 54 species (13% of the recorded New York State bee fauna) were collected over 4 yr. The nesting habits of these species include bees that nest in cavities (33% of species), hives (11% of species), pith (1.9% of species), wood (1.9% of species), or soft/rotting wood (7.4% of species) substrates. Soil-nesting individuals were relatively rare (25% of individuals), perhaps due to a lack of proper soils for nesting sites. Parasitic species were scarce (5.6% of species, 2.6% of individuals), most likely because of an absence or rarity of host species. Overall, exotic species were abundant and constituted 27% of the total individuals collected and 19% of the identified species. We compare these results to several bee faunal surveys in New Jersey and New York State, including newly reported species lists for Central Park and Prospect Park in New York City. Relative to other studies, bee richness of the urban gardens is reduced and composition is biased toward exotic and cavity-nesting species. Nevertheless, despite their small size and location within highly urbanized areas, urban community gardens harbor a diverse assemblage of bees that may provide pollination services and opportunities for ecological exposure and education.

KEY WORDS urban ecology, community gardens, invasive species, insect survey, pollinator conservation

Urbanization is increasing worldwide (United Nations Population Division 2005); yet, little is known about the effects of urbanization on the richness and composition of insect communities (McIntyre 2000), including beneficial taxa such as bees (Cane 2005). Habitats within urban areas are almost always fragmented, are frequently disturbed (Gilbert 1989, Rebele 1994, McIntyre 2000), and are subject to elevated pollution levels and altered light and moisture regimes (Rebele 1994, Niemela et al. 2002, Connor et al. 2003). In addition, invasive species are particularly abundant in urban areas (McKinney 2002, 2006). Given these characteristics of urban ecosystems, it should not be surprising that species richness is often reduced in urban areas and that urbanization is considered a leading cause of species endangerment in the United States (Czech et al. 2000).

Despite the potential negative impacts of urbanization on insect richness, many bee species are common within urban habitats (Owen 1991; Saure 1996; McIntyre and Hostetler 2001; Antonini and Martins 2003; Tommasi et al. 2004; Cane 2005, and references therein; Frankie et al. 2005; Cane et al. 2006). However, relative to less disturbed habitats, the richness of urban assemblages may be reduced and species composition may be altered. The fragmented nature of urban habitats may prevent their colonization by certain bee species, whereas the frequency and intensity of disturbance within sites (e.g., mowing, soil turning, and development) may limit the long-term persistence of others. Bee species that build nests in soil may be selectively excluded by the compacted soils that characterize many urban parks and gardens (Cane 2005, Cane et al. 2006). In addition, the floral diversity of urban habitats, such as small parks and gardens, is often dominated by exotic and horticultural varieties (Thompson et al. 2003, Frankie et al. 2005) potentially increasing the number of generalist (polylectic) bee species that can make use of a variety of floral resource types. As a result of these and other characteristics of urban green spaces, overall composition of urban bee communities may be biased toward polylectic and cavity-nesting species (Cane 2005, Cane et al. 2006) and exotic species (Ascher 2001, Cane 2003).

In New York City, urban parks and gardens are prime sites to address the effects of a highly urbanized landscape on bee communities. Across the five boroughs of New York City, >700 community gardens have been created since the 1970s (Englander 2001). Various nonprofit and local government agencies own the community gardens in New York City, and neighborhood residents of diverse ethnic and cultural heritage (Shinew et al. 2004) locally cultivate a variety of

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Table 1. Names, addresses, location, and latitude/longitude coordinates (accuracy of ± 10 m) of urban community gardens included in this study

Garden	Address within New York City	Location	Latitude	Longitude
Peaceful Valley	E. 117th St. (between Park and Madison Ave.)	Harlem	40° 48′ 1.5840″	73° 56′ 38.9760″
The Herb Garden	111th St. (between Lexington and Park Ave.)	Harlem	40° 47′ 42.8495″	73° 56′ 37.3740″
La Casita Community Garden	223 E. 119th St. (between Second and Third Ave.)	Harlem	40° 47′ 58.7939″	73° 56′ 15.5508″
Papo's Garden	218 E. 119th St. (between Second and Third Ave.)	Harlem	40° 47′ 57.4259″	73° 56′ 15.8892″
Clinton Garden	757 E. 179th St. (corner of Prospect Ave.)	Bronx	40° 50′ 45.5965″	73° 53′ 16.7532″
Krystal Garden	E. 180th St. and Vyse Ave.	Bronx	40° 50′ 37.2841″	73° 52′ 50.3760″
El Gallo Social Club	118th St. and Lexington Ave.	Harlem	40° 47′ 59.0639″	73° 56′ 26.0484″
East Harlem Council Garden	E. 117th St. (between Pleasant and first Ave.)	Harlem	40° 47′ 46.0967″	73° 56′ 3.1632″
Mapes Ave. Community Garden	E. 181st St. and Mapes Ave.	Bronx	40° 50′ 52.3321″	73° 53′ 4.8732″
Holy Rosary Garden[a]	433–439 E. 119th St. (between Pleasant Ave. and First Ave.)	Harlem	40° 47′ 51.1907″	73° 55′ 57.1655″
Garden of Life	1685 Week Ave. (corner of 173rd St.)	Bronx	40° 50′ 37.7305″	73° 54′ 26.5753″
Jackie Robinson Tenant Association Garden	115 E. 122nd Street (between Park and Lexington Ave.)	Harlem	40° 48′ 11.1888″	73° 56′ 24.0000″
Fordham Bedford Lot Busters	2593 Bainbridge Ave.	Bronx	40° 51′ 50.8895″	73° 53′ 33.6588″
Bathgate Garden	Bathgate Ave. (between 175th and 176th)	Bronx	40° 50′ 41.4925″	73° 53′ 52.2600″
Pleasant Village Community Garden	342–353 Pleasant Ave. (between 118th and 119th St.)	Harlem	40° 47′ 47.7635″	73° 55′ 54.1631″
Garden of Happiness	2156 Prospect (between 181st and 182nd)	Bronx	40° 50′ 55.0069″	73° 53′ 6.2376″
Tremont Community Garden	Corner of East Tremont Ave. and LaFontane	Bronx	40° 50′ 50.2441″	73° 53′ 39.8292″
El Sitio Feliz (Union Settlement)	234 E. 104th St. (between Third and Second Ave.)	Harlem	40° 47′ 24.3851″	73° 56′ 41.3628″
Drew Community Garden[b]	C.S. 214, 1970 West Farms Rd.	Bronx	40° 50′ 22.7329″	73° 52′ 40.0008″

[a] Garden developed in December 2006.
[b] Garden included in study in May 2004.

fruits and vegetables and manage the garden habitats. Many urban community gardens were founded on vacant or abandoned lots in low to moderate-income neighborhoods (Pottharst 1995) where green space is limited and human population densities are high. Thus, in addition to potential benefits for urban crop production via pollination, maintenance of urban bee diversity may increase ecological awareness (Pyle 1978, Miller 2005) in human-dominated landscapes.

Our objectives were to 1) identify the bee species present within urban community gardens; 2) characterize the urban bee assemblage according to the prevalence of various ecological characteristics, including nesting habit, sociality, and behavior, floral specificity and native versus exotic status; and 3) compare these results to the bee fauna of other sites in New York City and southern New York state, and of a New Jersey site. We discuss our results in the context of implications for urban conservation.

Materials and Methods

Community Garden Study Sites. Bees were collected over four growing seasons from 19 community gardens located in the Bronx (Bronx County) and East Harlem (Manhattan, New York County) in New York City, NY (Table 1; Fig. 1). The community gardens that were sampled are owned or supported by various nonprofit and city agencies, including The New York Restoration Project, Trust for Public Land, and Greenthumb program of the New York City Parks Department. However, management of individual gardens at the local level is dependent on the dedication and involvement of neighborhood residents. In spring 2003, gardens were chosen for inclusion in this study based on gardeners' interest in the project, the accessibility of individual gardens (all gardens are gated and pad-locked when gardeners are not present) and garden location (to facilitate sampling within the Bronx gardens or East Harlem gardens).

The area of the sampled gardens ranged from 224 to 2,188 m^2 (910 ± 540 m^2, mean ± SD) (Matteson 2007). The gardens were planted with a variety of introduced and native plants that were cultivated as ornamentals or crops. Commonly grown crops included vegetables such as tomato (Solanaceae), beans (Fabaceae), cucumbers, and eggplant and pumpkin (Cucurbitaceae), and herbs such as oregano, basil, and sage (Lamiaceae). Introduced ornamental flowers included zinnias, marigolds, and sunflower cultivars (Asteraceae); roses (Rosaceae); and other common exotic garden flowers. Native ornamental flowers included coneflowers (Asteraceae), wild mint (*Mentha arvensis* L. [Lamiaceae]), and butterfly milkweed (*Asclepias tuberosa* L. [Asclepiadaceae]). Synthetic chemicals are applied in some gardens for insect control. Gardens also vary in the proportion of surrounding green space.

Bee Sampling Methods. Two methods were used to collect bees: yellow bowl traps and hand-netting. For yellow bowl traps, we used round, 355-ml yellow bowls (15 cm in diameter, 4.5 cm in depth, Solo Cup Company, Urbana, IL) filled with a solution consisting of ≈300 ml of water, 4 ml of detergent to act as a surfactant (Colgate-Palmolive Company, NY, NY), and 3 g of table salt (NaCl) to act as a preservative. To reduce disturbance from humans or other animals within the heavily trafficked gardens, traps were suspended in trees, shrubs, or along fences, ≈1.5–2.5 m off of the ground. The traps were retrieved after 24–48 h,

Fig. 1. View from within an urban community garden in the Bronx, NY. There are >700 community gardens in New York City providing habitat for various bee species amid a highly developed landscape.

and the contents were poured through a strainer (0.3-mm mesh size). Collected insects were then washed with distilled H_2O and transferred into vials containing 70% ethanol, where they were stored for later identification. This procedure was followed biweekly from July through August in 2003 and from May through September in 2004 and 2005 for a total of 17 trapping dates. The number of traps placed in each garden was scaled to garden size. On average, one trap was allocated per 500 m^2 of garden area, for a total of 666 traps in all gardens over the 3 yr.

Bees were netted by hand in gardens once per month in June, July, and August of 2005 and 2006. Collecting was again scaled to garden size, with 10 person minutes of collecting time per 500 m^2 of garden area, for a total of 2,280 person minutes over 2 yr. Once netted, insects were transferred to a kill jar containing ethyl acetate and stored at −17°C for later pinning and identification to species.

All individual bees collected in pan traps or by hand-netting were pinned in the laboratory by K.C.M., sorted by P. Gambino, and later identified to species by J.S.A. Some of the *Dialictus* females were identified by S. Droege. Most voucher specimens are deposited at the Louis Calder Biological Field Station of Fordham University in Armonk, NY. An additional synoptic collection is maintained at the American Museum of Natural History in New York City, NY.

Bee abundance was calculated as the total number of bees collected from both pan trapping (2003–2005) and hand-netting (2005–2006) in all gardens. The incidence of bees across the 19 gardens was determined as the number of gardens where at least one individual was collected, divided by the total number of gardens that were sampled.

Ecological information for each species was compiled from primary literature, catalogs, and revisions and follows the format of Giles and Ascher (2006). For each species, we determined their nesting substrate (e.g., cavity, pith, wood, soft rotting wood, and soil), social behavior (e.g., solitary or communal, subsocial, eusocial, and parasitic), and floral specificity (e.g., oligolectic and polylectic). In addition, we determined whether a species was native or exotic (i.e., adventive or deliberately introduced) to North America based on Cane (2003); *Megachile centuncularis* (L.) was classified as putatively native because this species may be an early introduction from Europe (Giles and Ascher 2006). In the absence of species-specific ecological data, ecological categories were inferred based on the habits of closely related congeners.

Comparison Sites. We compared the total number of species and the similarity of bee community composition in the East Harlem and Bronx gardens to the bee assemblages of seven locations within a 150-km radius of New York City. Four sites are located within the New York City limits and include a Staten Island landfill site (Yurlina 1998) and the summed composition of three Staten Island Parks (Yurlina 1998). In addition, data on bees in Central Park and Prospect Park are presented here for the first time. Data from Central Park are from scattered historical collections in the AMNH (many from 1961 to 1962), Bioblitzes held on 27–28 June 2003 and 23 June 2006, and infrequent collections by J.S.A. and colleagues during 2004–2006. Most records from Prospect Park are from opportunistic net-collecting and observations in the park during 2004–2007 by J.S.A. In addition to these faunal surveys within New York City, there are three available studies of bee richness from areas within a 150-km radius of New York City: Black Rock Forest in Orange County, NY (Giles and Ascher 2006), Gardiner's Island in Suffolk County, NY (J.S.A., R. G. Goelet, and S. Kornbluth, unpublished), and the New Jersey Pinelands Biosphere Reserve in southern New Jersey (Winfree et al. 2007). The small number of comparison sites and variation in sampling methodology prevented a quantitative analysis of differences in regional bee assemblages. Nevertheless, descriptive comparisons of disparate studies provide important insights into the effects of urbanization on bee species composition and distribution.

Results

Composition of Bee Fauna of Urban Gardens. In total, 54 bee species were collected from the 19 surveyed gardens (Table 2). The most abundant species were two exotic bees (Colletidae), *Hylaeus leptocephalus* (Morawitz) and *Hylaeus hyalinatus* Smith, and the native bumble bee *Bombus impatiens* Cresson. An abundance of *Lasioglossum* individuals exhibiting characteristics of both *L. rohweri* and *L. lineatulum* was found and is referred to as "*Lasioglossum* 1." Individuals of this type have been found throughout the Northeast, and they may represent a distinct species (S. Droege, personal communication). More than half (59%) of all species were represented by <10 individuals. Species that were not collected in abundance but that were found in a high percentage of gardens include *Apis mellifera* (L.) (72% of gardens), and the native species *Bombus griseocollis* (DeGeer) (66% of gardens), *Lasioglossum bruneri* (Crawford) (61% of gardens), and *Xylocopa virginica* (L.) (61% of gardens). Most species (69%) were found in <50% of the gardens over the four sample years.

The ecological characteristics of bee species and individuals collected from the surveyed gardens are presented in Table 3. The majority of species and individuals were solitary or communal (56% of species, 50% of individuals), polylectic (89% of species, 97% of individuals), and either nest in soil (44% of species but only 25% of individuals) or in cavities (33% of species but 46% of individuals). Species and individuals of Apidae were abundant (30% of species, 31% of individuals), whereas individuals and species of Andrenidae were scarce (<1.0% of individuals, 5.6% of species). Scarcity of Andrenidae likely reflects a lack of collecting and/or a lack of appropriate flowering plants in urban gardens in the early spring, when *Andrena* species are most active.

Exotic species made up 19% of all species and 27% of all individuals collected. Individuals of the two aforementioned exotic species, *H. leptocephalus* and *H. hyalinatus*, were extremely abundant and constituted 77% of colletid individuals and 20% of all bees collected. Other notable exotic species included *Hylaeus punctatus* (Brullé), first reported here for New York state (this is the second record for eastern North America; see Ascher et al. 2006), and *Megachile sculpturalis* Smith. Although *M. sculpturalis* is only recently recorded from New York (Ascher 2001), it is now known to be an abundant species in New York City, including downtown Manhattan, where it collects pollen from the pagoda tree, *Styphnolobium japonicum* (L.) Schott. (Fabaceae).

Both parasitic and oligolectic species were rare. Parasites made up only 5.6% of the collected species, of which the social parasite *Bombus citrinus* (Smith) predominated, making up 83% of the parasitic individuals. Six oligolectic species were collected, including *Peponapis pruinosa* (Say), an oligolege of Cucurbitaceae. The other five species are specialists on Asteraceae: *Andrena placata* Mitchell, *Melissodes druriella* (Kirby) [=*rustica* (Say)], *Melissodes subillata* LaBerge, *Melissodes trinodis* Robertson, and *Melissodes agilis* Cresson.

Comparison with Other Bee Fauna. The richness and similarity of the bees collected from our study sites, relative to bee assemblages documented by other faunal surveys, is presented in Table 4. Of the seven locations compared with the urban gardens, the three sites furthest from New York City (Black Rock Forest, the Pinelands Biosphere Reserve, and Gardiner's Island) had the most bee species (144, 130, and 128, respectively) although the former two sites were sampled for only one year each. The four sites within New York City (Prospect Park, Central Park, Staten Island Freshkills landfill, and Staten Island parks) had similar species totals to the 54 species found in the urban gardens (range, 57–61 species, with the exception of the Staten Island parks collectively, with 69 species recorded). In total, 43 species documented in Prospect or Central Park were not found in the gardens (Table 5). These included 20 soil-nesting species, 13 parasitic species, and only one exotic species [*Osmia cornifrons* (Radoszkowski)]. Specific to the island of Manhattan, the combined species total reported for Central Park and the urban gardens located in Harlem (61 species) constitutes 78% of the 78 species currently known to inhabit Manhattan (J.S.A., new data) but only 28% of the New York City total of 219 species (J.S.A., new data, updated from Giles and Ascher 2006).

Table 2. Bee species collected in 19 community gardens in the Bronx and East Harlem, New York City, 2002–2006

Species	Occurrence[a]	Abundance in urban gardens[b]	% individuals (n = 1,145)[c]	% garden sites where present (n = 19)	Native vs. exotic[d]	Nest substrate[e]	Pollen specificity[f]	Behavior[g]
Hylaeus (*Hylaeus*) *leptocephalus* (Morawitz, 1870)	C	130	11.4	83.3	E	C	P	S
Hylaeus (*Hylaeus*) *mesillae* (Cockerell, 1896)	C, P, +	18	1.6	50	N	C	P	S
Hylaeus (*Prosopis*) *affinis* (Smith, 1853)		1	0.1	5.6	N	C	P	S
Hylaeus (*Prosopis*) *modestus* Say, 1837	C, P, +	19	1.7	55.6	N	C	P	S
Hylaeus (*Prosopis*) *modestus* Say, 1837 [or *affinis* (Smith, 1853)]	–	14	1.2	44.4	N	C	P	S
Hylaeus (*Spatulariella*) *hyalinatus* Smith, 1842	C	99	8.6	83.3	E	C	P	S
Hylaeus (*Spatulariella*) *punctatus* (Brullé, 1832)		1	0.1	5.6	E	C	P	S
Hylaeus undet.	–	13	1.1	33.3	–	C	P	S
Augochlora (*A.*) *pura* (Say, 1837)	P	3	0.3	16.7	N	SW	P	S
Augochlorella aurata (Smith 1853), [=*striata* (Provancher 1888)]	+	1	0.1	5.6	N	S	P	E
Agapostemon (*A.*) *sericeus* (Förster, 1771)	C, P, +	11	1	44.4	N	S	P	S
Agapostemon (*A.*) *virescens* (F., 1775)	P, +	7	0.6	16.7	N	S	P	S
Halictus (*Odontalictus*) *ligatus* Say 1837	C, P, +	18	1.6	38.9	N	S	P	E
Halictus (*Protohalictus*) *rubicundus* (Christ, 1791)	P, +	2	0.2	11.1	N	S	P	E
Halictus (*Seladonia*) *confusus* Smith, 1853	P, +	2	0.2	11.1	N	S	P	E
Lasioglossum (*Dialictus*) *illinoense* (Robertson, 1892)		2	0.2	5.6	N	S	P	E
Lasioglossum (*Dialictus*) *1* [aff. *rohweri* and *lineatulum*]		80	7	100	N	S	P	E
Lasioglossum (*Dialictus*) *bruneri* (Crawford, 1902)	P, +	48	4.2	61.1	N	S	P	E
Lasioglossum (*Dialictus*) *cattellae* (Ellis, 1913)		1	0.1	5.6	N	S	P	E
Lasioglossum (*Dialictus*) *coeruleum* (Robertson, 1893)	C, P, +	8	0.7	33.3	N	SW	P	E
Lasioglossum (*Dialictus*) *cressonii* (Robertson, 1890)		1	0.1	5.6	N	SW	P	E
Lasioglossum (*Dialictus*) *imitatum* (Smith, 1853)	+	5	0.4	11.1	N	S	P	E
Lasioglossum (*Dialictus*) males undet.	–	85	7.4	66.7	N	–	P	E
Lasioglossum (*Dialictus*) *pilosum* (Smith, 1853)		5	0.4	22.2	N	S	P	E
Lasioglossum (*Dialictus*) *rohweri* (Robertson, 1890)	+	4	0.3	11.1	N	S	P	E
Lasioglossum (*Dialictus*) undet.	–	4	0.3	22.2	N	–	P	E
Lasioglossum (*Dialictus*) *zephyrum* (Smith, 1853)	C, P	9	0.8	22.2	N	S	P	E
Andrena (*Callandrena sensu lato*) *placata* Mitchell 1960		1	0.1	5.6	N	S	O	S
Andrena (*Larandrena*) *miserabilis* Cresson, 1872	C, P, +	3	0.3	16.7	N	S	P	S
Andrena (*Taeniandrena*) *wilkella* (Kirby 1802)	C, P, +	5	0.4	16.7	E	S	P	S
Anthidium (*A.*) *manicatum* (Linnaeus, 1758)	C	12	1	44.4	E	C	P	S
Anthidium (*Proanthidium*) *oblongatum* (Illiger, 1806)		1	0.1	5.6	E	C	P	S
Osmia (*Melanosmia*) *pumila* (Cresson 1864)	C, P, +	1	0.1	5.6	N	C	P	S
Megachile (*Callomegachile*) *sculpturalis* Smith 1853	P	6	0.5	27.8	E	C	P	S
Megachile (*Eutricharaea*) *concinna* Smith, 1879	C, P	5	0.4	16.7	E	C	P	S
Megachile (*Eutricharaea*) *rotundata* (F., 1793)	C, P	19	1.7	44.4	E	C	P	S

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Table 2. Continued

Species	Occurrence[a]	Abundance in urban gardens[b]	% individuals (n = 1,145)[c]	% garden sites where present (n = 19)	Native vs. exotic[d]	Nest substrate[e]	Pollen specificity[f]	Behavior[g]
Megachile (*Litomegachile*) *mendica* (Cresson, 1878)	C, P, +	18	1.6	50	N	C	P	S
Megachile (*M.*) *centuncularis*, (Linnaeus, 1758)	C, P	79	6.9	83.3	N[h]	C	P	S
Megachile (*M.*) *montivaga* Cresson, 1878		1	0.1	5.6	N	C	P	S
Megachile (*M.*) *texana* Cresson, 1873	C, P	44	3.8	83.3	N	C	P	S
Megachile (*Xanthosarus*) *frigida* Smith 1853	C, P	4	0.3	16.7	N	C or SW	P	S
Coelioxys (*Boreocoelioxys*) *sayi* Robertson 1897	C, P	3	0.3	16.7	N	[C]	P	P
Xylocopa (*Xylocopoides*) *virginica* (L., 1771)	C, P, +	17	1.5	61.1	N	W	P	B
Ceratina (*Z.*) *calcarata* Robertson, 1900 or *dupla* Say, 1837	–	49	4.3	83.3	N	P	P	B
Ceratina (*Zadontomerus*) *calcarata* Robertson 1900	P, +	25	2.2	44.4	N	P	P	B
Melissodes (*Eumelissodes*) *agilis* Cresson, 1878	C	32	2.8	38.9	N	S	O	S
Melissodes (*Eumelissodes*) *druriella* (Kirby, 1802) [=*rustica* (Say)]		2	0.2	11.1	N	S	O	S
Melissodes (*Eumelissodes*) *subillata* LaBerge 1961	P	2	0.2	5.6	N	S	O	S
Melissodes (*Eumelissodes*) *trinodis* Robertson, 1901		2	0.2	5.6	N	S	O	S
Melissodes (*M.*) *bimaculata* Lepeletier, 1825	P	20	1.7	61.1	N	S	P	S
Anthophora (*Clisodon*) *terminalis* Cresson 1869	P	1	0.1	5.6	N	SW	P	S
Peponapis (*Peponapis*) *pruinosa* (Say 1837)		1	0.1	5.6	N	S	O	S
Triepeolus lunatus (Say 1824)	C, P	2	0.2	11.1	N	[S]	P	P
Bombus (*Fervidobombus*) *fervidus* (F., 1798)	C, P, +	19	1.7	50	N	H	P	E
Bombus (*Psithyrus*) *citrinus* (Smith, 1854)	C, P, +	25	2.2	44.4	N	[H]	P	P
Bombus (*Pyrobombus*) *bimaculatus* Cresson 1863	C, P, +	2	0.2	11.1	N	H	P	E
Bombus (*Pyrobombus*) *impatiens* Cresson 1863	C, P, +	96	8.6	100	N	H	P	E
Bombus (*Separatobombus*) *griseocollis* (DeGeer 1773)	C, P, +	27	2.4	66.7	N	H	P	E
Apis (*Apis*) *mellifera* L., 1758	C, P, +	30	2.6	72.2	E	H	P	E

In total, 54 species were identified. Some individuals could not be identified to species level (shaded). One common and distinctive *Lasioglossum* morphotype did not conform to any known species descriptions (S. Droege, personal communication) and is referred to here as "*Lasioglossum* 1."

[a] Locations in New York City where each species has been collected including Prospect Park (P) and Central Park (C). + denotes ubiquitous species found in urban gardens and at least four of the seven comparison sites.

[b] Total number collected summed across all sites and all years.

[c] Number of gardens where at least one individual of a species was found divided by the total number of gardens.

[d] Each species is classified as native (N) or exotic (E) based on Cane (2003).

[e] The known or inferred nest substrate of each nonparasitic species is categorized as either soil (S), cavity (C), soft/rotting wood (SW), wood (W), pith (P), or hive (H); nest substrates in brackets indicate those of the host of a parasitic species.

[f] Species have been classified as oligolectic (pollen specialist; usually collecting pollen from flowers belonging to a single plant family) or polylectic (pollen generalist; regularly collecting pollen from more than one family).

[g] Each species is characterized as solitary or communal (S), subsocial (B), eusocial (E), or parasitic (P). For some of the categories the behavior of some species is inferred based on that of closely related species.

[h] Putatively considered native but may be an early introduction from Europe (Giles and Ascher 2006).

Regardless of size or location, all seven sites shared approximately the same number of species with the urban gardens (range, 27–34 shared species) (Table 4). Of these, 25 species were found in the urban gardens and four or more of the seven comparison sites. These widespread and ubiquitous species are noted in Table 2.

Discussion

Composition of Bee Fauna of Urban Gardens. The 54 bee species observed in urban gardens of the Bronx and East Harlem comprise a modest 13% of the 430 species recorded from New York state (J.S.A., new data, updated from Giles and Ascher 2006) and rep-

Table 3. Percentage of bee species and individuals found in various taxonomic and ecological groupings within community gardens of New York City (see Table 2 for description of terms)

Taxonomic/ecological grouping	% species (n = 54)	% individuals (n = 1,145)
Family		
Colletidae	11	26
Halictidae	32	26
Andrenidae	5.6	0.8
Megachilidae	22	17
Apidae	30	31
Exotic/native		
Exotic	19	27
Native	81	73
Floral specificity		
Oligolectic	11	3.5
Polylectic	89	97
Nesting site		
Cavity	33	46
Hive	11	19
Wood	1.9	1.6
Pith	1.9	7.0
Soil	44	25
Soft/rotting wood	7.4	1.2
Behavior		
Solitary/communal	56	50
Parasitic	5.6	2.6
Eusocial	35	39
Subsocial	3.7	7.9

resent many species which persist in fragmented habitats within a heavily urbanized area. Although these gardens represent a relatively small proportion of the total green space within New York City, the sampling effort associated with this study (2,280 person hours spent hand netting and 666 water bowl traps over 4 yr) suggests that the species list presented in Table 2 is fairly comprehensive with respect to bees regularly found in urban areas of upper Manhattan and the south Bronx. The number of bee species documented in these urban gardens (54) is remarkably similar to the 56 bee species found in gardens and other urban green spaces of Vancouver, British Columbia (Tommasi et al. 2004) and to the 51 bee species that were found in a longer term study (over 10 yr) of a single private garden in Leicester, United Kingdom (Owen 1991).

One of the most striking results to emerge from this study was the abundance of exotic species. Ten of the 21 (48%) species reported by Cane (2003) as exotic in North America were collected in the small urban gardens of this study. In total, 19% of the species and 27% of individuals collected are non-native to North America. The percentage of exotic species encountered in our urban gardens is much higher than the percentage found in the exurban comparison sites. For example, at Black Rock Forest six species (4.2%) and 1.7% of individuals were exotic (Giles and Ascher 2006), and on Gardiner's Island, only four of 128 collected species (3.1%) were exotic. Exotic bees also have been found to constitute a relatively small percentage (2.3%) of the species assemblage at sites within the New Jersey Pinelands Biosphere Reserve (Winfree et al. 2007). However, studies reporting rather few exotic bees are not limited to exurban sites. For example, in residential areas of Berkeley, CA, only four of 76 (5.3%) collected bee species were exotic (Frankie et al. 2005), and in habitat fragments in Tucson, AZ, only one of the 62 species collected (1.6%) from creosote bush (*Larrea* spp.) was exotic (Cane et al. 2006). The greater richness and abundance of exotic species in our sample may be due to New York City being more densely developed than these other locations, or a greater prevalence of adventive bees in eastern North America due to historical or ecological factors, or both (Ascher 2001, Cane 2003). Although some exotic bee species may adversely affect native species via competition for nests sites, floral resources, or both (Barthell and Thorp 1995, Barthell et al. 1998), the degree to which this occurs in urban gardens has not been determined.

The exotic bees encountered in the urban gardens included three exotic *Hylaeus* species: *H. leptocepha-*

Table 4. Comparison of the richness and species composition of urban gardens of New York City with surveys of other locations in a 150-km radius of New York City

Site	Reference	Sampling area (ha)	Sampling yr	Bee richness	No. species shared with urban gardens
Urban Gardens, East Harlem and the Bronx, New York and Bronx County, NY	This study	1.7	4	54	N.A.
Central Park, Manhattan, New York County, NY	J.S.A., new data	341	3[a]	58	29
Prospect Park, Brooklyn, Kings County, NY	J.S.A., new data	212	3[b]	59	34
Staten Island Freshkills landfill, Richmond County, NY	Yurlina 1998	10	4	57	28
Staten Island Parks[c], Richmond County, NY	Yurlina 1998	344	2	69	27
Black Rock Forest, Orange County, NY	Giles and Ascher 2006	1,520	1	144	31
Gardiner's Island, Suffolk County, NY	J.S.A., Goelet, and Kornbluth, unpublished	1,343	4	128	32
Pinelands Biosphere Reserve, Burlington County, NJ	Winfree et al. 2007	4.8	1	130	34

N.A., not applicable.

[a] Many records based on bees collected or observed by J.S.A. and colleagues during 2004–2006; others from study of historical material in the American Museum History (most collected 1960–1980).

[b] Most records based on bees collected or observed by J.S.A. during 2004–2007.

[c] Summed data from the following three Staten Island Parks: Wolfe's Pond Park, Blue Heron Park, and LaTourette Park.

Table 5. Additional bee species that have been collected in Prospect Park, Brooklyn and Central Park, Manhattan, New York City, but not in the urban gardens (see Table 2 for definition of terms and for additional bee species found in Prospect Park and Central Park that also were found in the urban gardens of this study)

Species	Occurrence	Native vs. exotic	Nest substrate	Pollen specificity	Behavior
Colletes compactus Cresson, 1868	P	N	S	O	S
Colletes thoracicus Smith, 1853	C, P	N	S	P	S
Sphecodes aroniae Mitchell, 1960[a]	P	N	[S]	P	P
Sphecodes davisii Robertson, 1897	C	N	[S]	P	P
Sphecodes dichrous Smith, 1853	C	N	[S]	P	P
Lasioglossum (*Dialictus*) *cephalotes* (Dalla Torre, 1896)	C, P	N	[S]	P	P
Lasioglossum (*Dialictus*) *nigroviride* (Graenicher, 1911)	P	N	S	P	E
Lasioglossum (*Dialictus*) *pectorale* (Smith, 1853)	P	N	S	P	S
Lasioglossum (*Lasioglossum*) *fuscipenne* (Smith, 1853)	P	N	S	P	S
Andrena (*Cnemidandrena*) *hirticincta* Provancher, 1888	C, P	N	S	O	S
Andrena (*Cnemidandrena*) *nubecula* Smith, 1853	P	N	S	O	S
Andrena (*Gonandrena*) *fragilis* Smith, 1853	C	N	S	O	S
Andrena (*Melandrena*) *carlini* Cockerell, 1901	P	N	S	P	S
Andrena (*Melandrena*) *pruni* Robertson, 1891	P	N	S	P	S
Andrena (*Melandrena*) *vicina* Smith, 1853	C, P	N	S	P	S
Andrena (*Plastandrena*) *crataegi* Robertson, 1893	P	N	S	P	S
Andrena (*Scrapteropsis*) *morrisonella* Viereck, 1917	C, P	N	S	P	S
Andrena (*Thysandrena*) *bisalicis* Viereck, 1908	C	N	S	P	S
Andrena (*Trachandrena*) *ceanothi* Viereck, 1917	C	N	S	P	S
Andrena (*Trachandrena*) *hippotes* Robertson, 1895	C	N	S	P	S
Andrena (*Trachandrena*) *nuda* Robertson, 1891	P	N	S	P	S
Andrena (*Trachandrena*) *spiraeana* Robertson, 1895	C	N	S	P	S
Calliopsis (*Calliopsis*) *andreniformis* Smith, 1853	C, P	N	S	P	S
Pseudopanurgus andrenoides (Smith, 1853)	P	N	S	O	S
Osmia (*Osmia*) *cornifrons* (Radoszkowski, 1887)	C, P	E	C	P	S
Osmia (*Osmia*) *lignaria* Say, 1837	C, P	N	C	P	S
Chelostoma (*Prochelostoma*) *philadelphi* (Robertson, 1891)	C, P	N	C	P	S
Megachile (*Chelostomoides*) *campanulae* (Robertson, 1903)	C	N	C	P	S
Megachile (*Megachile*) *relativa* Cresson, 1878	C	N	C	P	S
Megachile (*Sayapis*) *pugnata* Say, 1837	C	N	C	O	S
Megachile (*Xanthosarus*) *gemula* Cresson, 1878	C	N	C	P	S
Ceratina (*Zadontomerus*) *strenua* Smith, 1879	C	N	P	P	B
Nomada articulata Smith, 1854	C, P	N	[S]	P	P
Nomada cressonii Robertson, 1893	C, P	N	[S]	P	P
Nomada imbricata Smith, 1854	C, P	N	[S]	P	P
Nomada lepida Cresson, 1863	C	N	[S]	P	P
Nomada luteoloides Robertson, 1895	P	N	[S]	P	P
Nomada pseudops Cockerell, 1905	C	N	[S]	P	P
Nomada pygmaea Cresson, 1863	P	N	[S]	P	P
Holcopasites calliopsidis (Linsley, 1943)	C	N	[S]	P	P
Bombus (*Fervidobombus*) *pensylvanicus* (DeGeer, 1773)	C	N	H	P	E
Bombus (*Pyrobombus*) *perplexus* Cresson, 1863	C	N	H	P	E

[a] *S. aroniae* was previously described from only five localities in North Carolina and Virginia, but it is now known to be widespread, with records from Canada (Ontario), Connecticut, Indiana, Ohio, Kentucky, New York, New Jersey, Pennsylvania, Maryland, Delaware, District of Columbia, Tennessee, South Carolina, Alabama, and Georgia (most new records based on specimens examined by J.S.A.).

lus, H. hyalinatus, and *H. punctatus.* The former two species were extremely abundant in the urban garden sites, although neither species was found at Black Rock Forest (Giles and Ascher 2006). One individual of *H. punctatus,* the first and only known record from New York state, was collected in these urban garden sites. In just three decades since its first detection in the New World, *H. punctatus* is now abundant in urban areas such as Buenos Aires, Argentina (Roig-Alsina 2006), and Santiago, Chile, and it also has become widespread in California (Ascher 2001). Therefore, this species may be expected to increase in abundance and range in coming years in New York.

The percentage of oligolectic bees collected from urban gardens (11% of species and 3.5% of individuals) was not much different from the percentage collected at Black Rock Forest (13% of species and 4.5% of individuals; Giles and Ascher 2006) or Gardiner's Island (12% of species). The most abundant oligolectic species encountered in the gardens was *M. agilis,* which collects pollen from sunflowers (*Helianthus* spp. [Asteraceae]) that are commonly grown in gardens. Despite the availability of suitable cucurbit host plants in the urban gardens, only one individual of the squash specialist *P. pruinosa* was collected. Two additional individuals were trapped in 2006 during a separate experiment in the same gardens of this study using UV-yellow pan traps (G.A.L., unpublished data), and *P. pruinosa* also has been found in a private garden near Prospect Park in Brooklyn (J.S.A., new data). Its rarity in our collection may thus have resulted from our sampling in the afternoons, when *P. pruinosa* females are not active. In addition, no efforts were made to systematically search wilted squash blooms to find males sleeping within.

The majority of bee individuals (46%) collected in the urban gardens nest in cavities, whereas the diversity and abundance of soil-nesting species was relatively low. In contrast, soil-nesting species and individuals dominated the bee fauna at Black Rock Forest, and cavity-nesting species were relatively scarce (Giles and Ascher 2006). The relative abundance of cavity-nesting species in urban areas (Owen 1991, Yurlina 1998, Cane 2001, Cane et al. 2006) and specifically in gardens (Owen 1991) may be due to opportunistic use of artificial cavities in built structures, the loss of some soil-nesting species, or both. Although some soil-nesting species may be opportunistic in selection of urban nest sites [i.e., *Melissodes bimaculata* (Lepeletier) nesting in flowerpots in a backyard in the upper east side of Manhattan; J.S.A., new data], others may be excluded from urban environments, due to soil limitation and/or frequent disturbance (trampling and turning of soil in gardens). We found only one individual of the soil-nesting *Augochlorella aurata* (Smith) in the urban gardens, although this was the most abundant bee species at Black Rock Forest (Giles and Ascher 2006). Furthermore, we found only three species of soil-nesting andrenids, which represents a mere 4.1% of the 74 species recorded from southern New York atate (Giles and Ascher 2006), and far fewer than the 40 species found in one year of sampling at Black Rock Forest (Giles and Ascher 2006).

Scarcity of soil-nesting bees such as *Andrena* spp. may partially explain the scarcity of bee parasites in our sample (5.6% of the species and 2.6% of the individuals). In contrast, cleptoparasites made up 17% of the bee species at Pinnacles National Monument in California (Messinger and Griswold 2002) and 19% of the bee species at Black Rock Forest (Giles and Ascher 2006). In residential urban areas in Berkeley, CA, Frankie et al. (2005) found only 7.9% of species to be cleptoparasites. Cane (2005) noted that cleptoparasitic species are largely absent in urban bee faunas and suggested that such species may require large host populations to persist. We encountered no cleptoparasites in the genus *Nomada,* likely due to the scarcity of *Andrena* hosts. However, several *Nomada* species occur in larger New York City parks (Table 5). In addition, there were few cleptoparasites in the genus *Coelioxys* (one species, three individuals) despite the abundance of *Megachile* hosts collected.

Implications for Conservation. Compared with Black Rock Forest, Gardiner's Island, the Pinelands Biosphere Reserve, and New York City as a whole, the native bee richness of the urban gardens and comparison sites within New York City is remarkably low. This suggests that many native bees may be limited by urbanization. Because urbanization encompasses a suite of characteristics, including increased habitat loss and fragmentation, pollution, and a prevalence of exotic species (Gilbert 1989), identifying the specific mechanisms underlying native species absence in urban areas will be difficult. In contrast, exotic bee species were abundant in these small urban gardens. This supports the view that some urban habitats such as gardens may serve as reservoirs, and possibly points of establishment, for exotic species (Gilbert 1989, McKinney 2006), and it suggests that monitoring the establishment and spread of exotic bee species should be a priority for urban conservation.

We found that ≈50% of the species in the gardens were consistently present in the other city habitats (Table 4). This indicates that certain ubiquitous bees are able to colonize the variety of anthropogenic habitats available within the urban environment (e.g., parks, gardens, and landfills), irrespective of land use. However, New York also includes extensive seminatural areas on Staten Island, in the north Bronx, and along the beaches, where regionally scarce bee species may be found. Maintenance of bee richness at the city-scale requires future studies on the bees found within these seminatural habitats and increased and widespread awareness of the conservation potential of human-dominated habitats.

Species richness of bees at the local scale has been shown to correlate with percentage of surrounding seminatural habitats (Steffan-Dewenter et al. 2002, Dauber et al. 2003). In cities, however, it is difficult and sometimes impossible to significantly increase the availability of such habitats. Under such constraints, less traditional conservation actions must be taken (Niemela 1999). An intuitive conservation action that benefits bees in both urban gardens and parks is the addition and preservation of plants known to attract bees. Implementation of garden plantings to benefit pollinating insects is increasingly recommended by numerous national and local conservation groups (Pyle 1990, Buchmann and Nabhan 1997, Mizejewski 2004). However, the utility of such actions, particularly in terms of attracting and conserving native bees, has yet to be rigorously assessed. The results presented here also suggest that the availability of soil-nesting sites may be limiting bee richness and abundance (such as native andrenids) in urban habitats, a suggestion presented by other authors as well (Owen 1991, Cane 2005). Thus, urban gardeners interested in bee conservation can be encouraged to reduce soil disturbance in some areas of their garden, and agencies responsible for management of parks can maintain soil-nesting sites once these have been identified. Finally, further studies on bee nest site use in urban areas are required to provide a basis for better soil management.

The species total of bees found in the urban gardens is remarkably similar to species totals for Central Park, Prospect Park, and Freshkills landfill in Staten Island. This is surprising, because these sites (especially the two parks) are individually much larger in area than the summed area of the gardens of this study (Table 4), and they include extensive areas of seminatural vegetation. Although Central Park and Prospect Park have been opportunistically sampled for multiple years, they have not been systematically surveyed, and many species are likely present that have not yet been collected. Nevertheless the similarity in richness of the known bee faunas of urban gardens and the much larger parks of the city highlights the ecological value of the >700 human-maintained community gardens located throughout New York City, despite their small size and location within highly developed urban neighborhoods.

The ecological value of community gardens is also apparent when considering the distribution of species across the 19 sampled gardens. Most species were found in only a few gardens. The sampled gardens vary in diversity and abundance of floral resources, garden area, and other factors that may affect presence of bees at the garden-level, with some gardens harboring >20 native bee species (Matteson 2007). Despite the importance of individual community gardens for certain bee species, many gardens in New York City are under threat of development for real estate (Englander 2001). Wide-scale losses of urban community gardens may result not only in localized reduction of bee species and the pollination services they provide, but also in the loss of community-based venues for environmental education and exposure.

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