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Evaluating the dependence of urban pollinators on ornamental, non-native, and 'weedy' floral resources

David M. Lowenstein[1,2] · Kevin C. Matteson[3] · Emily S. Minor[1,4]

Abstract

Urban landscapes are often florally rich due to extensive management of cultivated plants around the city. High abundance and diversity of these floral resources has been linked to more abundant and diverse pollinator communities, but little is known about how urban pollinators select from the wide variety of available flowers. This study provides unique insight into urban plant-pollinator interactions by examining how many plant taxa, and which taxa, are visited by pollinators. Over a three-year period, we observed foraging of urban pollinators across 63 neighborhoods in Chicago, Illinois (USA). We observed 1815 plant-pollinator interactions between 24 pollinator morpho-types and 106 plant taxa. An additional 57 plant taxa were flowering but not visited by pollinators. On average, each pollinator morpho-type visited 19 plant taxa, and most pollinators showed generalist tendencies. We identified 42 plant taxa that were visited by more pollinator morpho-types than their floral abundance would predict; we call these 'highly attractive' plants. In general, perennial and native plants received more pollinator visits than their counterparts, and ornamental plants were visited by more species than unintentional 'weeds'. However, the two most-visited plant taxa were non-native, perennial weeds. Our results suggest that many flowering plants in cities are not visited by pollinators. Furthermore, the plant-pollinator network could be reduced to only four plant taxa without losing any pollinator morpho-types. To enhance urban pollinator conservation, urban residents can select ornamental plants from our list of 'highly attractive' plant taxa, or can allow some of the highly attractive 'weeds' to persist in their gardens.

Keywords Residential yards · Gardens · Generalist · Specialist · Bees · Flowers · Plant-pollinator networks

Introduction

The world-wide decline of pollinators has received significant attention in recent years. Although much public concern has focused on honey bees, wild bees and other pollinators are also declining (Potts et al. 2010). These declines could have

✉ Emily S. Minor
  eminor@uic.edu

1 Department of Biological Sciences (MC 066), University of Illinois at Chicago, 845 W. Taylor St, Chicago, IL 60607, USA

2 Present address: Department of Horticulture, Oregon State University, 2750 SW Campus Way, Corvallis, OR 97331, USA

3 Department of Biology, Miami University, 27 Peabody Hall, Oxford, OH 45056, USA

4 Institute for Environmental Science and Policy, University of Illinois at Chicago, Chicago, IL, USA

serious consequences for our food supply (Garibaldi et al. 2011) and for the health of native ecosystems (Ollerton et al. 2011). Both wild and managed pollinators face many stressors, including habitat loss, land use change, agrochemicals, invasive species, and disease (Cane and Tepedino 2001; Goulson et al. 2015). Pollinator conservation should thus be a global priority (Ollerton 2017).

Recent research suggests that urban areas might offer important opportunities for pollinator conservation (Hall et al. 2017). Despite extensive impervious surfaces, cities can contain a remarkable level of apparent floral resources for pollinators (Hülsmann et al. 2015). These potential resources include crops in urban community gardens (Matteson and Langellotto 2009), ornamental flowers in residential neighborhoods (Frankie et al. 2005), and spontaneously growing 'weeds' in unmanaged urban areas (Lowenstein and Minor 2016). Urban residents influence plant community composition (Knapp et al. 2012; Loram et al. 2011) and plant functional traits (Lowenstein and Minor 2016) through their garden management decisions. Little is known about how those human decisions affect urban pollinators.

Gardeners might intentionally select plants with certain traits, such as flower color and symmetry, which could affect interactions between plants and pollinators (Giurfa et al. 1999; Herrera and Pellmyr 2002). Other plant attributes might also have ecological implications. For example, annual plantings might provide less predictable floral resources compared to perennial plants. Furthermore, while many pollinators readily visit non-native plants (Garbuzov and Ratnieks 2014; Razanajatovo et al. 2015; Williams et al. 2011), and may even be dependent on them in certain heavily developed urban settings (Matteson and Langellotto 2011), some research suggests that native or "near-native" species are preferred (Chrobock et al. 2013; Salisbury et al. 2015). Finally, some ornamental species are unattractive to flower visitors (Garbuzov et al. 2015; Garbuzov et al. 2017) and it is possible that unintentional 'weeds' may be preferred over plants intentionally selected by humans.

Generalists are common in pollination systems (Waser et al. 1996; Bascompte et al. 2003; Petanidou et al. 2008), but this trend could be even stronger in urban landscapes for several reasons. First, generalist pollinators are more likely than specialists to persist in anthropogenic landscapes, due to their ability to exploit a wide range of resources and tolerate a wide range of environmental conditions (Biesmeijer et al. 2006; Jędrzejewska-Szmek and Zych 2013; Zanette et al. 2005). Second, the prevalence of non-native plant resources in cities may result in more generalists if pollinators forage on these new resources. On the other hand, some urban pollinators restrict their foraging to a relatively small subset of available floral resources (MacIvor et al. 2014; Baldock et al. 2015). The altered plant community in cities poses an interesting question of how pollinators incorporate these novel and varied floral resources into their diet.

Building on our previous work on distribution of urban floral resources (Lowenstein and Minor 2016), we studied foraging pollinators for 3 years in Chicago, IL (USA). In addition to bees (Hymenoptera: Apoidea), we also recorded visits by hoverflies (Diptera: Syrphidae), as these are the two most common flower visitors in our system (unpublished data) and Diptera in general, and Syrphids in particular, are recognized as the second most important group of flower-visiting insects (Larson et al. 2001). First, we investigated which plant taxa were visited by pollinators, and whether pollinators preferred plants with certain attributes. We identified particular plant taxa that were highly attractive to urban pollinators. Second, we investigated the number of plant taxa visited and level of specialization for each pollinator morpho-type in our system. Finally, we evaluated the level of redundancy in urban floral resources by simulating plant removal from the system and determining the minimum number of plant taxa that could hypothetically support the pollinator community. We expected that pollinators would exhibit non-selective visitation and accept a diverse group of resources, resulting in more generalist

pollinators and redundancy for most plants. By examining multiple years of plant-pollinator interactions across 63 urban neighborhoods, our study provides unique insight into how pollinators forage in urban landscapes and which plant characteristics can help promote urban pollinator conservation.

Methods

Sample sites

To investigate the relationships between plant attributes, floral characteristics, and pollinator visitation patterns, we combined and then assessed plant and pollinator data collected from 63 urban neighborhoods over 3 years in and around Chicago, IL. Here we use the term 'neighborhood' loosely to refer to a separate sample location, and do not use the term to refer to specific (i.e., named) Chicago neighborhoods. Sample locations were distributed across the city in a variety of neighborhoods ranging in income and other socio-economic characteristics. With the exception of one pair of sites, all sites were > 550 m apart (average distance between nearest neighbors = 1810 m; 95% CI [1544.5, 2075.5]). In each neighborhood, we used a transect-based sampling approach to record interactions between pollinators and plants along a 150×5 m linear path paralleling the sidewalk, following the methods in Lowenstein et al. (2014). Due to the small size of Chicago lots—the standard lot size is 25 ft. × 125 ft., or 7.6 m × 38.1 m, with the typical house set back less than 5 m from the sidewalk (personal observation)—this transect encompassed most plants in front gardens.

In 2011, we visited 28 sites three times between 7 July and 22 August. In 2012, we visited the same sites as well as an additional five sites two times between 18 June and 27 August. In 2013, we visited all of the previous 33 sites and an additional 30 sites twice between 10 June and 21 August. In a given summer, site visits were separated by at least 20 days. Visits occurred on days with full to partial sun between 9:00 and 16:00.

Plant and pollinator data collection

All flowering plants (except trees) along the transect were recorded and identified to species or genus in the field, or photos were taken for later identification. Trees were excluded due to their height, which made it challenging to count flowers or observe flower visitors. Floral abundance was recorded for each flowering plant; inflorescences, racemes, umbels, and floral clusters were treated as a single unit when counting floral abundance (Baldock et al. 2015). We used field guides and the Missouri Botanic Garden plant finder (http://www. missouribotanicalgarden.org/plantfinder/plantfindersearch. aspx) to identify and classify plants according to various

attributes: life cycle (perennial or annual), biogeographic origin (native or non-native, with native plants originating in the USA east of the Rocky Mountains), cultivation intent (weedy—most likely spontaneous, or ornamental—most likely deliberately planted), flower symmetry (radial or bilateral), and flower color (white/pink; red; yellow/orange, or blue/purple).

All interactions between bees (Hymenoptera: Apoidea) and hoverflies (Diptera: Syrphidae) (collectively called "pollinators" hereafter) and flowers observed within the transect were recorded. An interaction was counted if a pollinator contacted the reproductive structure of a flower for at least 1 second. Although short-term visitation does not always equate to an actual pollination event, it is a useful proxy for pollination (Vázquez et al. 2005) and enables identification of pollination networks based on field observations.

In the first year of sampling, pollinators were collected and identified to species (Lowenstein et al. 2014). In subsequent years, we avoided collecting specimens on private property, and pollinators were identified in the field to the lowest possible taxonomic level. To maintain a consistent taxonomic resolution across years, all pollinator-level analyses were performed at the genus level with the exception of the following easily recognizable bees identified to species level: bumble bees (*Bombus spp.*, 4 species), *Apis mellifera (European honey bee), Agapostemon virescens* (bicolored striped-sweat bee)*, Anthidium manicatum* (European wool carder bee)*, Halictus ligatus* (ligated furrow bee)*, Melissodes bimaculata* (two-spotted longhorn bee), and *Xylocopa virginica* (eastern carpenter bee). Recorded taxa are listed in Table 1; hereafter, we use the term "morpho-types" to describe pollinator taxa. Although it is not ideal to identify organisms to different levels of taxonomic specificity, this is an accepted approach when identifying bees on the wing (e.g., Kremen et al. 2002; Moretti et al. 2009).

Data analysis

We used individual two-tailed tests of population proportion to evaluate the proportion of plant taxa that were visited by at least one pollinator, comparing among categories for life cycle, biogeographic origin, cultivation intent, flower color, and floral symmetry. We also used Mann-Whitney Wilcoxon tests to compare the number of pollinator visits and richness of visitors between plants with different attributes. Abundance and richness of visitors to each plant taxon were averaged over the number of sampling events when a plant was observed. This method removed potential bias toward more abundant plant taxa, so that a plant taxon would not show higher pollinator abundance and richness simply because it was abundant. To compare number of visits and richness by flower color, we used one-way ANOVAs with response variables log-transformed to improve normality. Because only four plant

taxa had red flowers, we excluded red flowers from color-preference analyses. In addition, taxa with multiple colors on petals were excluded from the analysis of flower color, as were plants with different-colored cultivars across our study sites.

To identify especially important pollinator-supporting plants within the urban system, we evaluated which plant taxa were visited by more pollinator morpho-types than would be expected based on their floral abundance. To identify these highly-visited plant taxa (hereafter called 'highly attractive' taxa), we used least squares regression, with pollinator richness as the response variable and floral abundance across all study sites as the predictor variable. Both variables were log-transformed, and only plants that had been visited by at least one pollinator were included in the analysis. We classified species as highly attractive if they appeared above the 95% confidence intervals in the linear regression model, similar to the 'bee plants' identified in Harmon-Threatt and Hendrix (2015).

To determine level of specialization for pollinator morpho-types, and investigate how the loss of plant species would impact pollinators, we built a plant-pollinator network in the bipartite package of R version 3.1 (Dormann et al. 2009; R Development Core Team 2015). Network links were weighted by the number of observed interactions between each plant and pollinator. We then calculated a pollinator specialization index (d') that measures how strongly a pollinator's interactions deviate from a random selection of plants (Bluthgen et al. 2006). This measure corrects for the abundance of both pollinators and plants, and the output ranges from 0 (no specialization) to 1 (complete specialization on a plant host).

To investigate how the loss of plant species would impact pollinators, we simulated plant removal from the plant-pollinator network using the 'second.extinct' function in the bipartite package. We used a model that removed plant taxa systematically from the least to most abundant, only including plants with at least a single pollinator visit. As plants were removed, the simulation recorded when a pollinator was predicted to be extirpated from the system. From this information and evaluating the links between plants and pollinators, we constructed a reduced network that included the minimal number of plant species that potentially supports all pollinator taxa.

Results

Over 3 years, we recorded 1815 pollinator visits from 24 pollinator morpho-types (Table 1) to 106 plant taxa (Supporting Information Table 1). An additional 57 plant taxa were recorded on transects but were not visited by pollinators. We were more likely to observe at least one pollinator visiting a plant if that plant was blooming on numerous transects (Fig. 1). Of the

Table 1 Pollinators recorded on neighborhood blocks. d' is a floral specialization index ranging from less specialized (0) to more specialized (1). Due to the potential of bias, we did not calculate d' for pollinators with fewer than 9 recorded visits

Pollinator	d'	Total recorded visits	# plant taxa visited
Andrena spp	0.656	18	11
Anthidium manicatum	0.172	25	13
Agapostemon virescens	0.492	87	23
Agapostemon spp	0.210	19	9
Augochlora spp		2	2
Apis mellifera	0.298	245	44
Bombus bimaculatus	0.342	78	29
B. griseocollis	0.294	12	8
B. fervidus	0.264	28	17
B. impatiens	0.338	190	48
B. spp. 1	0.285	26	16
Ceratina spp		1	1
Coelioxys spp		2	1
Halictus ligatus	0.299	25	13
Hylaeus spp	0.478	231	46
Lasioglossum spp	0.219	274	63
Megachile spp	0.297	132	35
Melissodes bimaculata	0.128	36	14
Melissodes spp	0.257	36	16
Nomada spp	0.389	9	8
Stelis spp		3	2
Syrphus spp	0	13	11
Toxomerus spp	0.524	309	43
Xylocopa virginica	0.703	14	9

plant taxa that were visited by pollinators, most were non-native (72%), perennial (65%), and ornamental (71%), and flowers tended to be purple (25%) or white (25%) and have radial symmetry (66%). Plant taxa with the most pollinator visits included *Trifolium repens* (white clover; 6.7% of visits), *Convolvulus* spp. (bindweeds and morning glories; 6.2% of visits), and *Hibiscus syriacus* (rose of Sharon: 5.0% of visits); these plants were observed on 56, 26, and 22 transects, respectively (Supporting Information Table 1). The highest

pollinator richness was observed on *Convolvulus* spp. (N = 17) and *Rudbeckia* spp. (black-eyed Susans and cone-flowers; N = 16); *Rudbeckia* was observed on 53 transects. The pollinators most frequently observed visiting flowers included *Toxomerus* spp. (hoverflies; 17%), *Lasioglossum* spp. (sweat bees; 15.1%), and *A. mellifera* (European honey bees; 13.4%). *Lasioglossum* spp. and *Bombus impatiens* (common eastern bumblebees) visited the most plant species (N = 63 and N = 48, respectively).
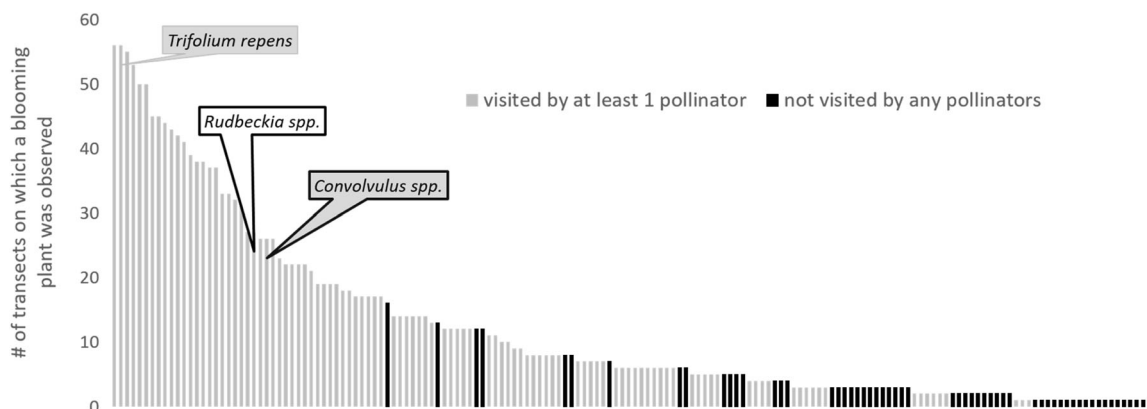

Fig. 1 Rank abundance of blooming plants observed along study transects. The labelled plants are the two plant taxa with the most pollinator visits (gray labels), and the two plant taxa visited by the most pollinator species (labels with thick black outline)

When comparing the proportion of plant taxa with different attributes that were visited by at least one pollinator, there were no effects of biogeographic origin (native versus non-native), life cycle (perennial versus annual), cultivation intent (weedy versus ornamental), or floral symmetry (radial versus bilateral) (Fig. 2). In other words, we could not predict whether a plant would be visited by at least one pollinator based on those particular traits. However, there was a significant effect of flower color, with a greater proportion of yellow-flowered taxa being visited by at least one pollinator than white-flowered taxa ($X = 7.93$, $P = 0.005$; Fig. 2). In addition, overall pollinator abundance was greater on native than non-native plants ($W = 1152$, $P = 0.05$) and on perennial than annual plants ($W = 757$, $P = 0.02$; Fig. 3). There were no differences in pollinator abundance between ornamental or weedy plants ($W = 1186$, $P = 0.87$), plants with bilateral or radial floral symmetry ($W = 946$, $P = 0.60$), or plants with different flower colors ($F = 0.48$, $P = 0.62$). Finally, pollinator richness was slightly greater on ornamental than weedy flowers ($W = 1589$, $P = 0.003$; Fig. 3). There were no significant differences in pollinator richness by plant origin

($W = 1127$, $P = 0.08$), life cycle ($W = 922$, $P = 0.23$), flower symmetry ($W = 1040$, $P = 0.85$), or flower color ($F = 1.03$, $P = 0.36$).

Based on residuals above the 95% confidence interval in the regression of pollinator richness on floral abundance, 42 plant taxa can be considered 'highly attractive' to a diversity of urban pollinators. Although the most highly attractive plant taxon includes a common weed (*Convolvulus* spp.)*, 29 of the 42 taxa are ornamental plants including *H. syriacus, Nepeta* spp. (catmint)*, and *Rudbeckia* spp. (Fig. 4, Supporting Information Table 1). A diverse pollinator assemblage visited the 42 attractive species (Supporting Information Fig. 1).

On average, each pollinator morpho-type visited 19 plant taxa. Yet, of plants that were visited by pollinators, most were visited by few morpho-types (mean ± SE = 4.5 ± 0.4, Supporting Information Table 1). For pollinators with at least five observed floral interactions, the mean floral specialization index (d' = 0.35) indicated a tendency towards being a generalist. However, there was considerable variation between morpho-types, ranging from complete generalist to somewhat specialized (Table 1). *Melissodes bimaculata* (two-spotted longhorn bees) and

Fig. 2 Proportion of all observed plant taxa with and without recorded pollinator visits. The number of taxa in each group is shown on the bar. Plant taxa that could not be classified by attribute were excluded from this analysis. Letters above bars indicate significant differences in proportion of plant taxa visited by pollinators
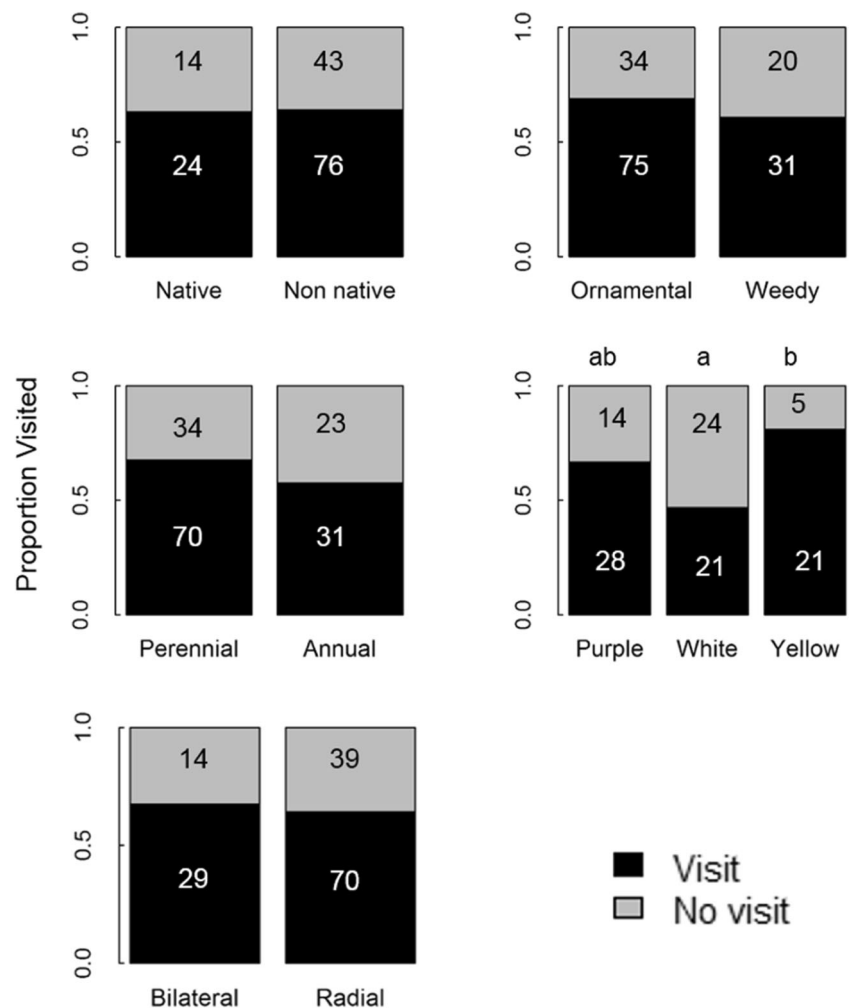
Fig. 3 Median (±95% CI) number of pollinator visits and morpho-type richness by plant attribute, in first row, and flower characteristics, in second row. Only plants that were visited by at least one pollinator are included. The y-axis shows number of pollinator visits or number of morpho-types per plant taxa. Asterisks indicate a significant difference ($P \leq 0.05$, Mann-Whitney Wilcoxon test)
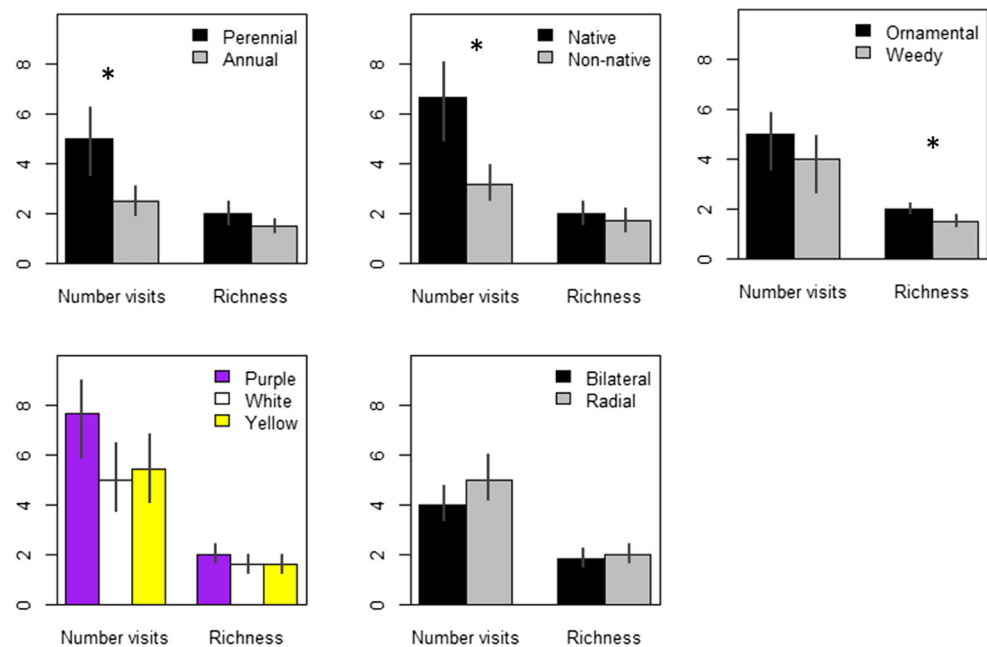
Syrphus spp. (hoverflies) were the most generalized pollinators, while *Xylocopa virginica* (eastern carpenter bees) and *Andrena* spp. (mining bees) were the most specialized.

In the plant removal simulation, the first pollinator morpho-type was predicted to be lost from the system after 65 plant taxa were removed. Generally, our simulation revealed that most pollinator morpho-types would be

Fig. 4 Regression of floral abundance of each visited plant taxon versus pollinator richness. Floral abundance was summed over all study sites. Slope and 95% confidence limits are plotted with log10(floral abundance), but floral abundance is labeled in untransformed scale. Plants included in the reduced network simulation are circled and labeled. Full list of species above 95% CI are noted in Supporting Information Table 1. APOC = *Apocynum cannabinum*, CONV = *Convolvulus* spp., DAUC = *Daucus carota*, HIBI = *Hibiscus syriacus*, NEPE = *Nepeta* spp., and RUDB = *Rudbeckia* spp.

retained until the removal of abundant plant taxa with high pollinator richness, since all pollinators except *Coelioxys* spp. (leaf-cutting cuckoo bees) foraged on multiple plant taxa. Several reduced assemblages of four plant taxa could hypothetically support all pollinator morpho-types in the community, and we show one such combination in Fig. 5. All reduced plant assemblages included *Rudbeckia* spp., *Apocynum cannabinum* (Indian Hemp), and *Convolvulus* spp.; *Daucus carota* (Queen Anne's lace), *Nepeta* spp., and *H. syriacus* are interchangeable as the fourth plant. All of these plants were found on fewer than half of the transects (Supporting Information Table 1).
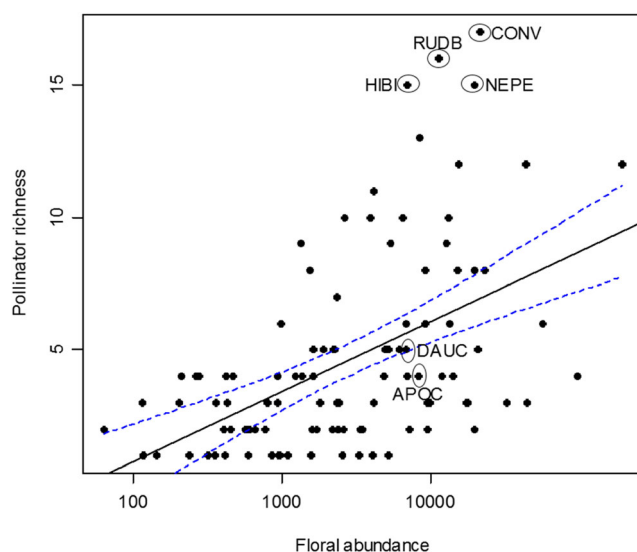
Discussion

Although cities often contain abundant floral resources (Knapp et al. 2012; Lowenstein and Minor 2016) and harbor diverse pollinator assemblages (e.g., Frankie et al. 2005; Hennig and Ghazoul 2011; Matteson et al. 2008), little is known about how urban pollinators select resources among the wide variety of available flowers. In our multi-year evaluation of pollinator foraging in Chicago neighborhoods, we found a rich floral community with 163 plant taxa. While neighborhoods contained many flowering plants, one-third of the plant taxa were not visited by any pollinators. Our results are similar to a study by Theodorou et al. (2017), who found that urban areas had a higher floral richness but urban bees visited a lower proportion of the available flowering plants compared to agricultural sites. This suggests a trend in urban areas.
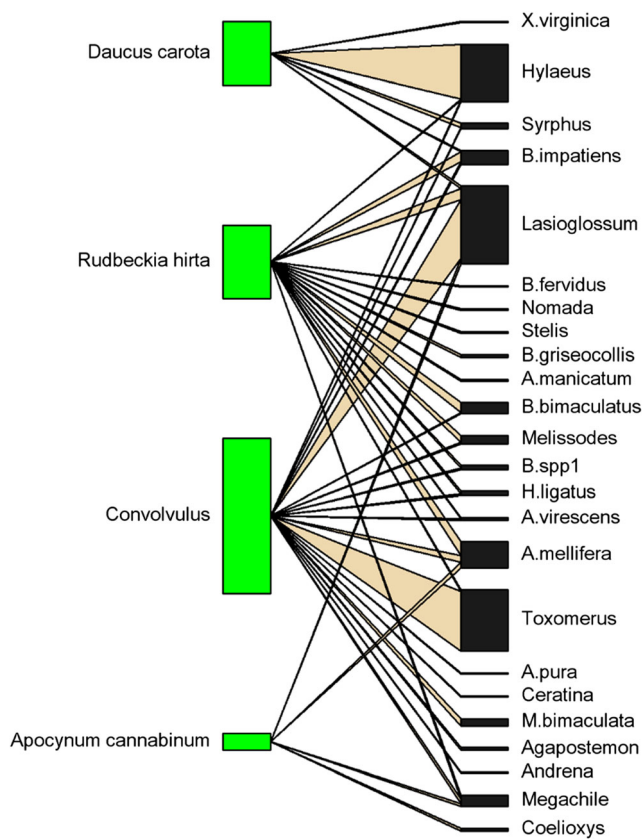
Fig. 5 Plant-pollinator network based on removal simulation, showing one combination of minimum number of plants (left) from a reduced network whose connections would support all pollinator morpho-types (right). Full pollinator names are listed in Table 1. Bar size corresponds to abundance of plants and pollinators with link width corresponding to number of pollinator visits. The full network can be seen in Supporting Information Fig. 1

Chicago's plant-pollinator system differs from many others in an interesting way. In most published networks, pollinator diversity outnumbers plant diversity by as much as a 6:1 ratio (Vázquez et al. 2009), but we noted the opposite pattern in our system. Although we did not identify all pollinators to species level in this study, pollinator taxa still greatly outnumbered plant taxa in a different Chicago study when pollinators were identified to the species level (Lowenstein et al. 2014). We attribute this pattern to several factors. First, our system has a higher-than-usual plant richness due to the abundance of non-native and ornamental plants, which is a typical pattern exhibited in urban areas (Knapp et al. 2012; Aronson et al. 2015). Second, although bees and hoverflies are likely the most important pollinators in our system, other insects visit flowers and feed on pollen and nectar (e.g., butterflies, beetles, wasps). Had we included all flower-visiting insects in our analysis, the ratio of insects to plants would have been higher. However, due to the high level of human involvement in the plant community, we believe that this system would have a higher diversity of plants than pollinators regardless of how 'pollinators' was defined and measured.

We found perennial and native plants received more total visits than their counterparts. Perennial plants included both those that are native (32%) and non-native (68%) to the region. Furthermore, most native plant species documented in this study were perennials (84%). Taken together, this suggests that plant life cycle may be more important in this system than biogeographic origin. Our finding on the importance of perennial flowers in urban ecosystems corresponds with a study that found that urban meadows planted with perennial flowers can produce 20× as much nectar and 6× as much pollen as meadows planted with annual flowers (Hicks et al. 2016). However, it is important to note that some annual flowers can be strong producers of pollen and nectar resources (Hicks et al. 2016).

We also found that, on the whole, ornamental flowers were visited by slightly more pollinator taxa than typically unmanaged, 'weedy' species. These results are based on the average pollinator richness per plant taxa on a transect, and thus are not an artefact of the overall abundance of ornamental flowers. However, several abundant ornamental plants were rarely visited in our system. Similarly, Garbuzov et al. (2017) found that many plants sold in large garden centers in England are not attractive to pollinators. In our study area, three of the most common ornamental annual plants—*Petunia*, *Impatiens*, and *Tagetes (petunias, impatiens, and marigolds)*—were visited by few pollinators despite being observed in 50, 45, and 43 neighborhoods, respectively. Yet they are popular in residential gardens because they can be grown in pots, retain their color, and bloom for much of the summer. Interestingly, the two most-visited plant taxa were abundant non-native plants often considered to be weeds: *T. repens* (white clover) and *Convolvulus spp.* (bindweeds and morning glories). These two non-native taxa had more than twice the number of visits of the most visited native species. This potentially important role of select non-native 'weeds' in supporting pollination networks has also been suggested in other urban (Larson et al. 2014; Hicks et al. 2016) and agricultural settings (Rollin et al. 2016). Thus, our data lend support to the ecological value of weedy lawns and unmanaged areas. Additionally, urban plant communities may aid pollinators by their extended bloom times compared to native plant communities in less disturbed environments (Harrison and Winfree 2015). However, we note that invasive weeds can cause ecological damage in other ways (Schirmel et al. 2015).

While our results corroborate the generalist tendencies of urban pollinator communities (Geslin et al. 2013; Baldock et al. 2015), we identified a few examples that suggest some degree of specialization related to flowering phenology and morphology. Mining bees (*Andrena* spp.) are among the few pollinators active in spring, and their specialization is associated with visits to ephemerals and early-season bloomers (e.g. *Rhododendron* spp.). Our observations of the eastern carpenter bee, *X. virginica*, were restricted to visits to tubular flowers

with deep nectaries such as *Lilium (lilies)*. Masked bees (*Hylaeus* spp.) are considered to be generalist foragers but we found their interactions to be skewed towards one non-native plant species that appeared in the reduced network - *Daucus carota* (Queen Anne's lace). The small compound umbels on this flowering plant are favored by small-bodied bees to the extent that all foraging records of the non-native *H. punctatus* in Toronto, Canada were on this plant species (Sheffield et al. 2011). Our observations were limited to the summer months (June–August), so specialization metrics may have differed if we had sampled over a longer time period when different plants were in bloom.

We observed pollinators visiting over 100 plant taxa at our study sites. However, a simulation of plant removal revealed that as few as four taxa, two of which are considered weeds by most gardeners, could hypothetically support all pollinators. Removal of plant species from urban neighborhoods might occur, for example, due to restrictions imposed by a home-owners' association, more rigorous weed removal in city parks, or changes in plant availability at garden centers. One rare plant, *A. cannabinum* (Indian hemp), was considered crucial due to being the sole link with a cleptoparasitic bee, *Coelioxys* spp. Because *Coelioxys* was only observed twice in our study, the importance of this particular plant should be investigated further. The remaining plant taxa in the reduced assemblages were fairly abundant across neighborhoods and visited by a diverse group of pollinators. The results of the simulation should not be interpreted as a call to focus plant conservation on this narrow pool of species. In fact, a higher diversity of floral resources can help sustain pollinator health by providing different nutritional resources or being available at different times of day or season (Blüthgen and Klein 2011). We also caution that our results cannot account for rare pollinators that were not identified to species level or that may have been historically extirpated from the region, or for other insects that rely on floral resources but might be less efficient pollinators (e.g., Lepidoptera).

Conclusions and recommendations

Urban ecosystems appear to have a diversity of floral resources, but our observations indicated that some commonly planted flowers are rarely used or unused by pollinators. This pattern could be due to the restricted distribution of some plants, or to inadequate or inaccessible pollen or nectar (Corbet et al. 2001). Since the number of plant taxa was large relative to pollinators (even when removing unvisited taxa), it seems unlikely that most urban pollinators are food-limited. In fact, several plant genera frequently recommended for pollinator conservation (Garbuzov and Ratnieks 2014; Tuell et al. 2008) were notably present across urban neighborhoods (e.g. *Agastache* (hyssops), *Coreopsis* (tickseeds), *Nepeta* (catmints); Supporting Information Table 1). To further support conservation of urban pollinators, we advocate for evaluating nectar and pollen loads of common ornamental species (e.g. Garbuzov and Ratnieks 2014) and integrating 'attractive' plant taxa, which include native and non-native perennial ornamental plants, into neighborhood plantings. In addition, providing unique floral hosts for oligolectic and monolectic bees may be a complementary strategy for promoting conservation of urban pollinators.

Compliance with ethical standards

Conflict of interest The authors declare that they have no conflict of interest.

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