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Cover Photograph: A Spring Beauty Miner Bee (*Andrena erigeniae*) nectaring at a small patch of Spring Beauty (*Claytonia virginica* L.) on the right of way in Edison, New Jersey, USA on 7 May 2019. Photo by David Moskowitz.

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The Bee (Hymenoptera: Apoidea) Fauna of a Transmission Right-of-way in a Highly Developed and Fragmented Landscape of Central New Jersey

David Moskowitz[1*] and David Grossmueller[2]

Abstract – Bees are declining globally from a broad suite of anthropogenic impacts. Transmission rights-of-way (ROW) can provide important habitats for diverse bee faunas. Due to high power demands in urban and semi-urban environments, transmission lines are particularly abundant in these areas and therefore have the potential to provide important green spaces for wildlife. However, studies detailing the bee fauna in these linear habitats are rare. Our study documented the bee fauna of an overhead transmission ROW crossing through a highly developed landscape in central New Jersey. The 82 species found during our survey represent 22% of the 371 bees recorded in New Jersey, albeit with a high percentage (13%) being non-native. We conclude that transmission lines in highly developed landscapes may be important habitats for bees and should be a focus for further research efforts.

Introduction

Bees (Hymenoptera: Apoidea) are declining globally (Lerman et al. 2018, Potts et al. 2010, Russell et al. 2018, Winfree 2010) from habitat loss and degradation caused by agriculture, development, and urbanization (De Palma et al. 2015, Geslin et al. 2016, Hernandez et al. 2009). Nonetheless, green spaces in developed and urban areas may have a rich bee fauna, albeit often with a high percentage of non-native species (Droege and Shapiro 2011, Fitch et al. 2019, Gruver and CaraDonna 2021, Matteson and Langellotto 2009, Theodorou et al. 2020, Tommasi et al. 2004). A growing number of recent studies have demonstrated that transmission rights-of-way (ROW) provide habitat for diverse bee faunas (Gardiner 2018, Wagner 2014). These ROWs can be abundant in urban and developed areas, providing extensive linear habitats, but little research has focused on their bee faunas (Twerd et al. 2021). In order evaluate the ecological value of a transmission line easement though a highly developed landscape in Central New Jersey, we surveyed wild bees in 2018 and 2019.

Methods

Study area

The bee survey was conducted on a 5.8 km portion of an 11.3 km long, 61 m wide transmission right-of-way (ROW) in a highly developed landscape in Edison and Woodbridge Townships, Middlesex County, New Jersey. The study area is approximately 40.5 ha and consists of 3 parallel overhead electric transmission lines constructed in 1972. The northern extent of the study area is generally bounded by the 4 lane Route 9, and the southern extent by the 9 lane Route 287. During 2015 and 2016 the ROW was reconstructed to a 230 kV line, resulting in extensive removal of vegetation in the center of the ROW. The ROW within the study area parallels and abuts the 6 to 8 lane Route 1. The ROW is highly frag-

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mented, bounded, and bisected by 31 roads ranging from 1 to 8 lanes and a rail line. The 10 lane Garden State Parkway bisects the study area. Cumulatively, the ROW is bisected by 65 lanes of roadway. A 149 m long and 76 m wide utility substation and gravel storage area is also located within the ROW, encompassing the entire ROW at that location.

Based on New Jersey Department of Environmental Protection Landuse/Landcover mapping (NJDEP 2023), the landscape adjacent to and within 0.6 km of the study area is highly developed with roads, residential, and commercial land uses (Fig. 1 and Supplemental Fig. 1 [available online at https://eaglehill.us/URNAonline2/suppl-files/urna-218-Moskowitz-s1.pdf]). Of the surrounding landscape, 81.2% is developed, and an additional 6.3% is a highly maintained cemetery. The remaining 12.5% of this area is mapped as undeveloped land uses, primarily a large county park (44.5 ha) separated from the study area by Route 1 and a 4.9 ha forest located in the center of a large apartment complex. The Landuse/Landcover study area was defined by the distance most solitary bees are expected to forage within (Gathmann and Tscharntke 2002, Hofmann et al. 2020, Zurbuchen et al. 2010).

The park across Route 1 from the ROW has mature trees but few natural areas, and is mostly heavily maintained. The forest surrounded by a large apartment complex is in 3 separate approximately equal 1.6 ha stands each, and is better characterized as woodlots than as a forest. Most of the ROW is regularly mowed approximately once a month, from April through October. The remainder of the ROW is maintained through mechanical or herbicide treatments at least once every 5 years. The ROW is largely characterized by early successional upland communities. There are abundant unvegetated, exposed soils that are patchily distributed within the study area generally associated with embankments and access roads. With the exception of a forested wetland adjacent to the ROW, wetlands in and adjacent to the ROW are limited to small manmade stormwater management basins and drainage ditches. The vegetation and characteristics of the forested wetland was previously described (Moskowitz 1998).

Bee sampling

The bee survey was conducted from 4 May 2018 to 4 October 2018 and again from 5 April to 22 May 2019. The 2018 survey was initiated in May due to a late season (2 April 2018) snowstorm. All bee surveys were conducted during rain-free periods. The sampling methodology followed Droege (2015). Four survey stations were established within the ROW study area (Fig. 1 and 2). The 4 stations ranged from 1130 to 1963 meters apart (average 1533 m). Sampling consisted of yellow, white, and blue colored plastic bee bowls (Solo® brand plastic bowls 0.36 l) set every other week. At each station 13 bee bowls alternating yellow (4 bowls), white (4 bowls), and blue (5 bowls) were set on the ground approximately 1.4 m apart on a 10 m cross pattern. Bowls were filled with soapy water using Dawn Ultra® blue dishwashing liquid and left for approximately 24 hours before being checked. Net surveys were conducted for 1 hour per station in an approximately 1.1 h area between 10:00 and 17:00.

Netting focused on bee species richness. Collected bees were transferred to 70% isopropyl alcohol filled jars for subsequent identification. Bees were identified using the keys at Burrows et al. (2018), DiscoverLife (Ascher and Pickering 2020), Mitchell (1960, 1962), Gibbs et al. (2013), and Williams et al. (2014). Identifications were also made by S. Droege (USGS Eastern Ecological Science Center) and J. Ascher (American Museum of Natural History), and for the *Lasioglossum* (Dialictus) by J. Gibbs (University of Manitoba Department of Entomology).

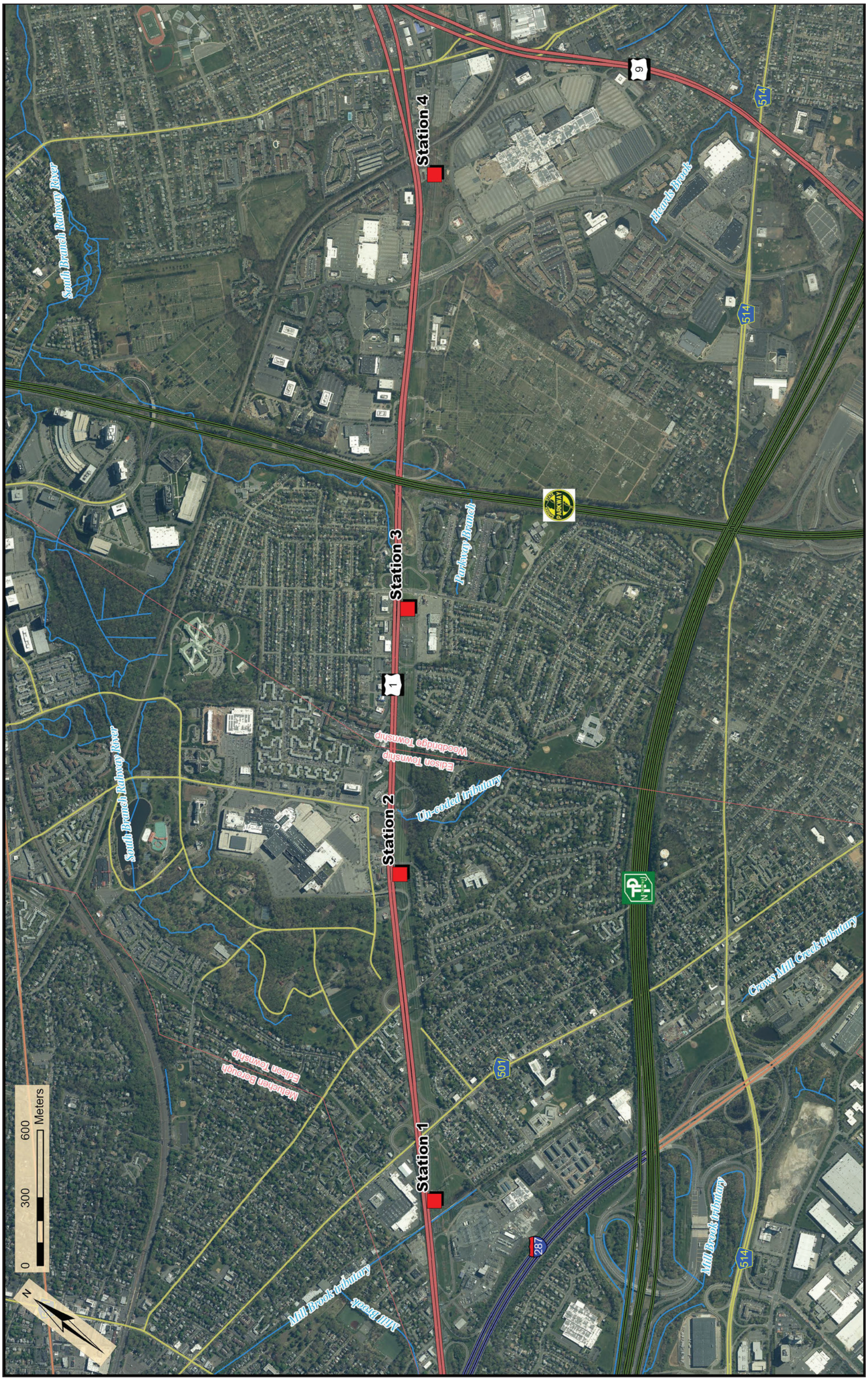

Figure 1. Bee Survey Station Locations.

Results

During the survey, 1716 bees were collected, representing 82 species (Table 1) in 5 families (Andrenidae, Apidae, Colletidae, Halictidae, and Megachilidae). The Halictidae were the most diverse with 25 species followed by Megachilidae (24 species), Apidae (22 species), Andrenidae (9 species), and Colletidae (3 species). Seventy-four species (90%) are polylectic and 8 species (10%) are oligolectic (Fowler 2016, Wood and Roberts 2017). Eleven of the species (13%) are non-native (Droege 2018). The 82 species found during our survey (Table 1) represent 22% of the 371 bees recorded in New Jersey (R. Somes, Endangered and Nongame Species Program, Clinton, NJ, USA, pers. comm.). A single male *Coelioxys coturnix* (Pérez, 1884) (Red-Tailed Cuckoo Leaf-cutter Bee) was found for the first time in New Jersey during our survey on 8 June 2018 (Moskowitz and Grossmueller 2022). This introduced species has been spreading in the northeastern United States since its first report in Washington, D.C. in 2004 (Ascher and Pickering 2020, Droege and Shapiro 2011), and is 1 of 11 introduced species found on the ROW during the survey.

The majority of the bee species collected on the ROW during our survey, (90% [74/82] species) are polylectic. Eight species (10%) are oligolectic: *Andrena erigeniae* (Robertson, 1891) (Spring Beauty Miner Bee), *Andrena wilkella* (Kirby, 1802) (Wilkes Miner Bee), *Andrena simplex* (Smith, 1853) (Simple Miner Bee), *Melissodes denticulatus* (Smith, 1854) (Denticulate Long-Horned Bee), *Melissodes subillatus* (LaBerge, 1961) (Long-Horned Bee), *Ptilothrix bombiformis* (Cresson, 1878) (Rose Mallow Bee), and

Figure 2. Photographs of the 4 bee survey locations within the ROW in Edison and Woolbridge Townships, Middlesex County, NJ, USA.

Table 1. Bee species collected on the right of way.

Species Name	Family	Status	Nest	Diet Breadth
Andrena barbara Bouseman & LaBerge, 1979	Andrenidae	N	S	P
Andrena carlini Cockerell, 1901	Andrenidae	N	S	P
Andrena cressonii Robertson, 1891	Andrenidae	N	S	P
Andrena erigeniae Robertson, 1891	Andrenidae	N	S	O
Andrena miserabilis Cresson, 1872	Andrenidae	N	S	P
Andrena simplex Smith, 1853	Andrenidae	N	S	O
Andrena wilkella Kirby, 1802	Andrenidae	I	S	O
Andrena commoda Smith, 1879	Andrenidae	N	S	P
Calliopsis andreniformis Smith, 1853	Andrenidae	N	S	P
Apis mellifera L., 1758	Apidae	I	C	P
Bombus bimaculatus Cresson, 1863	Apidae	N	C	P
Bombus vagans Smith, 1854	Apidae	N	C	P
Bombus fervidus Fabricius, 1798	Apidae	N	C	P
Bombus griseocollis De Geer, 1773	Apidae	N	C	P
Bombus impatiens Cresson, 1863	Apidae	N	C	P
Bombus perplexus Cresson, 1863	Apidae	N	C	P
Ceratina calcarata Robertson, 1900	Apidae	N	P	P
*Ceratina dupla S*ay, 1837	Apidae	N	P	P
Ceratina mikmaqi Rehan and Sheffield, 2011	Apidae	N	P	P
Ceratina strenua Smith, 1879	Apidae	N	P	P
Melissodes bimaculatus Lepeletier, 1825	Apidae	N	S	P
Melissodes denticulatus Smith, 1854	Apidae	N	S	O
Melissodes subillatus LaBerge, 1961	Apidae	N	S	O
Nomada sp. bidentate Scopoli, 1770	Apidae	N	NP	P
Nomada denticulata Robertson, 1902	Apidae	N	NP	P
Nomada depressa Cresson, 1863	Apidae	N	NP	P
Nomada luteoloides Robertson, 1895	Apidae	N	NP	P
Ptilothrix bombiformis Cresson, 1878	Apidae	N	S	O
Triepeolus lunatus Say, 1824	Apidae	N	NP	P
Xylocopa virginica L., 1771	Apidae	N	W	P
Hylaeus leptocephalus Morawitz, 1871	Colletidae	I	C	P
Hylaeus mesillae Cockerell, 1896	Colletidae	N	C	P
Hylaeus modestus Say, 1837	Colletidae	N	C	P
Agapostemon sericeus Forster, 1771	Halictidae	N	S	P
Agapostemon texanus Cresson, 1872	Halictidae	N	S	P
Agapostemon virescens Fabricius, 1775	Halictidae	N	S	P
Augochlora pura Say, 1837	Halictidae	N	SW	P

Table 1. Continued.

Species Name	Family	Status	Nest	Diet Breadth
Augochlorella aurata Smith, 1853	Halictidae	N	S	P
Halictus confusus Smith, 1853	Halictidae	N	S	P
Halictus poeyi/ligatus Smith 1853	Halictidae	N	S	P
Halictus rubicundus Christ, 1791	Halictidae	N	S	P
Lasioglossum imitatum Smith, 1853	Halictidae	N	S	P
Lasioglossum hitchensi/weemsi Gibbs, 2012	Halictidae	N	S	P
Lasioglossum pilosum Smith, 1853	Halictidae	N	S	P
Lasioglossum subviridatum Cockerell, 1938	Halictidae	N	S	P
Lasioglossum platyparium Robertson, 1895	Halictidae	N	NP	P
Lasioglossum bruneri Crawford, 1902	Halictidae	N	S	P
Lasioglossum lineatulum Crawford, 1906	Halictidae	N	S	P
Lasioglossum gotham Gibbs, 2011	Halictidae	N	S	P
Lasioglossum zephryus Smith, 1853	Halictidae	N	S	P
Lasioglossum hitchensi Gibbs, 2012	Halictidae	N	S	P
Lasioglossum foxii Robertson, 1895	Halictidae	N	S	P
Lasioglossum ephialtum Gibbs, 2010	Halictidae	N	S	P
Lasioglossum admirandum Sandhouse, 1924	Halictidae	N	S	P
Lasioglossum georgeickworti Gibbs, 2011	Halictidae	N	S	P
Lasioglossum tegulare Robertson, 1890	Halictidae	N	S	P
Lasioglossum ellisiae Sandhouse, 1924	Halictidae	N	S	P
Lasioglossum illinoense Robertson, 1892	Halictidae	N	S	P
Anthidium manicatum L., 1758	Megachilidae	I	C	P
Anthidium oblongatum Illiger, 1806	Megachilidae	I	C	P
Coelioxys alternatus Say, 1837	Megachilidae	N	NP	P
Coelioxys coturnix Pérez, 1884	Megachilidae	I	NP	P
Coelioxys modestus Smith, 1854	Megachilidae	N	NP	P
Coelioxys sayi Robertson, 1897	Megachilidae	N	NP	P
Coelioxys rufitarsis Smith, 1854	Megachilidae	N	NP	P
Heriades carinata Cresson, 1864	Megachilidae	N	C	P
Heriades variolosa Cresson, 1872	Megachilidae	N	C	P
Hoplitis pilosifrons Cresson, 1864	Megachilidae	N	P	P
Lithurgus chrysurus Fonscolombe, 1834	Megachilidae	I	W	O
Megachile campanulae Robertson, 1903	Megachilidae	N	C	P
Megachile pusilla Pérez, 1884	Megachilidae	I	C	P
Megachile petulans Cresson, 1878	Megachilidae	N	C	P
Megachile frigida Smith, 1853	Megachilidae	N	C	P
Megachile frugalis Cresson, 1872	Megachilidae	N	C	P

Table 1. Continued.

Species Name	Family	Status	Nest	Diet Breadth
Megachile mendica Cresson, 1878	Megachilidae	N	C	P
Megachile rotundata Fabricius, 1787	Megachilidae	I	C	P
Osmia cornifrons Radoszkowski, 1887	Megachilidae	I	C/P	P
Osmia georgica Cresson, 1878	Megachilidae	N	C/P	P
Osmia pumila Cresson, 1864	Megachilidae	N	C/P	P
Pseudoanthidium nanum Mocsáry, 1881	Megachilidae	I	P	O
Stelis lateralis Cresson, 1864	Megachilidae	N	NP	P
Stelis louisae Cockerell, 1911	Megachilidae	N	NP	P

N = Native, I = Introduced, NP = Nest parasite, S = Soil, C = Cavity, P = Pith, SW = Soft wood , W = Wood. Diet Breadth: P = Polylectic; O = Oligolectic

Psuedoanthidium nanum (Mocsáry, 1881) (European Small-Woolcarder Bee) (Fowler 2016, Fowler and Droege 2020, Wood and Roberts 2017). Our study found 3 Colletidae including the non-native *Hylaeus leptocephalus* (Morawitz, 1870) (Slender-Faced Masked Bee) and no *Colletes* species, similar to reports from other urban areas (AMNH 2018, Danforth et al. 2019, Hernandez et al. 2009). A scarcity of Andrenidae species has also been reported from urban areas (Hernandez et al. 2009), but our study found 9 species (11% [9/82]). Parasitic bees (16% [13/82] species) were consistent with surveys in other developed areas (Banaszak-Cibicka and Żmihorski 2012, Fortel et al. 2014). Urban bees also tend to be ground or cavity nesting species (Danforth et al. 2019, Gruver and CaraDonna 2021, Hernandez et al. 2009), and our results are consistent with those reports (89% [73/82] species).

Discussion

With global declines of bees (Lerman et al. 2018, Potts et al. 2010, Russell et al. 2018, Winfree 2010) because of habitat loss from urbanization (De Palma et al. 2015, Geslin et al. 2016, Hernandez et al. 2009), understanding the ecological functions of bees in urban and developed environments is of increasing importance (Ayers 2021, Braman and Griffin 2022, Brant et al. 2022, da Rocha-Filho et al. 2018, Twerd and Banaszak-Cibicka 2019). The bee diversity in the ROW found during our study suggests the importance of these habitats in developed landscapes. However, 13% of the bees encountered were non-native and either accidentally or purposefully introduced into North America, as has been reported in other urban areas (Droege and Shapiro 2011). Additionally, the 11 non-native species encountered on the ROW represent 48% of the introduced bees known from Eastern North America (Droege 2018). Urban bees are most frequently polylectic owing to the unpredictable availability of floral resources (Danforth et al. 2019, Droege and Shapiro 2011), and our results support this.

It is expected that the majority of bees encountered on the ROW during our study are resident, based on the highly developed and fragmented nature of the landscape. Most solitary bees have small foraging ranges (Gathmann and Tscharntke 2002, Hofmann et al. 2020, Zurbuchen et al. 2010), and the lack of natural areas and barriers in the study vicinity suggests their habitat is largely confined to the ROW.

Roads can be substantial barriers to the movement of bees, and can cause high mortality (Andersson et al. 2017, Baxter-Gilbert, et al. 2015, Dorchin 2013, Fitch 2021, Keilsohn et al. 2018, Muñoz et al. 2015) that increases as roadway speed and traffic volume rises (Bhattacharya et al. 2003, Fitch and Vaidya 2021, Martin et al. 2018). The ROW is bounded along its entire length of the study area by Route 1, a 6 to 8 lane highway, and to the east and west by the 4 lane Route 9 and the 9 lane Route 287, respectively. The 10 lane Garden State Parkway also bisects the study area. Cumulatively, the ROW is crossed by 31 roads ranging from 1 to 10 lanes and by 65 lanes of roadway. The most readily available traffic count data for the major roadways adjacent to, crossing, and bisecting the ROW show high daily traffic flows (45,768 to 200,000) and posted speed limits ranging from 80.5 to 105 kph (NJDOT 2023). It is expected that the cumulative effect of numerous lanes, high speed limits, and heavy traffic flows on these roadways create significant barriers to the movement of bees within and beyond the ROW.

Bees are declining globally as urbanization reduces habitats (De Palma et al. 2015, Geslin et al. 2016, Hernandez et al. 2009, Lerman et al. 2018, Potts et al. 2010, Russell et al. 2018, Winfree 2010). In these urban and developed landscapes, transmission ROW can provide habitats for bees that are otherwise lacking (Russell et al. 2005, Russo et al. 2021). Solitary bees are also important for ecosystem functions and pollination in urban areas (Andrade et al. 2019, Dorea et al. 2017, MacIvor et al. 2014), but a broad suite of life histories and ecological functions including behavior, foraging, plant use, nesting, competition, parasites, disease, and dispersal in developed landscapes are not well understood (Braman and Griffin 2022, Brant et al. 2022, da Rocha-Filho et al. 2018, Martins et al. 2019). Our survey suggests that transmission ROW in highly developed and fragmented landscapes can support a rich bee fauna and should be the focus of further study (Brant et al. 2022, Wojcik and Buchmann 2012).

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