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Cover Page Footnote

We thank John Ascher for confirming our initial identification of Megachile apicalis on BugGuide. Thanks to Maya Dutta, Elaine Jiang, and Alicia Wala for fieldwork assistance. We thank also thank the Iler + CaraDonna Lab Group and two anonymous reviewers for constructive comments on the manuscript. Research was supported by an NSF Graduate Research Fellowship (DGE-1842165 to A.M.G.) and the Northwestern University Plant Biology and Conservation Research Award (to A.M.G.).

First Records of *Megachile apicalis* (Hymenoptera: Megachilidae) for Illinois Found in Heavily Urbanized Areas Within the City of Chicago

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Abstract

We provide the first record of the non-native *Megachile apicalis* Spinola (Hymenoptera: Megachilidae) in Illinois. Thirty *M. apicalis* specimens were collected in the summer of 2018 in a highly urban area of Chicago, IL, USA. Our findings suggest that the range of *M. apicalis* appears to be rapidly expanding across North America, inward from both the East and Western Coasts. *Megachile apicalis* in Chicago has a broad activity period, can take advantage of abundant non-native floral food resources and has competitive nesting behavior, all of which may facilitate its successful establishment in disturbed urban environments, as well as its continued spread across North America.

Keywords: new record, *Megachile*, invasive species, bees, urban ecology, Chicago

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Non-native bee species continue to spread globally. Over 83 bee species have established outside of their native ranges worldwide and at least 40 species have established in North America alone (Cane 2003, Russo 2016, Gibbs and Dathe 2017, Martins et al. 2017). Non-native species can have detrimental effects on native ecosystems, yet the consequences of non-native bees are generally unknown, especially for unintentionally introduced species (Goulson 2003, Russo 2016). Some non-native bee species may be well-equipped to navigate harsh, urban landscapes, with a number of non-native species recorded exclusively in urban environments (Russo 2016, Portman et al. 2019). As urbanization increases worldwide, non-native species may be able to exploit urban environments compounding threats to local biodiversity (McKinney 2008, 2006).

Bees in the genus *Megachile* represent over 1,500 described species in 56 subgenera, accounting for 1/3 of all bees in the family Megachilidae (Michener 2007, Ascher and Pickering 2020). At least thirteen *Megachile* species are considered non-native across the globe, having expanded outside their native range—the most of any genus of bees (Russo 2016). There are at least six non-native *Megachile* species in the continental United States, many of which appear to be expanding rapidly, including *Megachile apicalis* Spinola (Hymenoptera: Megachilidae). *Megachile apicalis* is a cavity nesting species native to Europe, North Africa, and the Middle East and was accidently introduced to North America. The first record of *M. apicalis* in North America is from two specimens from Virginia, one from 1931 and the other from 1883, although the latter specimen is somewhat questionable. Following the first collections, *M. apicalis* was recorded in California in 1982 (Mitchell 1962, Cooper 1984) and expanded throughout parts of the west (Sheffield et al. 2011b, Droege 2015). *Megachile apicalis* has since been reported in Pennsylvania in 1996 (Donovall and VanEngelsdorp 2010), Ohio in 2010 (Sivakoff et al. 2018), Michigan in 2013 (Gibbs et al. 2017) and Missouri (date unknown; Camilo et al. 2017). The spread of *M. apicalis* across North America has been attributed, in part, to being transported in managed *Megachile rotundata* (Fabricius) pollinator nesting tubes (a close relative, which was accidently introduced in the 1940's, and is now widely managed as an important alfalfa pollinator; Pitts-Singer and Cane 2011, Droege 2015, Russo 2016).

Here, we report the first records of the non-native leafcutter bee, *M. apicalis* in Illinois, which were found in a heavily urbanized area within the City of Chicago. We provide detailed information on the urban ecosystem within which they were recorded, describe several ecologically relevant traits for *M. apicalis*, and discuss the potential effects *M. apicalis* may have on existing bee communities.

Materials and Methods

Megachile apicalis specimens were collected during the 2018 growing season

as part of a larger study investigating bee communities along an urbanization gradient in the Chicago Metropolitan Area (Gruver and CaraDonna *unpublished*). Sampling occurred at eight different sites along an urbanization gradient that followed the Union Pacific North Metra Train Line. We quantified urbanization as the percent impervious surface within a 500 m radius from the sampling location. Across the eight study sites, impervious surface ranged from 69% within the urban core of Chicago to 15% in suburban areas outside of the city. Floral resources were sampled at each site four times from June to August 2018. To quantify the availability of floral resources, we divided each site into eight 25 × 3m sections; within each section, we recorded the identities of flowering species and counted the number of flowering inflorescences of each species. In addition, we recorded the percent cover of all flowering plants, non-flowering vegetation, bare ground, impervious surface, and lawn in each section.

Bees were sampled four times throughout the 2018 season (June–August) at each site using hand nets and pan trapping. *Megachile apicalis* specimens were identified using discover life keys, the Bees of Eastern United States, and the *Megachile* of Canada and Alaska (Mitchell 1962, Sheffield et al. 2011a, Andrus and Droege 2020). Bee specimens from this project are permanently deposited within the Arthropod Collection at the Field Museum (Chicago, IL, USA). Photographs of *M. apicalis* specimens were taken using a Canon EOS rebel T6i camera mounted on a Zeiss stemi 2000c stereomicroscope. Multiple photos were taken of specimens and stacked to create a composite image using Adobe Photoshop 2018 software (Adobe Systems Inc., San Jose, CA).

Results

During the summer of 2018, we collected 30 *M. apicalis* specimens. All specimens were collected from a single site along the urbanization gradient: the Clybourn Metra Train Station (here after Clybourn), Chicago, Cook County, Illinois (41°55′1.2″N, 87°40′4.″W). Of all eight sites sampled across the urbanization gradient, Clybourn exhibits the greatest surrounding percent impervious surface (69%) and is closest to the city center (5.5 km from downtown Chicago). *Megachile apicalis* specimens were collected during all sampling periods across the summer of 2018 (28 June, 11 July, 27 July, and 10 August). Among the *M. apicalis* specimens collected, 47% (14) were female and 53% (16) male. Most specimens were collected in pan traps 77% (23), and 23% (7) collected while foraging on flowers. We recorded male *M. apicalis* foraging on four flowering plant species, all of which are non-native to North America. Three of these flowering plant species were members of the Fabaceae, *Medicago lupulina*, *Melilotus albu*s, and *Melilotus officinalis,* and one was a member of Asteraceae, *Centaurea stoebe*. We did not record any females foraging on plants—all were caught in bee bowls. The Clybourn site was dominated by non-native plant species (87%) over the growing season, the most of any of the sampled sites in 2018. The non-native flowering plants were also more abundant than native flowering plants, and made up 92.5% of the inflorescences over the course of the season at the Clybourn site.

In addition to *M. apicalis*, we collected several other adventive *Megachile* species across our urbanization gradient: *Megachile rotundata*, *Megachile sculpturalis* Smith, and *Megachile pusilla* Pérez. Apart from those in the genus *Megachile*, we also recorded the non-native *Pseudoanthidium nanum* (Mocsáry), *Hylaeus punctatus* (Brullé), *Hylaeus leptocephalus* (Morawitz), *Hylaeus hyalinatus* Smith, *Chelostoma rapunculi* (Lepeletier), *Anthidium manicatum* (L.), *Anthidium oblongatum* (Illiger), *Andrena wilkella* (Kirby) and *Apis mellifera* L.

Species description. Members of the genus *Megachile* represent a group of robust bees that can be separated from other genera by the combination of the following characteristics: a lack of maculations on the integument, arolia absent, and abdominal tergum 1 (T1) with an anterior face creating a concave appearance (Mitchell 1962). Detailed descriptions of *M. apicalis* are provided in Mitchell (1962) and Sheffield et al. (2011a). Females of *M. apicalis* (Fig. 1) can be identified from other North American *Megachile* by the following combination of distinct characteristics: (i) clypeus with a distinct thick projection medially (Fig. 1C); (ii) abdominal terga 2 and 3 (T2 and T3) with lateral oval impressions that are shallow and impunctate (Fig. 1D); (iii) abdominal sternum 4 (S4) with a few black hairs and sterna 5 and 6 (S5 and S6) with hairs entirely black (Fig. 1E) (Mitchell 1962, Parker 1978, Sheffield et al. 2011a). The average intertegular distance for female *M. apicalis* specimens collected in Chicago was 2.4mm (± 0.18).

Males of *M. apicalis* (Fig. 2) can be more difficult to distinguish. However, male *M. apicalis* can be readily identified by the combination of the following two characteristics: (i) T2 and T3 with lateral oval impressions (Fig. 2C), and (ii) T5 with black upright hairs (Fig. 2D) (Mitchell 1962, Parker 1978, Sheffield et al. 2011a). The average intertegular distance for male *M.*

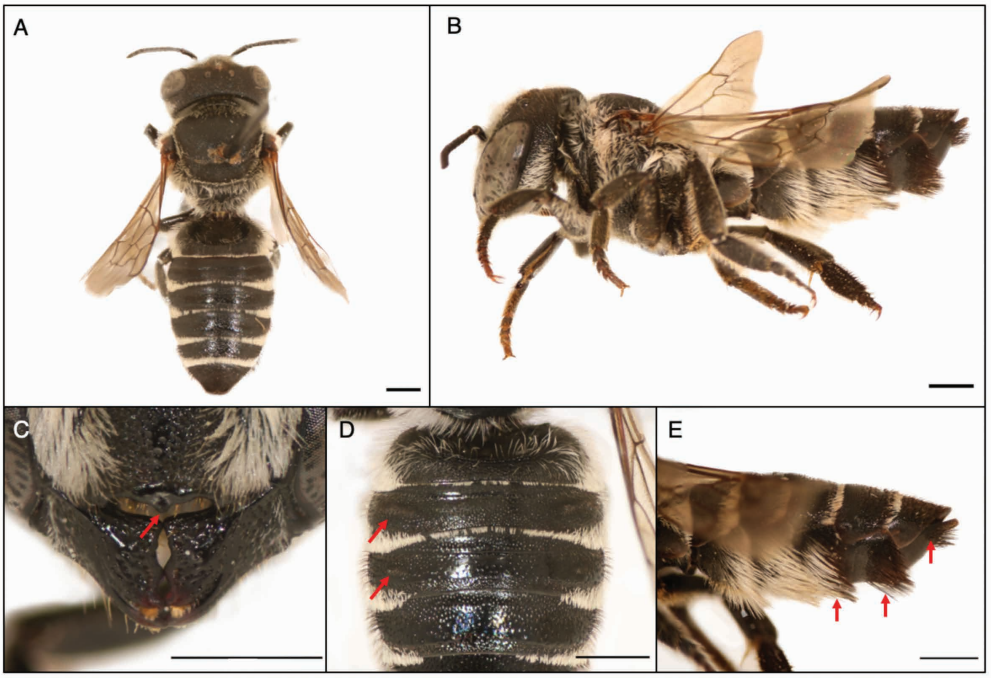

Figure 1: Female *Megachile apicalis*: A) dorsal view B) lateral view C) clypeus with medial projection D) dorsal view of abdomen showing terga 2 and 3 with shallow oval impressions E) lateral view of abdomen showing sterna 4, 5, and 6 with dark hairs. Scale bars = 1mm.

apicalis specimens collected in Chicago was 2.1mm (± 0.19).

Discussion

These first records of *M. apicalis* in Illinois found within the City of Chicago suggest that this non-native bee is fully capable of taking advantage of extreme, urban environments. Across our urbanization gradient, with sites ranging from 15–69% impervious surface, *M. apicalis* was found exclusively at the site exhibiting the most extreme levels of urbanization (Clybourn). We observed *M. apicalis* across all four of our sampling periods from late June until early August, indicating that this bee has a relatively broad flight activity period. We also observed *M. apicalis* foraging only from non-native flowering plant species, which were abundant at this urban sites.

One of the plants on which we observed *M. apicalis* foraging was *Centaurea stoebe* (Asteraceae). *Megachile apicalis* has been shown to have strong preferences for plants in the Cynareae tribe, including *C. stoebe* (Müller and Bansac 2004). Interestingly, *M. apicalis* has also been documented along rail lines in Michigan foraging on *C. stoebe* and it has been suggested that this non-native plant may facilitate the spread of *M. apicalis* (Gibbs et al. 2017). Furthermore, *C. stoebe* was only documented at the Clybourn site, which may partly explain why this was the only site in which *M. apicalis* was observed. The apparent preference of *M. apicalis* for non-native plant species suggests it may be able to flourish in highly disturbed areas with high abundance of non-native floral resources. In addition to the availability of floral resources in highly urban areas, other studies strongly suggest that urban areas likely contain numerous nesting opportunities for cavity nesting bees, including non-native species like *M. apicalis* (Matteson et al. 2008, Fortel et al. 2014).

Megachile apicalis may be well suited to exploit the urban environment given its behavior and ecological traits, potentially impacting other native bee species. Although we do not know the extent of the impact of non-native bee species, there is evidence that non-native species in the genus *Megachile* may compete strongly with native bees for nesting resources. Bees in the subgenus *Eutricharaea* (a non-native subgenus in North America), including *M. apicalis* and *M. rotundata*, create nests in cavities with

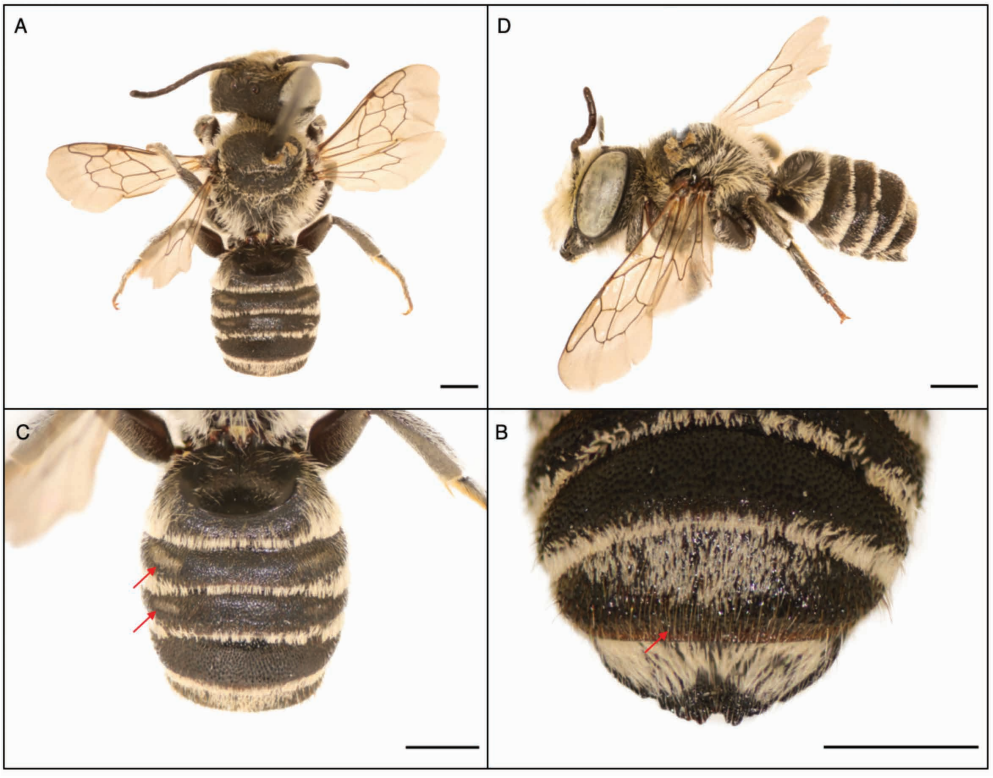

Figure 2: Male *Megachile apicalis*: A) dorsal view B) lateral view C) dorsal view of abdomen showing terga 2 and 3 with shallow oval impressions D) dorsal view of abdominal terga 5 with dark upright hairs. Scale bars = 1mm.

leaf disks that are glued together that act to protect brood from nest parasites and allow them to nest in a variety of cavities (Trostle and Torchio 1994, Frankie et al. 1998). This nesting flexibility and added protection may give them a competitive advantage against other *Megachile* species (Barthell et al. 1998, Frankie et al. 1998). In addition to nesting structure, *M. apicalis* females have been documented displaying aggressive nest usurpation behavior towards other bees, which may increase its ability to acquire and maintain nests (Barthell and Thorp 1995). *Megachile apicalis* has been documented competing with *M. rotundata* for nest sites, but it is not clear the extent to which *M. apicalis* may compete with locally native *Megachile* species that may have different nesting requirements than non-native *Megachile* species (Frankie et al. 1998). Taken together, *M. apicalis* in Chicago has a broad activity period, can take advantage of abundant non-native floral food resources, and has competitive nesting behavior, all of which may facilitate its successful establishment in disturbed urban environments, as well as its continued spread across North America.

Urban centers have been suggested to be refuges for bees (Hall et al. 2017). Although cities can potentially harbor a diversity of bee species, in some cases, cities appear to have larger proportion of non-native bees compared to less disturbed areas (Fetridge et al. 2008, Matteson et al. 2008, Fitch et al. 2019, Wilson and Jamieson 2019). In addition, some non-native bee species have only been documented in highly disturbed areas, as is the case here with *M. apicalis*, suggesting cities may be a favorable habitat for them (O'Brien et al. 2012, Portman et al. 2019). As urbanization continues to grow worldwide, it is important to monitor the spread of non-native bee species to help us determine the potential impacts they may pose on native bee species.

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Elaine Jiang, and Alicia Wala for fieldwork assistance. We also thank the Iler + CaraDonna Lab Group and two anonymous reviewers for constructive comments on the manuscript. Research was supported by an NSF Graduate Research Fellowship (DGE-1842165 to A.M.G.) and the Northwestern University Plant Biology and Conservation Research Award (to A.M.G.).

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